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Handbook on Building Fire Codes

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HANDBOOK ON BUILDING FIRE CODES

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HANDBOOK ON BUILDING FIRE CODES

SECTION-1 - INTRODUCTION

Building, whether used for living, working, entertainment or for other purposes, forms an integral and major constituent of human habitat. As a sequel to the all round socio-economic progress, and the steady urbanisation processes gathering momentum all over our country for the past few decades, there has been enormous increase in the number of buildings of all classifications, including high-rise and special buildings, especially in the urban and surrounding areas.

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

The first version of the National Building Code was published by the Bureau of Indian Standards in 1970, which was subsequently revised in 1983. The 1983 edition of NBC consists of 10 Parts, of which Part-4 deals with Fire Safety / Fire Protection aspects. All the Parts of NBC, including Part-4, are under revision now.The recently revised version of Part 4, Fire and Life Safety, is under print and expected to be out by June 2005, as per information furnished by BIS.

Part-4 of the NBC, dealing exclusively and comprehensively on Fire and Life Safety is the prime Code document on the subject in our country, supplemented by several other State and Local Authority level Development Control Regulations and Building Bye-laws. The whole objective of these regulatory documents is for ensuring the implementation and maintenance of basic minimum standards of construction, structural as well as fire and life safety in buildings of all types of occupancies which is, infact, the social, moral and legal responsibility of the entire community.

Building Codes and Fire Protection are two sides of the same coin which serve to alleviate losses of lives and property due to fire. Buildings vary so much in their interior layout, siting, height, area, cubic capacity, use and construction. The architectural and structural design of a building and construction have a significant effect on its fire safety standards. Similarly, the fire protection measures incorporated for the building, both active and passive, also provide reasonable safety from the effects of fire.

Building Codes and Regulations prescribe only the basic minimum requirements for achieving fire and life safety in buildings, and nothing in these documents prohibit better type of building construction, more exits, or provision of other safer conditions than what are prescribed in the documents. It is also recognised that absolute safety from fire is seldom attained in practice. Further, it has to be borne in mind that while implementing the provisions of the Codes and Regulations, the nature of occupants as well as the activities pursued by them in the building, must also be taken into consideration.

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. To provide necessary guidance and assistance in this regard the proposed qualifications and experience for their registration / accreditation, are also included in one of the Annexures to this Handbook.

All those concerned in the construction activity have to keep an up-to-date track of all the current Building Codes and Regulations as well as the relevant standards on the subject. Since such topics are seldom taught in any educational or academic institutions, an attempt has been made through this Handbook to provide necessary information and guidance for facilitating better understanding and knowledge of various aspects of Fire Science, Fire Protection / Safety and such other related subjects for all those concerned with the formulation, operation and implementation of the relevant Codes and Standards on Fire and Life Safety. It is hoped that this Handbook, being the first of its kind, to be published on the subject, will be found useful for reference by all concerned.

This Handbook has been prepared based on latest study material available with internationally accepted technical literature on fire and life safety, and Building Codes, including our National Codes, as well as the long standing experience of the authors in the field.

SECTION 2 - TERMINOLOGY

1. **Alternative escape routes**
   Escape routes sufficiently separated by either direction and space, or by fire resisting construction, to ensure that one is still available, should the other be affected by fire.

   Note:- A second stair, balcony or flat roof which enables a person to reach a place of safety.

2. **Alternative exit**
   One of two or more exits, each of which is separate from the other.

3. **Atrium**
   A space within a building, not necessarily vertically aligned, passing through one or more structural floors

   Note:- Enclosed lift wells, enclosed escalator wells, building services ducts and stairways are not classified as atria.

4. **Auto Ignition Temperature (AIT)**
   AIT is the lowest temperature at which substance will ignite spontaneously or by itself without any external source of ignition.

5. **Automatic Fire Detection and Alarm System**
   Fire Alarm system comprising components for automatically detecting a fire, initiating an alarm of fire and initiating other actions as appropriate.

   Note:- This system may also include manual fire alarm call points.

6. **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 discharge of water.

7. **Building**
Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundations, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platform, varandah, 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

8. **Building, Height of:**
The vertical distance measured in the case of flat roofs, from the average level of the ground around and contiguous to the building to the terrace of the last livable floor of the building adjacent to the external wall; and in the case of pitched roof up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and in the case of gables facing the road, the mid point between the eaves level and the ridge. Architectural features serving no other function except that of decoration, shall be excluded for the purpose of measuring heights.

9. **Co-efficient of linear expansion**
The amount by which unit length of a solid substance expands when its temperature is raised by $1^{o}C$ is called the co-efficient of linear expansion of the substance.

10. **Combustion**
Combustion is an exothermic, self-sustaining reaction involving a condensed-phase fuel, a gas-phase fuel, or both. The process is usually associated with the oxidation of the fuel by atmospheric oxygen with the emission of light.

11. **Combustible material**
The material which either burns itself or adds heat to a fire. when tested for non-combustibility in accordance with accepted standard [c(1)]

12. Compartmentation
The division of a building into fire-tight compartments by fire resistant elements of building construction in order to control a fire for a stated period of time within the compartment of origin.

13. Compartment (Fire)
A building or part of a building, comprising one or more rooms, spaces or storeys, constructed to prevent the spread of fire to or from another part of the same building, or an adjoining building

14. Compressed Gases
Are gases which exist solely in the gaseous state under NTP (Normal Temperature and Pressure) inside the container.

15. Covered Area
Ground area covered by building immediately above the plinth level. The area covered by the following in the open places is excluded from covered area (like garden, well & well structures, porch, portico, watchman's booth, security room, pumphouse, sub-stations or such other utility structures).

16. Cryogenic Gases
Are liquefied gases which exist in the container at temperatures far below normal atmospheric temperature, but usually slightly above their Boiling Point at NTP, and at correspondingly low to moderate pressures.

17. Dead End
Area from which escape is possible in one direction only

18. Down Comer
An arrangement of fire fighting 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 100mm 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 services appliances and air release valve at roof level to release trapped air inside.

19. Element of Structure
a) a member forming part of the structural frame of a building or any other beam or column;
b) a loadbearing wall or loadbearing part of a wall;
c) a floor;

d) a gallery;

e) an external wall; and

f) a compartment wall (including a wall common to two or more buildings).

20. Emergency Lighting
Lighting provided for use when the supply to the normal lighting fails.

21. Emergency Lighting System:
A complete but discrete emergency lighting installation from standby power source to the emergency lighting lamp(s), for example, self contained emergency luminaire or a circuit from central battery generator connected through wiring to several escape luminaries.

22. Escape Lighting:
That part of emergency lighting which is provided to ensure that the escape route is illuminated at all material times (for example, at all times when persons are on the premises), or at times the main lighting is not available, either for the whole building or the escape routes.

23. Escape Route
Route forming that part of the means of escape from any point in a building to a final exit.

24. Evacuation Lift
A lift that may be used for the evacuation of disabled people in a fire.

25. Exposure Hazard
The risk of fire spreading from a building, structure or other property to an adjoining building or structure, or to another part of the same building or structure by radiated heat across the intervening space.

26 Fire Damper
A closure which consists of a normally held open damper installed in an air distribution system or in a wall or floor assembly and designed to close automatically in the event of a fire in order to maintain the integrity of fire separation.

27. **Fire Detector**
A device which gives a signal in response to a change in the ambient conditions in the vicinity or within the range of the detector, due to a fire.

28. **Fire Door**
A fire-resistive door approved for openings in fire separation walls.

29. **Fire Exit**
A way out leading to an escape route. This can either be a doorway or even a horizontal exit.

30. **Fire fighting Access**
Approach facilities provided to or within a building to enable fire service personnel and equipment to gain access thereto for fire and rescue operations.

31. **Fire fighting Shaft**
A protected enclosure containing a fire fighting stair, fire fighting lobbies and, if provided, a fire fighting lift, together with its machine room.

32. **Fire Lift**
The lift installed to enable fire services personnel to reach different floors with minimum delay.

33. **Fire Load**
Calorific energy, of the whole contents contained in a space, including the facing of the walls, partition, floors and ceilings.

34. **Fire Load Density**
The fire load per unit area.

35. **Fire Point**
Is the lowest temperature at which the heat from the combustion of a burning vapour is capable of producing sufficient vapour to enable combustion to be sustained.

36. Fire Prevention
The whole set of precautions to prevent the outbreak of fire and to limit its effects.

37. Fire Protection
Design features, systems or equipment in a building, structure or other fire risk, to minimise the danger to persons and property by detecting, containing and/or extinguising fires.

38. Fire Resistance
Fire resistance is a property of an element of building construction and is the measure of its ability to satisfy for a stated period some or all of the following criteria:

(a) Resistance to collapse

(b) Resistance to penetration of flame and hot gases, and

(c) Resistance to temperature rise on the unexposed face upto a maximum of 180°C and / or average temperature of 150°C

39. Fire Resistance Rating
The time that a material or construction will withstand the standard fire exposure as determined by fire test done in accordance with the standard methods of fire tests of materials/ structures.

40. Fire Separation
The distance in meters measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space to the building for the purpose of preventing the spread of fire.

41. Fire Separating Wall:
The wall provides complete separation of one building from another, or part of a building from another part of the same building, to prevent any communication of fire or heat transmission to wallitself which may cause or assist in the combustion of materials on the side opposite to that portion which may be on fire.

42. Fire Stop:
A fire resistant material or construction having a fire resistance rating of not less than the 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.

43. Fire Tower:
An enclosed staircase which can only be approached from the various floors through landings or lobbies separated from both the floor areas and the staircase by fire-resisting doors, and open to the outer air.

44. Flash Point
Is the lowest temperature at which the vapour produced by a substance will flash momentarily when a flame is applied.

45. Floor Area Ratio
The quotient obtained by dividing the total covered area (plinth area) of all floors by the area of the plot;

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

46. Gallery
An intermediate floor or platform projecting from a wall of an auditorium or a hall providing extra floor area, additional seating accommodation etc. It shall also include the structures provided for seating in stadia.

47. Group Housing
Group or multi-storeyed housing for more than one dwelling unit, where land is owned jointly (as in the case of co-operative societies or the public agencies, such as local authorities or housing boards, etc.) and the construction is undertaken by one Agency/Authority.

48. High Rise Building
As per NBC Part-4, all buildings 15m and above in height shall be considered as high rise buildings.

49. Horizontal Exit
An arrangement which allows alternative egress from a floor area to another floor at or near the same level in an adjoining building or an adjoining part of same building with adequate fire separation.

50. Inhibition
A process of fire extinguishment in which the extinguishing agent used prevents the development of chemical reactions in the flame initiating and sustaining the fire.

51. Interior Finish
Generally consists of those materials or combinations of materials that form the exposed interior surface of walls and ceilings.

52. Latent Heat
The thermal energy or the heat of a substance absorbed when it is converted from a solid to a liquid, or from a liquid to a gas / vapour, is called **latent heat.** It is measured in Joules per unit mass(J/kg).

53. Latent Heat of Vapourisation
The heat which is absorbed by a liquid for conversion to its vapour stage is the latent heat of vapourisation for that liquid. The heat which is absorbed by water for conversion to steam is the **latent heat of vapourisation of water.**

54. Latent Heat of Fusion
The heat which is absorbed during change of state from solid to liquid is called the latent heat of fusion. When ice melts to form water and heat is absorbed, it is called as the latent heat of fusion of ice.

55. Liquefied Gases
Are gases which, at normal atmospheric temperature inside the container exists partly in the liquid state and partly in the gaseous state and under pressure, as long as any liquid remains in the container.

56. Means of Egress
A continuous and unobstructed way of travel from any point in a building or structure to a place of comparative safety.

57. Mezzenine Floor
An intermediate floor, between two floors, above ground level, accessible only from the lower floor

58. 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 buliding according to the occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

59. Occupant Load
The number of persons for which the means of egress of a building or a portion thereof is designed.

60. Plenum
An air compartment or chamber to which one or more ducts are connected and which forms part of an air distribution system.

61. Plinth Area
The built-up covered area measured at the floor level of the basement or of any storey.

62. Public Address System (PA System)
The complete chain of sound equipment (comprising essentially of microphones, amplifiers, and loud speakers) required to reinforce the sound emanating from a source in order to provide adequate loudness for comfortable hearing by the audience.

63. Public Building
A building constructed by government, semi-government organisations, public sector undertakings, registered Charitable Trusts or such other organisations for their non-profitable public activities.

64. Pyrolysis
Irreversible chemical decomposition of a material due to an increase in temperature.

65. Pressurisation
The establishment of a pressure difference across a barrier to protect a stairway, lobby escape route, or room of a bulding from smoke penetration.

66. Pressurisation Level
The pressure difference between the pressurised space and the area served by the pressurised escape route, expressed in pascals(Pa)

67. Protected Shaft
A shaft which enables persons, air or objects to pass from one compartment to another, and which is enclosed with fire resisting construction.

68. Roof Exits
A means of escape on to the roof of a building where the roof has access to it from the ground. The exit shall have adequate cut-off within the building from staircase below.

69. Smoke
A visible suspension in air of a mixture of gaseous and particulate matter resulting from combustion or pyrolysis.

70. Specific Heat
The heat energy required to raise the temperature of unit mass of a substance through 1^{o}C is the specific heat of the substance. (J/kg per ^{o}C)

71. Refuge Area
An area where persons unable to use stairways can remain temporarily to await instructions or assistance during emergency evacuation.

72. Stairway (Enclosed)
A stairway in a building, physically separated(eg. by walls, partitions, screens, barriers etc.) from the accommodation through which it passes, but not necessarily a protected stairway.

73. Stairway (Protected)
A stairway having the required degree of fire protection and forming the vertical component of a protected escape route or means of egress.

74. Special Building

(i) A building solely used for the purpose of a drama or cinema theatre, motion picture, a drive-in theatre, an assembly hall or auditorium, town hall, lecture hall, an exhibition hall, theatre museum, stadium, community hall, marriage hall;

(ii) A Hazardous Building;
(iii) An Institutional Building;
(iv) An Industrial Building;
(v) A Storage Building
(vi) A Multi-purpose Building or Multiplex

75. Stack Pressure

Pressure difference caused by a temperature difference creating an air movement within a duct, chimney or enclosure.

76. Stack Effect

Is the vertical natural air movement from the building caused by the differences in temperature and densities between the inside and outside air. This stack effect plays a vital role in smoke movement.

77. Travel Distance

The distance to be travelled from any point in a building to a protected escape route, external escape route or final exit.

78. Unsafe Building

A building which,

(i) is structurally unsafe,
(ii) is insanitary,
(iii) is not provided with adequate means of egress,
(iv) constitutes a fire hazard,
(v) is dangerous to human life, and
(vi) in relation to its existing use constitutes a hazard to safetly or health or public welfare by reasons of inadequate maintenance, dilapidation or abandonment.

79. Ventilation:

Supply of outside air into, or the removal of inside air from an enclosed space.

80. Venting Fire
The process of inducing heat and smoke to leave a building as quickly as possible by such paths so that lateral spread of fire and heat is checked, fire fighting operations are facilitated and minimum fire damage is caused.

81. Volume to Plot Area Ratio (VPR)
The ratio of volume of building measured in cubic metres to the area of the plot measured in square metres and expressed in metres.

82. Wet Riser
An arrangement for fire fighting within the building by means of vertical rising mains of not less than 100 mm diameter with landing valves on each floor/landing for fire fighting purposes and permanently charged with water from a pressurised supply.

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SECTION 3 - FIRE SCIENCE - BASIC PRINCIPLES

CHAPTER -1- BASIC PRINCIPLES OF COMBUSTION

1.1 Matter can exist in three states-solid, liquid or gas/vapour. These states are interchangeable by alteration of the temperature and pressure exerted on them. For instance, water can exist in all three states-liquid at normal temperature, as ice(solid state) at 0^o C, and as vapour above 100^o C.

1.2 Matter possesses mass and occupies space. Some substances are heavier than others.

For eg: Iron sinks in water, whereas wood floats on water. This is because wood has a lower density(mass per unit volume) than iron. Density of a substance can be calculated by dividing the mass of the substance by its volume:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Density is measured in kg/m^3 or g/cm^3. Water has a density of $1g/cm^{3.}$.

1.3 The ratio of the mass of any volume of a solid or a liquid substance to the mass of an equal volume of water is known as **relative density** or **specific gravity.**

$$\left.\begin{array}{r}\text{Relative density}\\ \text{or specific gravity}\end{array}\right] = \frac{\text{mass of any volume of the substance}}{\text{mass of an equal volume of water}}$$

(The specific gravity of water is taken as 1 at 4^oC)

Vapour Density- The vapour density(VD) of a gas or vapour is generally denoted in relation to the density of equal volume of hydrogen, which is the lightest gas. However, for fire service purposes, for ease of practical application, VD of gases and vapours are compared with the density of dry air, which is 1.

The following are the VDs of a few gases as compared with air:

Gas/Vapour	V.D as Compared with Air	
Hydrogen	0.07	lighter than air
Methane	0.556	
Ammonia	0.6	
Carbon-di-oxide	1.53	heavier than air
Chlorine	2.47	
Petrol	2.5	

1.4 Density of liquids and gases have a significant bearing on fire protection technology applications.

For instance, the density or specific gravity of a burning liquid determines partly whether water can be used as a extinguishing agent on it. Water miscibility of the liquid is also a matter to be reckoned with. Likewise, the density of a gas or vapour determines whether it will be accumulating at higher or lower levels of a building. It is a well known fact that petrol and other flammable liquids float on water, and hence, water jets which are effective for extinguishing ordinary fires will be ineffective in extinguishing a burning petrol tank fire.

If a volume of a gas has positive buoyancy, it is lighter than air, and will tend to rise. If it has negative buoyancy, it is heavier than air and will tend to sink. If propane(C_3H_8), the main component of Liquid Petroleum Gas(LPG), leaks from a cylinder, it will accumulate at lower levels and will present a serious fire and explosion hazard.

1.5 Melting point, Freezing point and Boiling point

1.5.1. **Melting Point (MP)** is the temperature at which a solid melts. The temperature at which a liquid turns into a solid is termed as its **Freezing Point(FP).** These two temperatures are identical for the same substance.The temperature at which a liquid boils and becomes a vapour is the **Boiling Point(BP)**

1.5.2. The MP, of some substances are listed below:

Substance	MP(approx)
Aluminium	650°C
Steel	1382°C
Sulphur	109°C
Cast Iron	1200°C
Glass	1300°C
Carbon	3600°C(C has the highest MP)

1.5.3. Even below the boiling point some molecules of the liquid may reach the surface and escape into the surrounding air. This phenomenon is called **evaporation**. The liquid boils when the saturation vapour pressure equals atmospheric pressure(101.3kPa)

1.6 Specific Heat

1.6.1 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).

1.6.2. Specific heat capacities of some substances are given below:

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

1.6.3 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 vaporise readily. Low specific heat capacities are of considerable importance in promoting fire risks.

1.6.4. The 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.

1.7. **Latent heat:**

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

1.7.1 When a container with water is heated, the temperature of the water goes on rising until it reaches 100°C, the BP of water. At this temperature the water boils. However, the temperature remains constant at 100°C, although heat continues to be applied to the container. This heat which is absorbed by water for conversion to steam(vapour stage) is what is known as **latent heat of vaporisation of water.** The latent heat of vaporisation 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 achieves extinguishment of the fire.

1.7.2. Heat is absorbed during the change of state from solid to liquid also. Ice melts to form water and heat is absorbed. It takes 336 kJ to convert 1kg of ice at 0°C to water at the same temperature. Likewise, when water at 0°C freezes to form ice, the same quantity of heat is given out for every 1kg of ice formed. This is called the **latent heat of fusion** of ice. Other substances also exhibit the same phenomenon of absorbing latent heat when they melt, and giving out latent heat on solidifying.

1.8. Thermal expansion

1.8.1 A substance expands when heated, unless prevented by some external cause. On heating liquids expand about ten times more than solids. Gases expand about 100 times more than liquids. Solid expands when heated, in all three dimensions, increasing in length, breadth and thickness. More often the increase in length is more predominant.

1.8.2. The amount by which unit length of a solid substance expands when its temperature is raised by 1 degree is called the **co-efficient of linear expansion** of the substance. For steel, the co-efficient of linear expansion is 0.000012 per°C. The typical values of linear expansion for a few other solids are:

Copper	-	0.000017 per °C
Aluminium	-	0.000023 per °C
Concrete	-	0.000012 per °C

This thermal expansion phenomenon has to be kept in view for building design and construction, and is quite relevant while a building gets involved in fire. The heat on the inner side of a wall of a burning building may cause it to expand at a higher rate than the other side, thus causing the wall to bulge outwards, or even leading to collapse.

1.8.3. More than in solids and liquids, thermal expansion is more apparent in gases. Hence the pressure exerted by a gas increases when heated. Thus, in the case of gases, there are three variables involved in thermal expansion process - temperature, pressure and volume.

1.9. Gases and Gas hazards.

1.9.1. Gas Laws: Gas particles more freely and fast and can produce significant effects if their temperature volume or pressure are changed. These changes are expressed in what are known as Gas Laws, and are explained below:

a) **Charles Law:** The volume of a given mass of gas is directly pro portional to its absolute temperature, provided its pressure is kept constant. In other words, volume of a given mass of gas increases by 1/273 of its volume at 0°C for every 1°C rise its temperature provided the pressure remains constant. It is expressed as: $\frac{Vi}{Ti} = \frac{V2}{T2}$

b) **Boye's Law:** The volume of a Gas is inversely proportional to the pressure upon it provided the temperature is constant. It is expressed as : $\frac{V2}{V1} = \frac{P1}{P2}$ and P1 V1= P2 V2

c) **Law of Pressures:** The pressure of a given mass of gas is directly proportional to its absolute temperature, provided its volume is kept constant.

It is expressed as: $\frac{P1}{T1} = \frac{P2}{T2}$

d) **The General Gas Law:** The above three Gas Laws can be combined and expressed in a single equation:

$$\frac{P1\,V1}{T1} = \frac{P2\,V2}{T2}$$

e) It is important to note that when the temperature and pressure levels of liquifaction point are attained, the Gas Laws are no longer applicable.

1.9.2. Classification of Gases

(a) Classification by chemical properties:

(i) Flammable Gases - Eg., Propane, Methane (C_3H_8, CH_4)

(ii) Non-flammable Gases - Eg., CO_2, SO_2, N_2

(iii) Reactive Gases - Eg., F_2 (most reactive), Cl_2

(iv) Inert Gases - Eg., Ar, He, CO_2, N_2

(v) Toxic Gases - Eg., Cl_2, H_2S, NH_3, CO, SO_2

(b) Classification by physical properties:

(i) **Compressed Gases** (which exist solely in the gaseous state under pressure at normal atmospheric temperature inside the container) Eg., O_2, N_2,

(ii) **Liquefied Gases** (which, at normal atmospheric temperatures inside the container, exists partly in the liquid state and partly in the gaseous state, and under pressure, as long as any liquid remains in the container) Eg., Liquified Petroleum Gases(LPG), Liquified Oxygen(LOX)

(iii) **Cryogenic Gases** (liquified gases, which exist in the container at temperatures far below normal atmospheric temperature, but usually slightly above their BP at NTP, and at correspondingly low to moderate pressures. Eg., Air (BP $-194.4^{o}C$); O_2(BP$-183^{o}C$)

(c) Classification by usage:

(i) Fuel Gases - Eg. Natural Gas(NG), LPG

(ii) Industrial Gases (Comprising entire range of gases utilised for industrial processes, welding and cutting, chemical processing, refrigeration etc.) Eg., H_2, O_2, N_2, C_2H_2, NH_3.

(iii) Medical Gases (Anaesthesia, respiratory therapy etc.) Eg. O_2, N_2O.

1.9.3. The primary hazards of gases arise from:

(a) Hazards of confinement - Gases expand when heated leading to pressure increase resulting in gas release and (or) container failure;

(b) Hazards of fire - Containers can fail due to metal fatigue, and can result in explosion. Flammable liquids, including LPG, in containers/vessels, when exposed to fire, can result in violent explosion, a phenomenon known by the term, **BLEVE**, meaning **Boiling Liquid Expanding Vapour Explosion,** which has immense damage potential. Flammable vapours, when released into the air, can mix with air, and when in correct proportions, can result in violent explosion known by the term UVCE, meaning **Unconfined Vapour Cloud Explosion**, with great damage potential. Under fire conditions, liquifiable gases are more hazardous than permanent gases.

1.10. Transmission of Heat

1.10.1 Heat is transferred from regions of higher temperature to regions of lower temperature. This transmission or transfer of heat is achieved through three methods - **(i) Conduction, (ii) Convection or (iii) Radiation.**

Transfer of heat governs all aspects of fire, from ignition through to extinguishment.

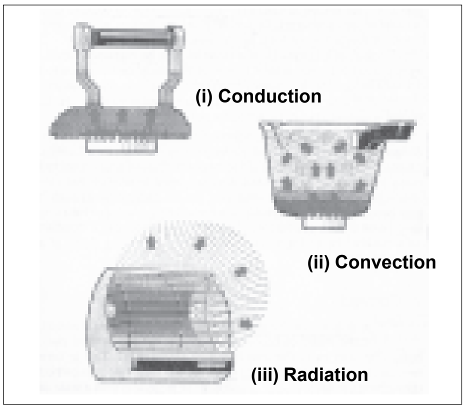


Fig-1 Showing methods of Heat Transmission (i) Conduction (ii) Convection (iii) Radiation

(a) Conduction

(i) Solids are better heat conductors than liquids or gases. **Thermal conductivity**, or the ability to conduct heat, varies between materials. Most metals are good conductors, the best conductors being silver and copper. Generally, good conductors of electricity are good conductors of heat also, and vice-versa.

(ii) In fires, thermal conductivity is relevant in terms of the danger of fire spread. A steel beam passing through a wall can be the cause of fire spread from one room to another.

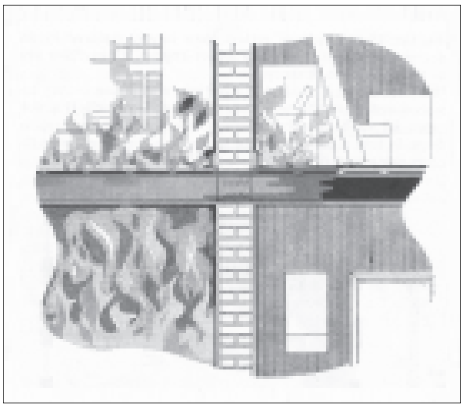


Fig-2 Fire spread in a building due to Conduction of heat along an unprotected steel beam/girder

A plain metal door can conduct heat from one side to another, whereas a wooden door will not, since wood is a poor conductor. The conductivity of building materials has an important role in the fire resistance capability of elements of structure.

(b) Convection

(i) Convection requires a circulating medium for transmission of heat and occurs only in liquids and gases. It transports the enormous amount of chemical energy released during a fire to the surrounding environment by the movement and circulation of hot gases. Convection is used in domestic heating systems or radiators. Convection also causes the up-draft in chimneys or the 'stack effect'.

(ii) In a multi-storey building fire, convection currents can convey hot gases and smoke upwards through stairwells and open lift shafts, spreading the fire to the upper floors through open doors and false ceilings.

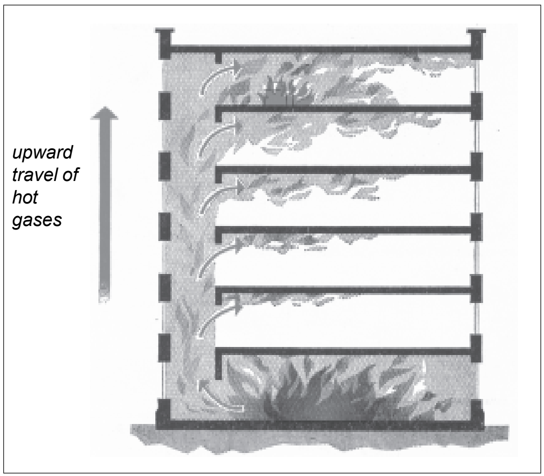


Fig-3 Showing how fire on a lower floor can spread to upper floors by convection

(c) Radiation

(i) Radiation is a form of energy that travels through a space without an intervening medium, such as a solid or a fluid. It is through the same method by which heat from the sun passes through the empty space to warm the earth. It travels as electromagnetic waves, similar to light, radio waves, and x-rays. In a vacuum, all electro-magnetic waves travel at the speed of light (300,000 km/sec.). When it falls on a body, it can be absorbed, reflected and / or transmitted.

(ii) In a fire, the hot gases rise vertically upwards in a plume that carries with it most of the heat(70% - 90%) released in the combustion process, depending upon the fuel. The rest of the heat is transmitted as radiation. Some radiation also comes from the gaseous combustion products, H_2O and CO_2. Roughly, about 10% of the heat of combustion is lost from the flame by radiation in these cases. However, larger fires involving ordinary fuels may release 30 to 50 percent of the total amount of energy as radiation, exposing nearby surfaces to high levels of radiant heat transfer. Water vapour and CO_2 in the atmosphere, which will generally be present in fires, absorb appreciable amount of thermal radiation emitted from large fires. This is the reason why forest fires or large LNG fires are relatively less hazardous when humidity is high. Water droplets are capable of absorbing almost all the incident infra-red radiation thereby cooling to surroundings. This is the reason why fire fighters normally enter a burning building or room with hose handlines fitted with water spray/fog nozzles.

(iii) All forms of radiant energy travel in straight lines. But the intensity of radiation decreases with distance. Twice the distance, intensity becomes one quarter; at three times the distance, the intensity is one-ninth, and so on. This is known as the **inverse square law** of radiation.

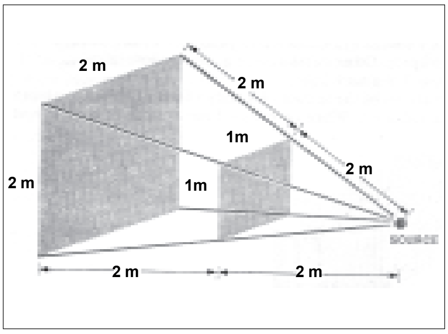


Fig-4 Showing the inverse square law in radiation

(iv) Radiation has been the cause for many fires. A common cause of home fires is clothing getting ignited by radiant heat when it is placed too close to a source of radiation.

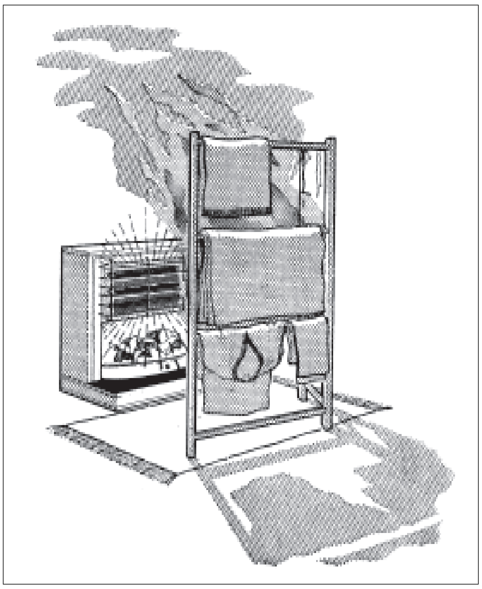


Fig-5 Clothing can get ignited if placed too close to a source of radiation

Similarly, radiant heat from the sun passing through a glass window or a bottle, which acts as a lens, had also been the cause of fires.

■

CHAPTER- 2 - COMBUSTION PROCESS (RELEVANT TO FIRE SCIENCE)

2.1 Chemical Reaction

A chemical reaction is a process by which reactants are converted into products. Thus the oxidation of propane is represented by the equation

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

The mechanism in the above reaction is quite complex and involves reactive species called **free radicals.** Free radicals include atomic Hydrogen(H), Oxygen(O), the hyroxyl radical (OH), and many more. The reaction stated above, though appears simple, actually involves many intermediate steps(elementary reactions), which create a chain reaction.

2.2 **Heat of Reaction -** (a) The heat of a chemical reaction is the energy that is absorbed or emitted when a given reaction takes place. **Exothermic reactions** produce substances with less energy than was in the reacting material, so that energy in the form of heat is released by the reaction. In **endothermic reactions**, the new substances formed contain more energy than the reacting materials, and so energy in the form of heat is absorbed by the reaction.

(b) All reactions get faster as the temperature is increased. **As a rough rule, the speed of chemical reaction doubles for every 10°C rise of temperature.** Some over-exo-thermic reactions are of direct concern to fire service. They are mostly vapour phase reactions or reaction between two or more gases, one of which usually is Oxygen.

2.3. COMBUSTION

2.3.1. Combustion is an exothermic, self sustaining reaction involving a condensed - phase fuel, a gas phase fuel, or both. The process is usually associated with the oxidation of the fuel by atmospheric oxygen with the emission of light. Condensed phase combustion, (comparatively slow oxidation) generally occurs as **glowing combustion or smouldering,** while gas phase combustion (representing rapid rate of reaction) usually occurs with a visible flame(flaming combustion).

2.3.2. A flame is the visible part of an exothermic vapour - phase reaction zone. Sufficient thermal energy is released in the combustion process. The reactions can be maintained in a flame only when sufficient heat is being transferred to the unburned gases to raise them to flame temperatures(commonly between 1500 ^{o}C to 2000^{o}C)

2.3.3. There are two types of flaming combustion - (i) **Pre-mixed flame** in which gaseous fuel is mixed intimately with air before ignition. Eg: Candle flame, and (ii) **Diffusion flame** in which combustion takes place in the regions where the fuel and air are mixing. Nearly all the flames seen by the fire fighters are diffusion flames, more often with turbulence. The rate of diffusion of the reacting gases to some extent controls the size of the flame. The flame becomes luminous because of the presence of carbon particles.

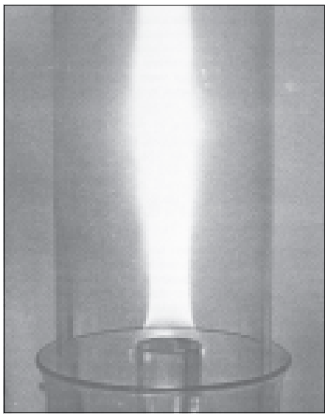


Fig-6 A diffusion flame

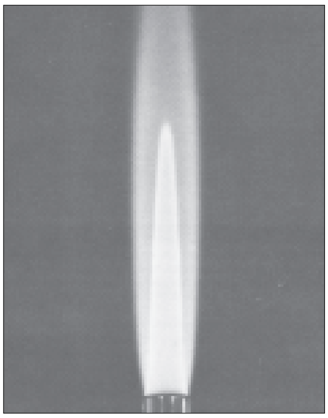


Fig-7 A premixed flame

2.3.4. Oxidation Reactions:

To the fire fighter, the term oxidation means a combination of substance with O2, as in the combustion of carbon. Oxidation reactions involved in fires are complex and exothermic. Basically, a combustible material (fuel) and an oxidising agent(more often air) are essential requirements for an oxidation reaction to take place. Fuels which can be oxidised comprise of numerous materials, which consist primarily of carbon and hydrogen, such as most combustible solid organic materials and flammable/combustible liquids.

2.3.5 Certain combustible materials such as pyroxylin plastics contain their own oxygen so that partial combustion may occur without oxygen from any external source. Combustion may also occur in certain special cases in an atmosphere of chlorine, carbon-di-oxide, nitrogen and some other gases without oxygen being supplied.

2.4. Ignition is the process of initiating self-sustained combustion. Ignition can be caused by the introduction of small external flame, spark or glowing ember when it is known as **piloted-ignition.** When it occurs without the assistance of an external source, it is called **auto-ignition.** Usually the piloted ignition temperature of a substance is considerably lower than its auto ignition temperature. Once ignition has started, it will continue until all the available fuel and /or oxidant has been consumed, or until the flame is extinguished.

2.5 For most combustible solids and liquids, initiation of the flame reaction occurs in the gas or vapour phase. Exceptions to this are carbon and certain metals where direct surface oxidation occurs. Generally, the solids and liquids have to be heated for generation of combustible vapour-air-phase mixture.

2.6. Flash Point - is the lowest temperature at which the vapour produced by a substance will flash momentarily when a flame is applied.

2.7 Fire Point - is the lowest temperature at which the heat from the combustion of a burning vapour is capable of producing sufficient vapour to enable combustion to be sustained.

2.8 Spontaneous Ignition Temperature / Auto Ignition Temperature - is the lowest temperature at which a substance will ignite spontaneously or by itself without any external source of ignition.

2.9 Spontaneous Combustion

2.9.1. Certain organic materials can react with oxygen at room temperatures. Eg. Linseed Oil has the property of reacting with atmospheric oxygen, generating heat which increases the rate of reaction. There have been several cases of cotton waste smeared with linseed oil or paint igniting in a few hours, especially in confined conditions. This kind of ignition is known by the term **spontaneous combustion.**

2.9.2. Action of bacteria on certain organic materials and agricultural products like wet or improperly cured hay can also result in spontaneous combustion. Such heating can initiate oxidation reaction may result in ignition within three to six weeks of storage. Likewise, powdered or pulvurised coal or some metal powders are also prone to spontaneous combustion. Thermal insulation factor plays an important role in causing spontaneous combustion. Table showing the list of substances liable to spontaneous combustion is given below.

Table-1
SUBSTANCES LIABLE TO SPONTANEOUS COMBUSTION

Substances	Tendency	Method of Storage	Precautions
1.Charcoal	high	bulk, bags	keep dry. Supply ventilation
2. Cod liver oil	high	containers	no contact with rags etc.
3. Fish oil	high	barrels, drums	avoid contact of leakage with rags etc.
4. Iron pyrites	moderate	bulk	keep dry and cool.
5. Linseed oil	high	drums, tank cars	avoid contact wet rags, cotton or other fibrous combustible materials
6. Menhaden Oil	high	bulk	-do-
7. Oily rags	high	bales	avoid storing in bulk in open

2.10. Flammability Limits(F.L)

2.10.1 A combustible or flammable gas or vapour - air mixture can burn in air only if the mixture is within certain proportions, or limits. If the proportion of the gas/vapour in air is too little, the mixtrue is said to be a **lean mixture,** and it will not burn. Similarly, if the proportion of gas/ vapour in air is too much, the mixture is said to be a **rich mixture,** and will not burn. These limits are referred to as **lower and upper limits of flammability (flammable limits or FL)** for the substance. Sometimes these limits are also called as **lower and upper explosive limits.**

2.10.2. A Table showing the Flash Point (FP), Auto Ignition Temperature(AIT) and Flammable Limits(FL) of certain chemicals is appended below:

Table-2
FP, AIT AND FL OF CERTAIN CHEMICALS

Chemical	FP	AIT	FL	
			Lr	Ur
1. Ammonia	-	651°C	16%	35%
2. Acetylene	−17.7°C	335°C	2%	85%
3. Acetone	−17.8°C	535°C	2.5%	13%
4. Benzene	−9°C	535°	C1.5%	8%
5. Hydrogen	-	585°C	4%	74%
6. Butane	−60°C	430°C	1.9%	8.5%
7. Propane	−104°C	473°C	2.4%	9.5%
8. Carbon Monoxide (CO)	-	650°C	12.5%	74%
9. Cyclohexane	−20°C	245°C	1.3%	8.3%
10. Ether	−42.8	180°C	1.9%	22%

Chemical	FP	AIT	FL	
			Lr	Ur
11. Petrol	–45.6°C	246°C to 456°C	1.5%	6%
12. Ethyl Alcohol	12.8°C	371° - 427°C	3.5%	19.%
13. Hydrocyanic Acid(HCN	–17.8°C	538°C	5.6%	40%
14. Naphtha	–17.8°C to 38°C	482°C	1.1%	4.8%
15. Carbon-di-sulphide (CS_2)	–8°C	125°C	1%	50%
16. Toluene	4.5°C	552°C	1.3%	6.7%
17. Sulphur(S)	207°C	232°C	M.P.	112.8°C
18. Kerosene	31°C	227°C	0.5%	9%
19. H_2S	-	270°C	4%	44%
20. Hydrazine (N_2H_4)	32°C	(May ignite spontaneously)	4.7%	100%

2.10.3. The above values, especially FL, for chemicals are not very rigid. There are variable factors which may slightly alter the values. For instance, increase in temperature and pressure can make the flammable limits slightly elastic - that is, the lower limits can be slightly lowered still further, or the upper limit can be raised slightly. The factors which influence FL are pressure, temperature, dimensions of container, flame propagation, and moisture content of the mixture.

2.11. Oxidising agents

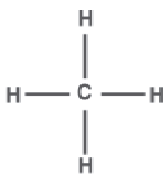
2.11.1. Oxidation in its most simple form is combination of a substance with oxygen. Certain elements other than oxygen also act as oxidising agents. For instance, most metals will react with chlorine or other halogens, which is also oxidation.

Eg: Mg +Cl_2 = Mg cl_2 (Cl_2 acts as an oxidising agent)

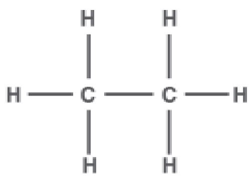
2.11.2. Apart from some acids. like Nitric acid, Perchloric acid etc., inorganic nitrates, permanganates, peroxides etc. are also strong oxidising agents, besides organic nitrates, nitro-compounds, organic peroxides and hyperoxides, which are also powerful oxidising agents. Some of them are not only flammable, but are highly explosive also.

2.12. There are numerous combustible organic substances, which are essentially carbon compounds. It is estimated that there are over a million such carbon compounds. Organic chemicals are of two classes: (a) **Aliphatic compounds (paraffins),** which contains chains of carbon atoms;

Eg. Methane(CH_4), Ethane(C_2H_6), Propane(C_3H_8) etc;



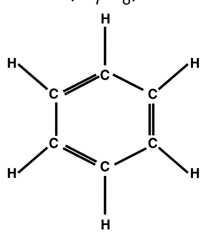
Methane, CH_4



Ethane C_2H_6
Showing chains of Carbon atoms

(b) Aromatic compounds, which contain rings of carbon atoms;

Eg. Benzene(C_6H_6), Toluene(C_7H_8) etc.



Benzene (C_6H_6)
Showing ring of carbon atoms

2.13. **Liquefied Petroleum Gas (LPG)**, which is commonly used cooking gas, is a mixture of propane(C_3H_8) and butane(C_4H_{10}), both being highly flammable gases. The expansion ratio of liquid to gas of LPG is approx. 1 to 270, and the vapour density(VD) is around 1.5 to 2, and in case of leakage, the gas/vapour collects at the lower levels.

2.13.1. These are gases at room temperatures and pressures, but can be liquified by the application of pressure since their critical temperatures are well above room temperature(critical temperatures propane and butane are 96.7°C and 152 °C respectively). LPG cylinders heated above the critical temperature are likely to explode due to enormous pressure increase.

2.14. Chemical fires

2.14.1.A chemical fire is a fire in which the material is a chemical. Certain chemicals which have O_2 content in them and in case they catch fire they will burn without the aid of air or O_2. If there is a rise in temp. or due to any reason spark falls on them, they catch fire. Hence they are highly dangerous in storage.

2.14. 2. Chemicals which contain O_2 and highly flammable are:

a) Solitary compounds: Such as celluloid (cellulo-nitrate), nitro-glycerine. They are compounds of C, H_2, N&O_2

b) Mixtures - (i) Gunpowder (charcoal + any oxidising agent like pot. chlorate) which is very sensitive to shock and heat.

(ii) Thermite (Al + Fe oxide) which is used in thermite bombs

(iii) Nitrous oxide (N_2O) or laughing gas.

2.14.3. Combustible materials + a supporter of combustion (which may not be O_2) such as Cl_2, Br_2, I_2, of the halogen group.

2.14.4. Oxidising Agents - Nitrates, Chlorates, Permanganates, Peroxides, Chromates etc.

2.14.5. Chemicals which in contact with organic substances react easily - Eg: acid.

2.14.6. Risks at chemical fires - When fighting chemical fires, the fire fighting party will be exposed to considerable danger from poisonous fumes and gases

(a) Irritants:-Cl_2, Tear gas, S, NH_3 (Ammonia)

(b) Toxic - CO

(c) Injurious by touch or contact - Acids, Alkalis, Phosphorus, Hydrocyanic acid gas

(d) Danger of fire spread - Chlorates or other oxidating agents when mixed with water used for fire fighting, dissolve and cause danger to other stores nearby. Phosphorus(P), which is normally kept under water, when gets exposed to air, starts burning and causes fire to other stores.

2.15 Chemicals on which use of water is restricted.

2.15.1. There are some substances which react with water, dissociate water into its elements with generation of heat, thereby promoting combustion. There are some others on which water should not be used as an extinguishing medium, since they are lighter than water.

(a) Metals:- At certain temperatures, different metals react with water. There are certain metals which react with water even at ordinary temperatures. The state of reaction for certain metals when in contact with water is shown under Table-3. When these metals are in powder form, danger is more.

(b) Calcium Oxide (Quick lime) Water on cal. oxide results in generation of heat which is enough to ignite nearby materials. Large quantities of steam are also produced.

(c) Cal. Carbide - Reacts with water and produces acetylene gas which is highly flammable. Cal. carbide godowns should be away from other stores. Walls of the godowns should be thick. Never use ferrous tools (which cause sparks) to open sealed drums of Cal. carbide. Leaky drums may contain acetylene gas produced by reaction of the chemical with moisture and one spark caused by ferrous tools might cause an outbreak of fire.

(d) Sod. Peroxide - With moisture of water, liberates O_2 and generates heat which can iginite surrounding combustible materials, and O_2 is a supporter of combustion.

(e) Other Substances - A list of substances on which use of water is restricted is given in Table-3. Water is not normally used on flammable liquids whose specific gravity is less than water itself - (eg. Petrol). Carbon-di-sulphide (CS2) has specific gravity more than water and is flammable; but water could be successfully used on it.

In tackling oil fires -use jet of water with discretion to cool down drums (and surroundings) which are near the fire, and use foam on fire itself. Finely divided water spray is also efficacious on small oil fires.

Table-3

METALS WHICH REACT WITH WATER

Metals	**State of Temperature**	
	Metal	**Water**
Potassium Sodium Barium Strontium Calcium	Cold	Cold
Magnesium Aluminium Zinc Iron Manganese	(a) burning (b) red-hot	(a) cold (b) Steam
Lead Copper Tin	no appreciable action	no appreciable action

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SECTION 4 - FIRE EXTINCTION / SUPPRESSION TECHNOLOGY

CHAPTER -1- CONSTITUENTS OF FIRE

1. Combustion Process

1.1 An understanding of the basic principles of combustion or fire, causes and sources of ignition, fire growth and fire spread is necessary for understanding the principles of fire control and extinguishment.

1.2. Combustion usually involves an exothermic chemical reaction between a substance or fuel and oxygen. Unlike slow oxidation, a combustion reaction occurs so rapidly that heat is generated faster than it is dissipated, causing a marked increase of temperature, even upto a few hundreds of degrees. Very often, the temperature reaches so high that visible light or flame is generated.

2. Triangle of fire

2.1. One way of discussing fire or combustion is in terms of the **'triangle of fire'** or combustion. It has been seen that for combustion to occur three factors are essential; heat, oxygen(or air) and a combustible substance (or fuel). Fire or combustion will continue as long as these three factors are present. Removal of one of them leads to the collapse of the triangle and the combustion process stops.

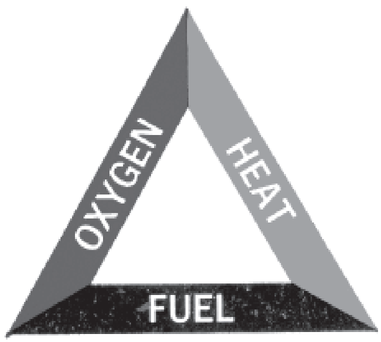

Fig-8 Triangle of Fire showing the three constituents of fire. (old concept)

2.2 Nature of flame

2.2.1. As has been stated, the burning of most materials produce a flame. A flame front stemming from a local ignition source is established in a flammable medium. A form of chemical reaction is set-up in the layer of gas adjacent to this source with the result that heat and what are called **'chain carriers'** pass into the next layer of gas and continue the cycle of the operations there, rather like runners in a relay race. Chain carriers are believed to be atoms or part of molecules, known as '**free radicals**' and these are extremely reactive. Combustion, therefore, is a type of chain-reaction.

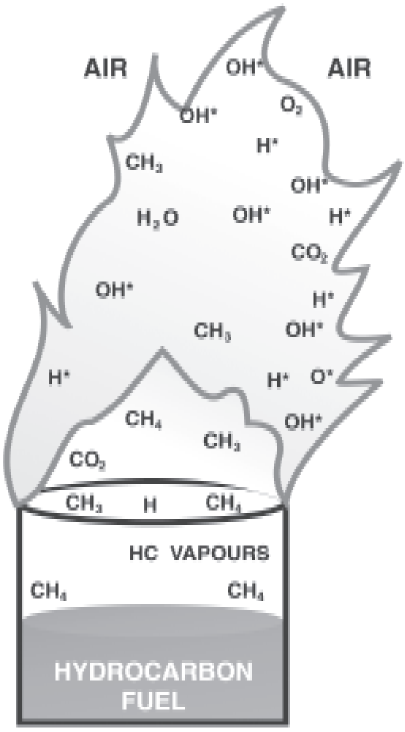

Fig-9 Uninhibited / Unbroken Chain Reaction showing active radicals like H^*, O^* & OH^* in the flame

2.2.2. The flame temperature is very important because the rate of a key combustion reaction ($H+O_2 = OH+O$) is very sensitive to temperature. A small decrease in temperature causes a disproportionately large decrease in the rate of the reaction. A single H atom, when introduced into an H_2-O_2 mixture at an elevated temperature will be transformed in a fraction of a millisecond to form 2 molecules of H_2O and 3 new H atoms. Each of these H atoms can immediately initiate the same sequence, resulting in a **branching chain reaction,** which continues until the reactants are consumed. The remaining H, O and OH species recombine according to the reaction

$$H+O = OH \text{ and } H+OH = H_2O$$

Similar chain reactions occur in flames of any H containing fuel. H is present in the vast majority of combustibles except for metals and pure carbon.

2.2.3. H atoms or other active species (radicals) may also be removed from the flame by purely chemical means, that is by an extinguishing agent capable of chemical inhibition. Hence, there are two fundamental ways of reducing combustion intensity in a flame, ultimately causing extinguishment:

(i) Reducing the flame temperature,

(ii) Adding a chemical inhibitor to interfere with the chain reaction.

2.2.4. The flame temperature is generally around 1900^{o}C and above. By bringing the flame temperature to below around 1200^{o}C to 1300^{o}C, flame is unable to continue burning. Thus, below a critical temperature (1200^{o}C to 1300^{o}C), the chain breaking reactions will dominate and the flame can no longer burn.

2.2.5. In the absence of oxygen within certain zones of the flames, the organic (carbon containing) materials are decomposed by heat giving rise to tarry and sooty decomposition products. In other words, smoke is generated. Besides, carbon monoxide is also formed due to incomplete combustion.

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SECTION-4
CHAPTER -2- METHODS OF FIRE EXTINGUISHMENT

3. FIRE EXTINCTION METHODS

3.1. It has been shown from the triangle of fire that three factors are essential for combustion, namely;

i) the presence of a fuel, or combustible substances;
ii) the presence of oxygen(usually as air) or other supporter of combustion; and
iii) the attainment and maintenance of a certain minimum temperature.

3.2 Fire extinction, in principle, consists in the limitation or elimination of one ore more of these factors, and the methods of extinguishing fire may be classified conveniently under the following headings:

(a) Starvation (or the limitation of fuel);
(b) Smothering / Blanketing (or the limitation of oxygen); and
(c) Cooling (or the limitation of temperature).

In practice, specific methods of fire extinction often embody more than one of these principles, but it will be convenient to consider them according to the main principle involved.

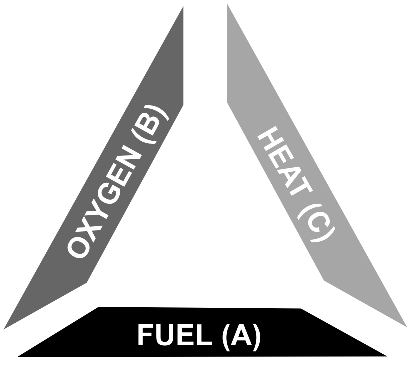


Fig-10 Fire Extinction Methods

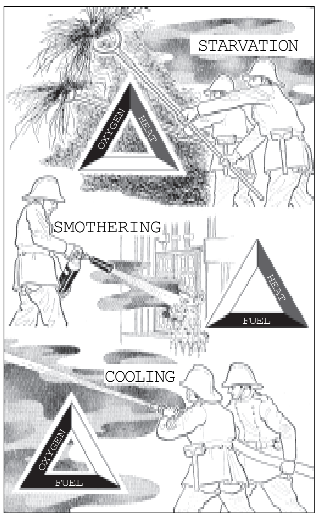


Fig-11 Triangle of Fire showing the three conventional methods of fire extinguishment-Starvation(A), Smothering(B), and Cooling(C)

3.3. Starvation

3.3.1. The extinction of fire by starvation is applied in three ways:

i) By removing combustible material from the neighbourhood of the fire. Examples of these are, the drainage of fuel from burning oil tanks; the working out of cargo at a ship fire, the cutting of trenches in peat, heath, and forest fires; the demolition of buildings to create a fire stop; counter-burning in forest fires;

ii) By removing the fire from the neighbourhood of combustible material as, for instance, pulling apart a burning haystack or a thatched roof;

iii) By sub-dividing the burning material, when the smaller fires produced may be left to burn out or to be extinguished more easily by other means. A typical example is the emulsification of the surface of burning oil, whilst the beating out of a heath fire owes much of its effectiveness to this.

3.4. Smothering

3.4.1. If the oxygen content of the atmosphere in the immediate neighbourhood of burning material can be sufficiently reduced combustion will cease. The general procedure in methods of this type is to prevent or impede the access of fresh air to the seat of the fire, and allow the combustion to reduce the oxygen content in the confined atmosphere until it extinguishes itself.

3.4.2. An important practical application of the smothering method is the use of foam. This forms a viscous coating over the burning material and limits, in so far as it is complete, the supply of air. It also tends to prevent the formation of flammable vapour.

3.4.3. Another method of smothering is by the application of a cloud of finely divided particles of dry powder, usually sodium bicarbonate, from a pressurised extinguisher.

3.4.4. A further development in the smothering method has been the discovery of a powdered compound for use on metal fires, such as uranium and plutonium, thorium and magnesium. This powder (ternary eutectic chloride)is applied by means of a gas cartridge pressurised extinguisher. As the fusing temperature of the powder is in the region of 580°C it forms a crust over the burning metal and this excludes the oxygen of the air.

The vigorous discharge of an inert gas in the immediate vicinity of the fire may so reduce the oxygen content of the atmosphere for the time being that combustion cannot be maintained. Carbon-di-oxide and nitrogen are familiar examples of this.

3.4.5. A group of extinguishants consisting of volatile liquids based on the halogenated hydrocarbons are also in use.

These evaporating liquids act partly as inerting blankets similar to those mentioned in the preceding section, and partly by chemical interference with the chain reaction of flame propagation.

3.5. Cooling

3.5.1. If the rate at which heat is generated by combustion is less than the rate at which it is dissipated through various agencies, combustion cannot persist.

3.5.2. The application of a jet or spray of water to a fire is invariably based on this simple but fundamental principle. There are many variations. Another example is the emulsificaton of the surface of oil by means of the emulsifying type of spray nozzle producing an oil-in-water-emulsion,

3.5.3. The cooling principle in fire extinction is the one most commonly employed, forming as it does the basis of the application of water and other liquids to burning materials.

3.5.4. The action of water depends predominantly on its thermal capacity and latent heat of vapourisation, the latter being by far the more important. Thus it takes about six times as much heat to convert a certain weight of water at its boiling point into steam as is required to raise the temperatures of the same amount of water from the usual atmospheric temperature to its boiling point. In fact, while changing from liquid (water) to vapour state(steam) water expands about 1760 times which also contributes to its smothering effect. In the interests of efficiency, it is clearly desirable that water should be applied to a fire in the liquid condition and in such a way that as much as possible is converted to steam. The smothering effects of the steam produced at the seat of the fire is thought to play a part in assisting in the extinguishig process.

3.5.5. On the basis of thermal capacity and latent heat of vapourisation, water is an excellent fire extinguishing agent since both figures are high. For instance, the thermal capacity or specific heat of water is 4.2 kJ/kg/^{o}C and latent heat of vapourisation is 2260 kJ/kg This fact, combined with its availability in large quantities, makes it by far the most useful fire extinguishing agent for general purposes.

4. Tetrahedron of Fire (Fourth factor contributing to fire)

4.1. The triangle of fire representing three basic constituents of fire is the conventional concept. Fire scientists have now found that there is a fourth constituent in all flaming fires which plays a vital part in the fire growth and sustenance. This is the unbroken or uninhibited chain reaction. Thus, as per modern concept, the previous figure of triangle of fire has been transformed into a **tetrahedron of fire,** each of its four sides representing one of the four basic requirements: fuel, temperature, oxygen and unbroken or uninhibited chain reaction. This last factor comes into play only in flaming mode of combustion which is normally applicable in the case of flammable liquids and gases.

Fig-12 Tetrahedron of Fire

4.2. In the flame front, due to chemical reaction, active free radicals of OH*, H* and O* species are produced which act as 'chain carriers' which help to sustain the flame. (Ref. Fig.10) Extinguishment of fire by flame inhibition or breaking the chain reaction is achieved when these active free radicals or chain carriers are inhibited or eliminated. This principle of fire extinguishment is known as 'breaking the chain reaction" which is achieved by removal/ suppression of the free radicals. The extinguishing agents used for this purpose are halogenated hydrocarbons or halons/halon alternatives and several types of dry chemical powders. On application of these agents, the flame becomes inhibited and extinguishment is achieved.

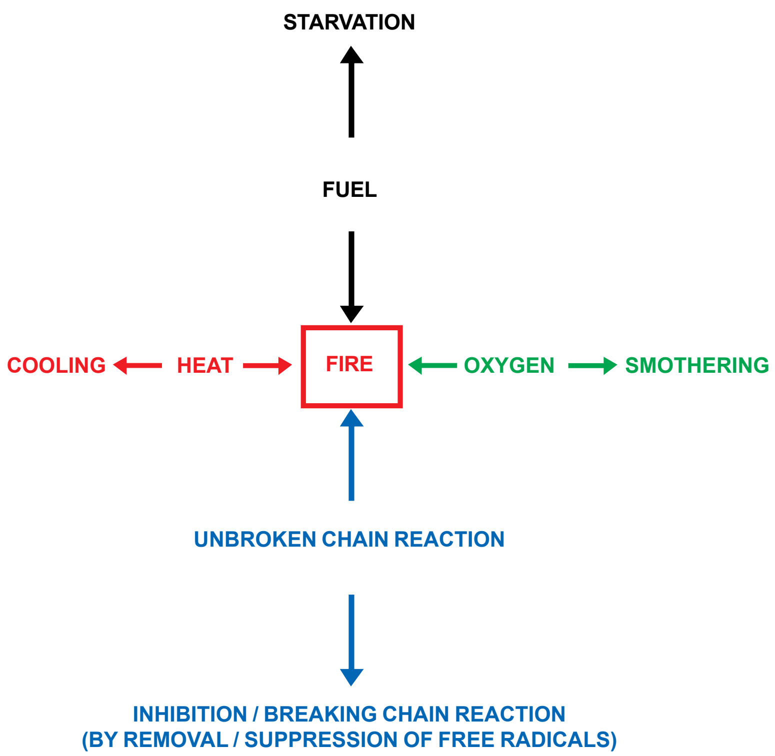


Fig-13 Fire Extinguishment(Fourth Factor)

SECTION-4

CHAPTER -3- EXTINGUISHING MEDIA

5. Classification of fires

5.1 Internationally accepted classification of fires is as follows.

Class 'A'

These are fires involving solid materials normally of an organic nature (compounds of carbon), in which combustion generally occurs with the formation of glowing embers. Class 'A' fires are the most common. Effective extinguishing agent is generally water in the form of a jet or spray.

Class 'B'

These are fires involving liquids or liquefiable solids. For the purpose of choosing effective extinguishing agents, flammable liquids may be divided into two groups:

i) Those that are miscible with water, and
ii) Those that are immiscible with water.

Depending on (i) and (ii), the extinguishing agents include water spray, foam, vapourising liquids, carbon dioxide and chemical powders.

Class 'C'

These are fires involving gases or liquified gases in the form of a liquid spillage, or a liquid or gas leak, and these include methane, propane, butane, etc. Foam or dry chemical powder can be used to control fires involving shallow liquid spills. (water in the form of spray is generally used to cool the containers.)

Class 'D'

These are fires involving metals. Extinguishing agents containing water are ineffective, and even dangerous. Carbon dioxide and the bicarbonate classes of dry chemical powders may also be hazardous if applied to most metal fires. Powdered graphite, powdered talc, soda ash, limestone and dry sand are normally suitable for class 'D' fires. Special fusing powders have been developed for fires involving some metals, especially the radioactive ones. Presently special dry chemical powders have been developed for extinguishing metal fires.

5.2 Electrical fires

It is not considered, according to present-day ideas, that electrical fires constitute a separate class, since any fire involving, or started by, electrical equipment, must, in fact, be a fire of class A, B or D. The normal procedure in such circumstances is to cut off the electricity and use any extinguishing method appropriate to what is burning. Only when this cannot be done with certainty will special extinguishing agents be required which are non-damaging to equipment. These include vapourising liquids, dry powders carbon-di-oxide, and other gaseous extinguishing agents.

6. EXTINGUISHING AGENTS / MEDIA

6.1 WATER

6.1.1. 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.

6.1.2. For major fires, greater quantities of water are necessary, and the built-in pumps driven by the vehicles' engines are often capable of pumping 4500 litres (1000 gallons) per minute (or more) giving the necessary energy to the water to provide adequate striking power.

6.1.3. 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 atomised fog effects. Judicious use of this type of application can not only cut down the amount of water used, minimising water damage, but will ensure that it is used to greater effect.

6.1.4. Some of the special properties which make water as the most efficient and generally accepted extinguishing agent are:

- Water has a high sepecific heat capacity are 4.2 kJ / kg / per ^{o}C
- Water has a high latent heat heat of evaporation per unit mass, atleast 4 times higher than that of any other non flammable liquid
- It is outstandingly non-toxic
- Its B.P. (100^{o}C) is well below the 250^{o}C to 450^{o}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: Additional information on the special properties which inquality water as an excellent extinguishing agent have already been given in para 3.5.4. and 3.5.5.

6.1.5. In practical fire fighting water has to be applied at 10 to 100 times the rates prescribed in laboratory tests because of the difficulty of ensuring that the bulk of it reaches the burning surfaces.

6.2. FOAM AND FOAM-MAKING COMPOUNDS

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

6.2.2. The desirable characteristics of foam are resistance to radiant heat, to fuel vapours 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 fire-fighting 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 litres per square metre (1 gallon of foam per square foot) of surface area per minute as the ideal rate, although in most cases it would be rather less than this.

6.2.3. Classification

Foam concentrates can be classified in two ways:-

(i) Classification by Expansion

Low expansion	(LX)
Medium expansion	(MX)
High expansion	(HX)

Expansion Ratio

Low expansion up to 50:1 (Usually between 5:1 and 15:1)

Medium Expansion: Between 50:1 and 500:1 (Usually between 75:1 and 150:1)

High Expansion: Between 500:1 and 1000:1 (Usually between 750:1 and 1000:1)

(ii) 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 burnback.

Fluroprotein 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 burnback and resistant to fuel contamination, making it the most suitable type for sub-surface injection for oil tanks.

Fluro-Chemical 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 burnback resistance not as good as the protein and fluoroprotein types. Undiluted concentrate may strip paint, and care should be taken not to allow contact with the skin. Commonly known as 'Aqueous Film - Forming Foam' (AFFF), since it provides a film over the liquid surface which prevents vapour 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 burnback 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 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.

6.2.4. Compatibility of Foam Concentrates and Foams

(i) It is important in all cases that the manufacturer's instructions should be adhered to, but as a broad basic guide, the following points should be borne in mind:

- Do not mix different types of foam concentrates in the same equipment.
- Do not mix different brands of the same type of foam concentrate.
- Do not mix different batches of the same brand and type of foam concentrate.

(ii) Follow manufacturer's recommendations with regard to the combined use of dry powders with foam. Some interact severely. Different foams may be used together on the same fire, but there may be a slight detrimental effect on the performance of any one type.

6.2.5. Foam Making Equipment

The basic items of equipment required to produce foam are as folows:

- A pump to impart the necessary energy to the water.
- A hose to deliver water to the required point.
- A means of introducing the foam concentrate into the water stream.
- A means of aerating the foam concentrate/water mixture.A means to project the foam on to the fire.
- Aerating and projecting are often carried out by the same piece of equipment.

6.2.6. Fireground Formula

(i) Number of foam making branches / generators required at incidents for a circular tank

$$\frac{4D^2}{\text{Output of branch in litres per minute}}$$

i.e, Branches available FB5x (output - 225 lpm foam solution)

Eg: For a tank of diameter 10m:

$$\text{No; of FB5x required} = \frac{4D^2}{225} = \frac{4x100}{225} = 2$$

(ii) High expansion foam concentrate required:

1 litre produces approximately 50 ºu metres of high expansion foam. Therefore, approx.

$$\frac{\text{Cubic capacity (in cu.metres)}}{50} \text{ plus reserve}$$

for topping up due to natural breakdown and wastage.

6.2.7. Weight of Foam Concentrates

Type	Weight per 100 litres
Protein	108 kg
Fluoro Protein	118 kg
Fluoro - Chemical	102 kg
Synthetic	110 kg
Alcohol Resistant	115 kg
Overall Average	111 kg

6.2.8. Output - Foam Making Branches (Low Expansion)

Type	Water (Litres/min)	Foam Conc. (Litres/min.)	Pressure (bars)	Finished Foam (Litres/min)
FB5x	200-300	0-14	5-7	2000-2300
No. 2FB	225	5.7-8	7	2050
No. 10FB	455	13.6	7	3640
No. 20FB	909	27.3	7	7270
No. 30FB	1360	40.9	7	10900

6.2.6. Hydrocarbon Fires (Amounts of Foam Required)

(a) The amounts of foam concentrate and foam solution, and the types of foam generator and branchpipes vary considerably with the size of fire.

(b)The foam concentrate requirements for dealing with large area flammable liquid fires will be considerable. As per guidance, the following figures will be useful:

Area of Fire	Rate of Application of foam concentrate	For duration	Foam Conc. required
100m2	80 lpm	20mins.	1600lit
1000 m2	800 lpm	20 mins.	16000 lt (20 tonnes)
10000 m2	8000 lpm	20 mins.	160000 lt (200 tonnes)

Note: A major fire outbreak in a big oil installation may last for several hours, or sometimes even for days.

(c) In Industrial and Storage Occupancies handling, processing and storage of large quantities of flammable liquids, where fire hazards are high, for tackling major fire outbreaks, large quantities of water and foam compounds, in addition to trained man power and several fire appliances will be required. Being a highly complex and specialised operation, lot of pre-planning will be necessary.

6.3 HALOGENATED AGENTS (HALONS AND HALON ALTERNATIVES)

6.3.1. Halogenated extinguishing agents, though a relatively recent innovation in fire protection, are already being phased out, since they have very high Ozone Depletion Potential or ODP (power for depleting the ozone layer above the earth which acts as a shield for protecting mankind from the harmful ultra-violet rays from the sun). They have been phased out already in the developed countries from 1st Jan. 1994, and will be phased out in the developing countries like India by 2010.

6.3.2. The Halons are chemical derivatives of Methane (CH_4) or Ethane (C_2H_6), in which some or all the H atoms are replaced with Flourine(F), Chlorine(Cl) or Bromine(Br) atoms, or by combinations of these halogen elements.

6.3.3. Of the various Halons, Halon 1301(Bromo-trifluoro-methane, CF_3Br) is the most commonly used, since it has the lowest toxicity and highest extinguishing efficiency. Most of the fires could be extinguished with 4 to 6 percent by volume of H1301.

6.3.4. Because of the phasing out of the Halons, during the last decade several Halon alternatives have been developed in the world market. In so far as India is concerned, 12 new Indian Standards on Halon Alternatives are in the process of publication by the Bureau of Indian Standards. They are:

(i) Gaseous Fire Extinguishing Systems--General Requirements for design, Installation and Commissioning;

(ii) Inert Gaseous Total Fire Protection(Total flooding) Systems--Inergen, Argonite, Nitrogen, Argon;

(iii) HFC-227 ea (FM-200) Total Flooding System;

(iv) NAF S-III(HCFC Blend A) Total Flooding System;

(v) Water Mist Fire Protection Systems;

(vi) Specification for Powdered Aerosol System;

(vii) Gaseous Fire Extinguishing System--Regular Maintenance;

(viii) Methods for Tests for determining fire extinguishing and inerting concentrations for flammable liquids and gases;

(ix) Specification for Halon 1211 and Halon 1301 for essential use(ISO 7201-1:1989)

(x) Code of Practice for Safe Handling and Transfer Procedures of Halon 1301 and 1211;

(xi) Carbondioxide systems, including high and low pressure and incabinet sub floor system;

(xii) Fire Protection-Fire Extinguising Media, Carbon-dioxide-Quality Assurance Test For Fire Extinguishing CO_2 Gas.

6.3.5. **International Scenario:**

(i) In developed countries like USA, National Standards on Halon Alternatives have already been published. NFPA published NFPA-2001, which is the Standard on Clean Agent Fire Extinguishing Systems. The relevant Table showing the agents addressed in 2000 Edition of NFPA-2001 is reproduced below:

Table 4 Agents Addressed in NFPA 2001

FC-2-1-8	Perfluoropropane	C_3F_8
FC-3-1-10	Perfluorobutane	C_4F_{10}
HCFC Blend A	Dichlorotrifluoroethane HCFC-123 (4.75%)	$CHCl_2CF_3$
	Chlorodifluoromethane HCFC-22 (82%)	$CHClF_2$
	Chlorotetrafluoroethane HCFC-124 (9.5%)	$CHClFCF_3$
	Isopropenyl-1-methylcyclohexene (3.75%)	
HCFC-124	Chlorotetrafluoroethane	$CHClFCF_3$
HFC-125	Pentafluoroethane	CHF_2CF_3
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3
HFC-23	Trifluoromethane	CHF_3
HFC-236fa	Hexafluoropropane	$CF_3CH_2CF_3$
FIC-13I1	Trifluoroiodide	CF_3I
IG-01	Argon	Ar
IG-100	Nitrogen	N_2
IG-541	Nitrogen (52%)	N_2
	Argon (40%)	Ar
	Carbon dioxide (8%)	CO_2
IG-55	Nitrogen (50%)	N_2
	Argon (50%)	Ar

Notes:
1. Other agents could become available at later dates. They could be added via the NFPA process in future editions or amendments of the standard.
2. Composition of inert gas agents are given in percent by volume. Composition of HCFC Blend A is given in percent by weight.

The NFPA-2001 covers all aspects of the HAs like applicability, use and limitations, safety, hazards to personnel, components and system design, inspection, maintenance, testing and training, marine systems, tests etc.

(ii) Similar new Standards have been published by British Standards Institute and Standards Australia and few other countries, besides International Standards Organisation (ISO).

The Gaseous Fire Extinguishing Systems for which ISO has published Standards are listed below: (See next page)

(iii) Halons Technical Options Committee(HTOC) under the United Nations Environment Programme (UNEP) is the nodal International Body dealing with all subjects connected with Halon Phase-out and Halon Alternatives. This expert body issues exhaustive guidelines on these subjects which are meant for global application, guidance and implementation.

Table - 5 - Listed extinguishants (ISO)

Extinguishant	Chemical	Formula	Trade name	standard
CF_3I	Trifluoroiodomethane	CF_3I	Triodide	ISO 14520-2
FC-2-1-8	Perfluoropropane	$CF_3CF_2CF_3$	CEA 308	ISO 14520-3
FC-3-1-10	Perfluorobutane	C_4F_{10}	CEA 410	ISO 14520-4
FC-5-1-14	Perfluorohexane	$CF_3(CF_2)_4CF_3$	CEA 614	ISO 14520-5
HCFC Blend A HCFC-123 HCFC-22 HCFC-124	plus Dichlorotrifluoroethane Chlorodifluoromethane Chlorotetrafluoroethane Isopropenyl-1-Methylcyclohexane	 $CHCl_2CF_3$ $CHClF_2$ $CHClFCF_3$ $C_{10}H_{16}$	NAF S-III	ISO 14520-6
HCFC 124	Chlorotetrafluoroethane	$CHClFCF_3$	FE-241	ISO 14520-7
HFC 125	Pentafluoroethane	CHF_2CF_3	FE-25	ISO 14520-8
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3	FM-200	ISO 14520-9
HFC 23	Trifluoromethane	CHF_3	FE-13	ISO 14520-10
HFC 236fa	Hexafluoropropane	$CF_3CH_2CF_3$	FE-36	ISO 14520-11
IG-01	Argon	Ar	Argotec	ISO 14520-12
IG-100	Nitrogen	N_2		ISO 14520-13
IG-55	Nitrogen (50%) Argon (50%)	N_2 Ar	Argonite	ISO 14520-14
IG-541	Nitrogen (52%) Argon (40%) Carbon Dioxide (8%)	N_2 Ar CO_2	INERGEN	ISO 14520-15

6.3.6. In addition to clean total flooding gaseous Halon Alternatives, new technologies such as Water Mist and Fine Solid Particulates are being introduced.

6.3.7. Water Mist - (a) This is a comparatively recent development as a Halon Alternative. Fine Water Mist technology relies on relatively small (less than 200 microns) droplet sprays to extinguish fires. The three methods of application of Water Mist are:

(i) Fixed installation - in a compartment / room for total flooding

(ii) Fixed spray nozzles, for local application, and

(iii) In portable extinguishers.

(b) Water Mist extinguishes a flame by adopting the following mechanisms:

(i) Mist droplets evaporate removing heat and producing cooling (gas phase cooling, which acts as the primary fire suppression factor)

(ii) The fine droplets evaporate in the hot environment even before reaching the flame, generating steam and effecting smothering (oxygen depletion)

(iii) The mist blocks radiative heat transfer between the fire and the combustible.

(c) Analytical studies have indicated that water liquid volume concentrations of the order of 0.1lit. of water per m^3 of air is sufficient to extinguish fires in the gas phase. This represents a potential of two times effectiveness in extinguishment over application rates for conventional sprinklers.

(d) There are currently two basic types of water mist suppression systems: single and dual fluid systems. Single fluid systems utilise water stored at 40-200 bar pressure and spray nozzles which deliver droplets of size 10-100 microns diameter range.

Dual systems use air, Nitrogen or other gas to atomise water at the nozzle. Both types are promising fire suppression systems.

(e) Water mist system using pure water do not present a toxicological and physiological hazard and are safe for use in occupied areas. Also there are no concerns regarding ozone depletion or global warming or atmospheric lifetime potentials.

6.3.8. Fine Solid Particulate Technology

(a) This technology has also been developed recently relating to fine solid particulates and aerosols. These take advantage of the well established fire suppression capability of solid particulates. One principle of these aerosol extinguishants is in generating solid aerosol particles and inert gases in the concentration required and distributing them uniformly in the protected space. Aerosol and inert gases are formed through a burning reaction of the pyrotechnic charge having specially proportioned composition.

(b) Extinguishment is achieved by combined action of two factors such as flame cooling due to aerosol particles heating and vaporising in the flame front as well as a chemical action on the radical level. Solid aerosols must act directly upon the flame. Gases serve as a mechanism for delivering aerosol towards the seat of a fire.

(c) However, toxicity problems about this new technology pose potential concerns.

6.4. CARBON-DI-OXIDE

6.4.1. Carbon-di-oxide posseses 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 energised electrical equipment. Also it leaves no residue.

6.4.2. At normal temperatures, carbon-di-oxide is a gas, 1.5 times as dense as air. It is 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.

6.4.3. As regards toxicity, a concentration of 9% in air is the maximum most persons can withstand without losing consciousness within a few minutes

6.4.4. The extinguising concentration of CO_2 required for various types of fuels vary from approx. 30% to 62% depending upon the fuel.

Table 6 - Minimum CO2 Concentration required for extinguishment of various materials

Materials	Minimum Extinguising Concentration required
Acetylene	55
Acetone	26*
Benzol, Benzene	31
Butadiene	34
Butane	28
Carbon Disulfide	55
Carbon Monoxide	53
Coal Gas or Natural gas	31*
Cyclopropane	31
Dowtherm	38*
Ethane	33
Ethyl Ether	38*
Ethyl Alcohol	36
Ethylene	41
Ethylene Dichloride	21
Ethylene Oxide	44
Gasoline	28
Hexane	29
Hydrogen	62
Isobutane	30*
Kerosene	28
Methane	25
Methyl Alcohol	26
Pentane	29
Propane	30
Propylene	30
Quench, Lubricating Oils	26

Note: Apart from the above the safety factor concentration has also to be added

6.4.5. On a volume basis, CO_2 is substantially more effective than N. However, on weight basis, both have nearly equal effectiveness as CO_2 is 1.57 times heavier than N

6.4.6. It is actually the depletion of the O_2 level in the air which is responsible for extinguishment in the case of inert gases. A reduction of the O_2% in the air from 21% to 10% by volume would make fires and explosions impossible, except for a few special gases like H, C_2H_2, or CS_2 which would require greater dilution.

6.5. STEAM

6.5.1. Steam is the oldest among the smothering agents. Now extinguishing systems based on steam are rarely used. Only in certain ship's holds and occasionally in industries involving flammable liquids they are used. These systems are not effective for total flooding, but only for local application by hand held branches or lances. Steam is taken from boilers through fixed piping. The control valves are opened slowly. A by-pass is opened first to warn occupants. Manual systems with flexible tubing and lances are more common. These systems may still be seen in some of the benzol plants, refineries, oil quenching tanks etc.

6.6. INERT GASES

6.6.1. There have been at least four inert gases or gas mixtures developed as clean total flooding fire suppression agents. Inert gases are used in design concentrations of 35 to 50 % by volume which reduces the ambient oxygen concentration to between 14% to 10% by volume, respectively. It is known that for most typical fuels oxygen concentrations below 12 to 14% will not support flaming combustion.

6.6.2. The inert gas mixtures developed so far contain Nitrogen and / or Argon; and one blend contains CO_2 (approx. 8%). They are not liquefied gases, but are stored as high pressure gases. Hence they require high pressure storage cylinders. These systems use pressure reducing devices at or near the discharge manifold. Discharge times are of the order of one or two minutes.

Table 7 on the next page denotes the physical properties of the inert gas agents.

Table -7 - Physical Properties of Inert Gas Agents

Generic Name	**IG-541**	**IG-55**	**IG-01**	**IG-100**
Trade Name	Inergen	Argonite	Argotec	NN 100
Chemical composition				
Nitrogen	52%	50%	0%	100%
Argon	40%	50%	100%	0%
Carbon-di-oxide	8%	0%	0%	0%
Chemical Group	Inert gas blend	Inert gas blend	Inert gas	Inert gas
Agent form, stored gas	Compressed gas	Compressed gas	Compressed gas	Compressed
Gas Density @ 20°C, Kg/m^3	1.434	1.412	1.661	1.165'
Heptane Extinguishing Conc. VOL %	29.1	32.3	37.5	33.6
Minimum Class B fire design Conc., VOL % (1)	34.9	36.8	45.9	40.3
Minimum Class A fiire desing Conc., VOL% (i)	33.8	31.6	35.9	41.0
Inerting:Methane-Air, design concentration,VOL%	47.3	-	61.4	41.7

6.7. DRY CHEMICAL POWDERS

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

6.7.2. 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.

6.7.3. 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.

6.7.4. 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.

6.7.5. These powders which are 10 to 75 microns in size are projected on the fire by an inert gas (usually CO_2 or N).

The commonly used dry chemical agents are listed below:

Chemical Name	Formula	Other Name(s)
Sodium bicarbonate	$NaHCO_3$	Baking soda
Sodium chloride	$NaCl$	Common salt
Potassium bicarbonate	$KHCO_3$	"Purple K"
Potassium chloride	KCl	"Super K"
Potassium sulffide	K_2SO_4	-
Monoammonium phosphate	$(NH_4)\ H_2PO_4$	"ABC" or Multipurpose Powder
Urea + potassium bicarbonate (Pot. Carbamate)	$NH_2CONH_2 + KHCO_3$	"Monnex"

6.7.6. 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).

6.7.7. 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.

6.7.8. The powders act on a flame by some chemical mechanism, like breaking of chain reaction as explained in para 2.2.2. of Chapter 1, Section-4 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.

6.7.9. Potassium bi-carbonate based agent, often known by the name **'Purple K'** is approx. twice as effective, on unit weight basis, as conventional soda bi-carb. based dry chemical. 'Monnex' drychemical is approx. 3 times as effective as the conventional soda bi-carb. based dry chemical.

■

SECTION-4

CHAPTER -4- FIRE SUPPRESSION EQUIPMENT & INSTALLATIONS (ACTIVE FIRE PROTECTION MEASURES)

7. General

7.1 The previous 3 chapters under this Section had dealt with:

- The constituents of fire (What is fire?)
- The methods / principles of fire extinguishment (How fire can be put out)
- Extinguishing Media (the extinguishing agents used for putting out a fire)

7.2. This Chapter deals with the undermentioned important component items of fire protection requirement of a building or structure or facility, all of which come under the active fire protection sector:

(a) Fire Detection and Alarm Systems (Automatic Fire Alarm Systems);

(b) Fixed Fire Extinguishing Systems / Installations and

(c) First Aid Fire Fighting Equipment.

7.3. (a) The first two, Fire Detection and Alarm Systems and Fixed Fire Extinguishing Systems, are both fixed installations, and the third, First Aid Fire Fighting Equipment covers mainly portable fire fighting equipment like Fire Extinguishers, except Hose Reels, which are normally included under First Aid Fire Fighting Equipment, although it is, in fact, a type of fixed installation.

(b) Automatic fixed extinguishing systems have proved to be the most effective means of controlling fires in buildings. For understanding the capabilities of these systems, knowledge of the main principles involved in their installation, uses and applications are necessary.

(c) Apart from the sound design and installation of the systems, an essential requirement for ensuring fail-free operation of all types of fire protection systems is that **all persons who may be expected to inspect, test, maintain or operate fire extinguishing systems shall be thoroughly trained and kept thoroughly trained in the**

functions they are expected to perform. (This requirement is invariably emphasised in all NFPA Standards, and is worthy of adoption by our Codes also).

7.4. FIRE DETECTION AND ALARM SYSTEMS (AUTOMATIC FIRE ALARM SYSTEMS)

7.4.1. General

7.4.1.1. Among the fire protection requirements for a building, fire detection and alarm system has an important role to fulfil. If properly designed, installed and maintained, automatic fire alarm systems can be a substantial help in minimising losses of lives and property from fires in buildings of all types of occupancies.

7.4.1.2. One of the prime 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.

7.4.1.3. 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. But, it will be good if the designers and builders keep themselves aware of the fact that recent fire research and analytical studies have come to the conclusion that partial detection does not often, if ever, provide early warning of a fire condition.

7.4.1.4. 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 eg., Some materials burn intensely giving out high levels of thermal energy, but with little or no smoke, whereas smouldering 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.

7.4.2. Heat Detectors

7.4.2.1. There are two types of heat detectors:

(a) Fixed temperature detectors, which are designed to operate when the detecting mechanism or element reaches a pre-determined temperature. These can again be subdivided into two types:

(i) Point detectors, which are small, each protecting a limited area, or

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

(b) Rate-of-rise detectors, designed to operate when the temperature rises abnormally quickly, or when a pre-determined temperature is reached.

Note: The temperature range normally adopted for heat sensitive (point) detectors is from 55°C to 180°C, inclusive if the rate of rise of the temperature is less than 1°C/min.

7.4.2.2. The methods used to detect heat are given below:

(a) 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:

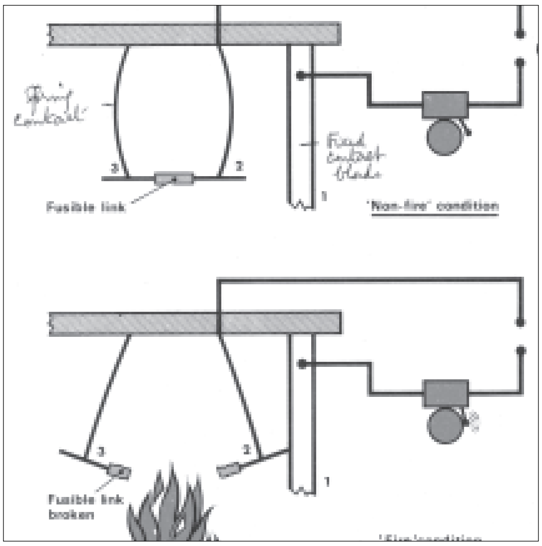


Fig-14 Fusible Link Detector

(b) 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.

(c) 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:

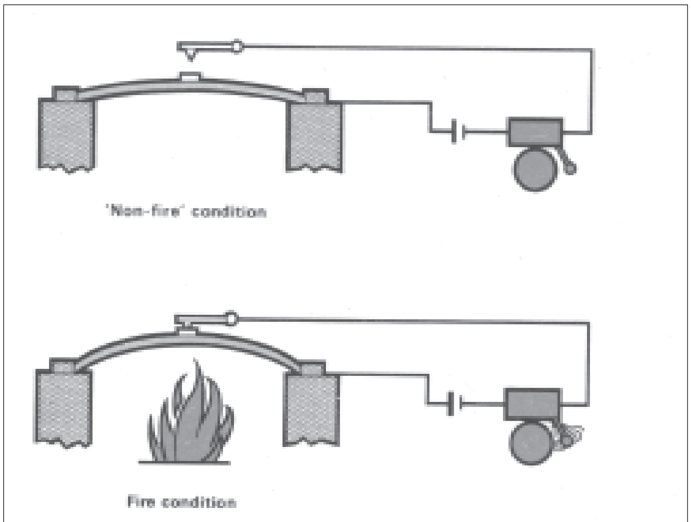


Fig-15 Heat detector using expansion of metal strip principle

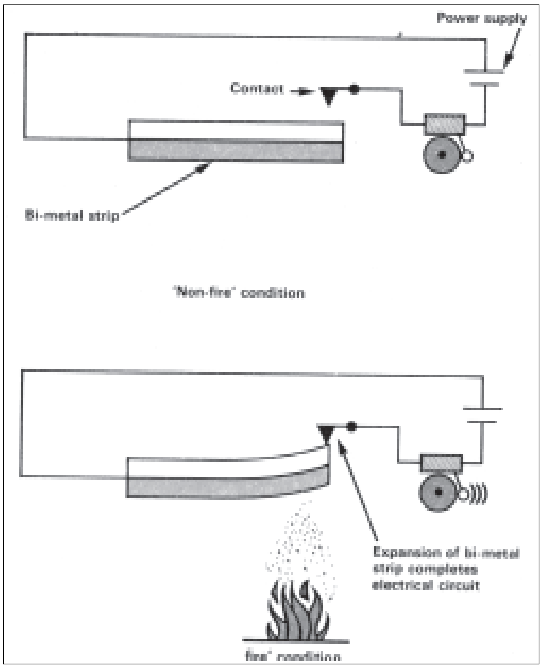


Fig-16 Heat detector - Bi-metal strip type

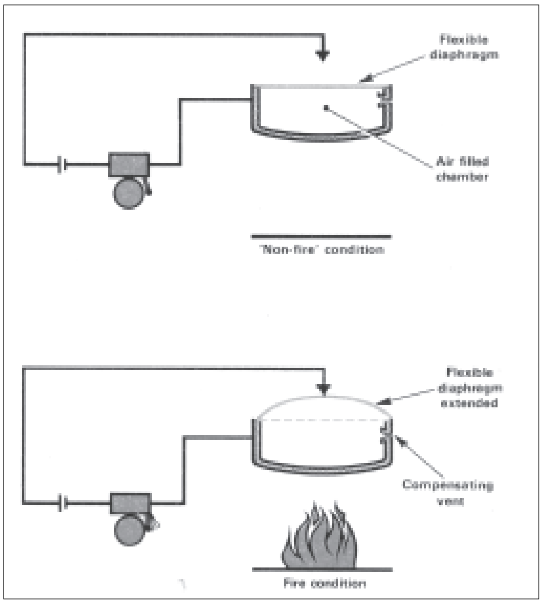


Fig-17 Heat detector - Rate-of-rise principle

(d) 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:

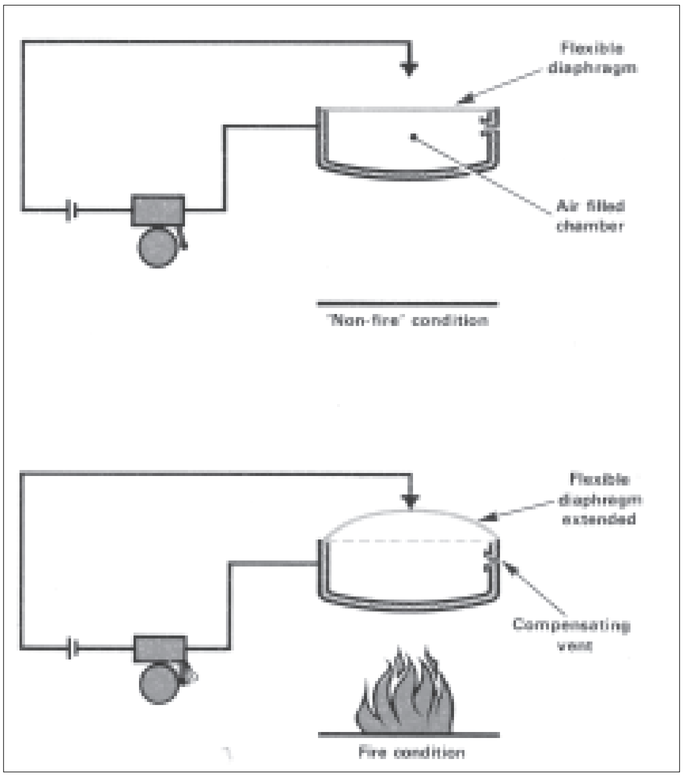


Fig-18 Heat detector - Using principle of expansion of air (pneumatic detector)

7.4.3. Smoke Detectors. There are two types:

7.4.3.1. Ionisation Detector
Figures depicting Ionisation type of smoke detector under 'non-fire condition' as well as 'fire condition' are shown overleaf:

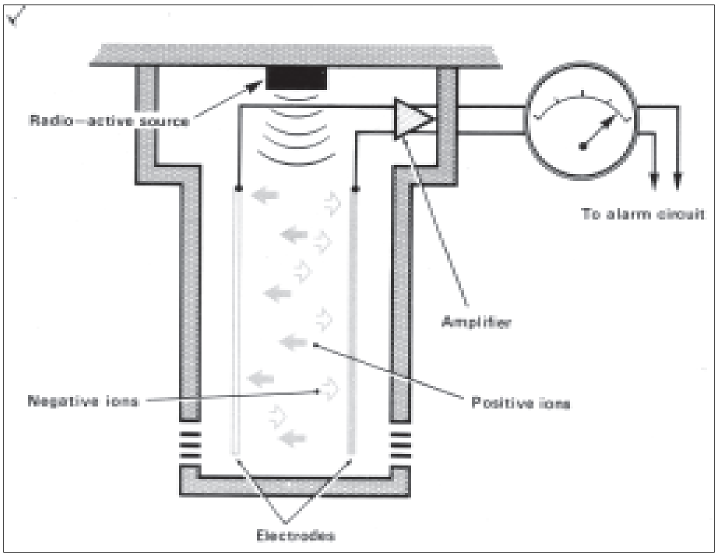


Fig-19 (a) Ionisation Detector - Non-fire condition

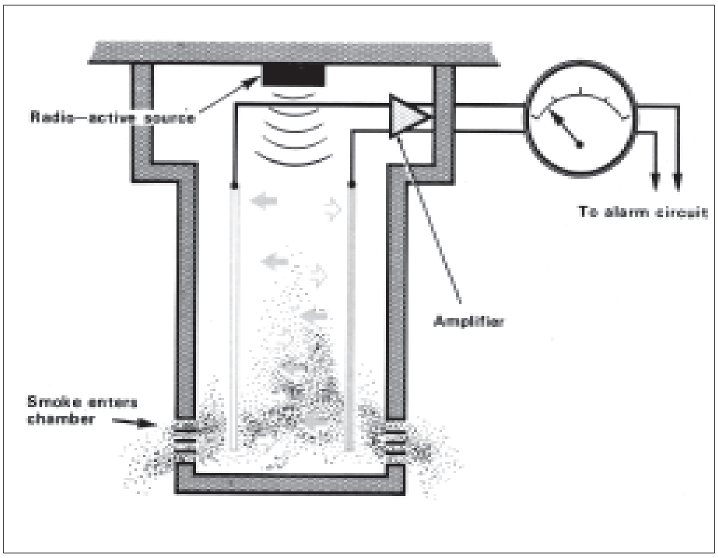


Fig-19 (b) Ionisation Detector -fire condition

The basic principles involved in Ionisation detector are as follows:

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

7.4.3.2. Optical Detector

While the ionisation 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:

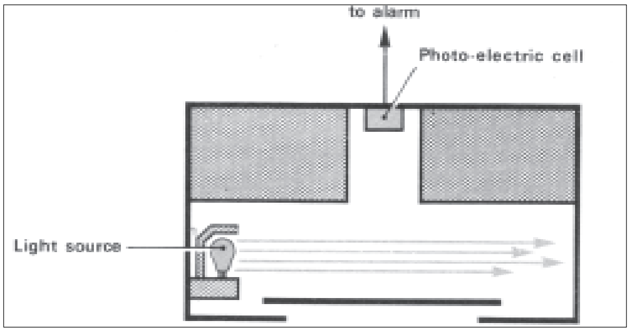


Fig-20 (a) Optical Detector - Light scatter type(Non fire condition)

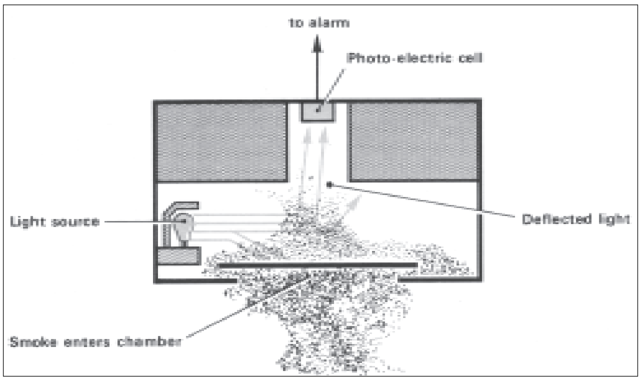


Fig-20 (b) Optical Detector - Light scatter type(fire condition)

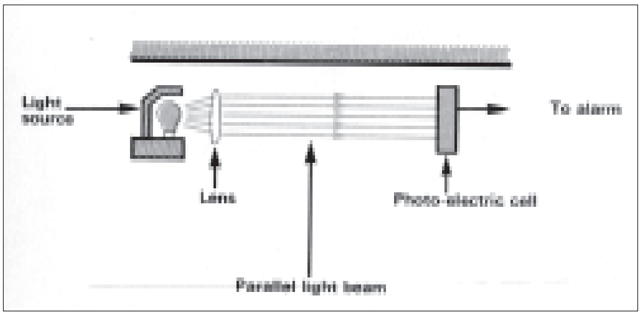


Fig-21 (a) Optical Detector - Obscuration Type-Non-fire condition

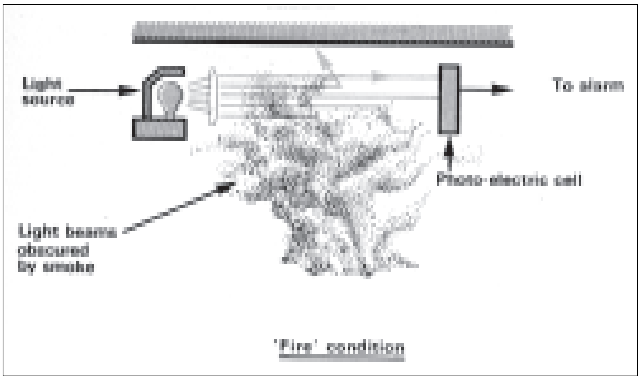


Fig-21 (b) Optical Detector - Obscuration Type-fire condition

7.4.4. Flame Detectors

7.4.4.1. Apart from producing hot 'gases', fire releases radiant energy in the form of :

(i) Infra-red radiation;

(ii) Visible light; and

(iii) Ultra-violet radiation (see figure 22 below).

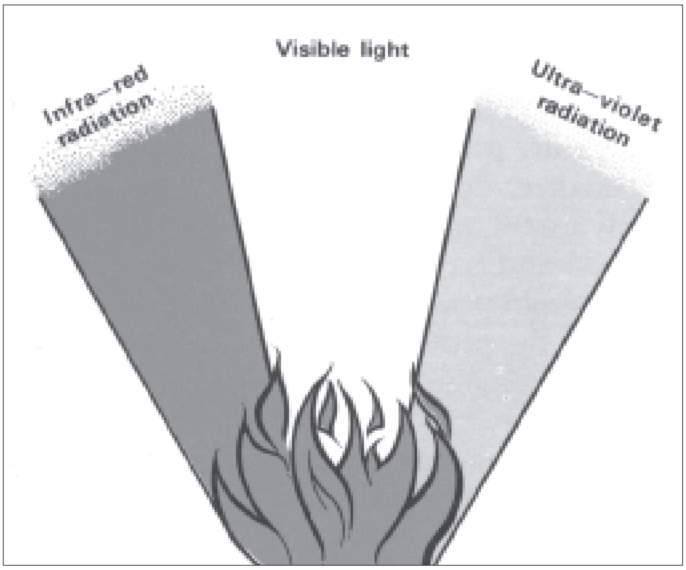


Fig-22 Forms of radiant energy produced in a fire

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, or
(ii) Ultra-violet radiation, or
(iii) Combination of IR/UV radiation

7.4.4.2. Infra-red Detector

(a) The figure given overleaf illustrates the basic components of this detector:

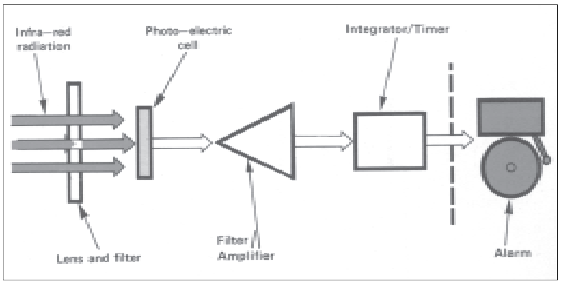


Fig-23 Components of an Infra-red Detector

b) 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 minimised. 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.

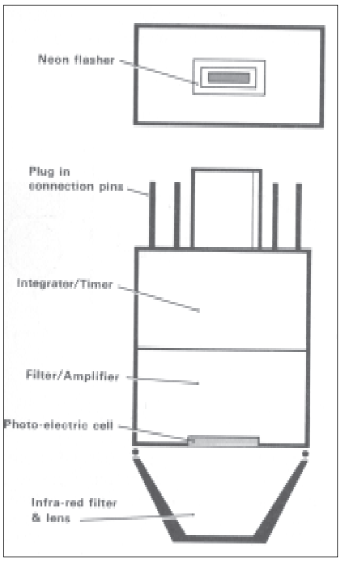


Fig-24 A typical Infra-red Detector

(c) 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 upto a radius of approx. 90m. The figure of a typical infra-scan detector is given below:

-

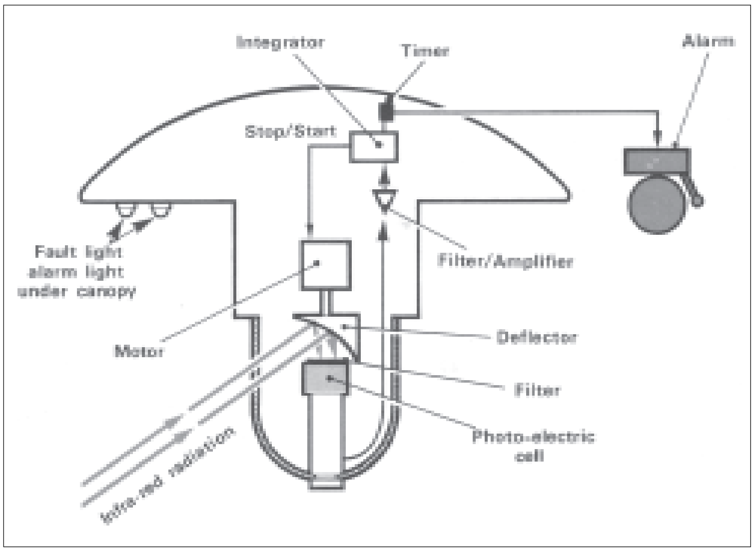


Fig-25 A typical Infra-scan Detector

7.4.4.3. 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 overleaf:

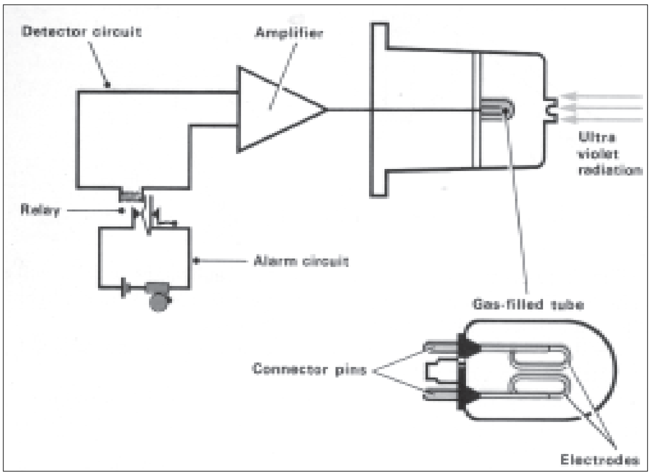


Fig-26 Components of an Ultra-violet Detector

The principle of operation of this detector is very similar to that of the ionisation detector. When ultra-violet radiation strikes the gas filled tube it ionises 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 specialised 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.

7.4.4.4. Multi-sensor fire detectors - These detectors are also under use and they are designed as point type resettable multi-sensor fire detectors installed in buildings, incorporating atleast 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)

7.4.5. Choice / Selection of Fire Detectors

7.4.5.1. 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.

7.4.5.2. The main characteristics of different types of fire detectors are enumerated below. This information will help in 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.
- Ionisation smoke detectors are unsuitable for smouldering / 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 turbulance detectors are particularly suitable for clean burning fires. Ionisation 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 (eg. 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, eg., 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.

7.4.6. 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, liftwell, 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.

(ix)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.

(x) A Control Centre should be provided especially for high rise and special buildings, preferably in the ground floor, where the following facilities should be made available:

- The Control Centre should have an area of approx. $16m^2$ - $20m^2$;
- 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.

7.5 FIXED FIRE EXTINGUISHING SYSTEMS / INSTALLATIONS

7.5.1. General

7.5.1.1. Portable fire fighting equipment like fire extinguishers, as well as mobile fire fighting equipment like Fire Tenders and other vehicle-mounted fire fighting appliances, can be used for tackling fires whether inside a building or in the open. On the other hand, for tackling fires particularly inside buildings, structures or in specific areas, fire extinguishing systems installed permanently within the premises will be required for providing adequate fire protection.

7.5.1.2. These fixed fire extinguishing systems/installations can be based on various extinguishing media used for protection, as stated below:

(a) Systems/Installations based on water:

(i) Hydrant Installations;

(ii) Automatic Sprinkler Installations;

(iii) Automatic Water Spray Installations;

(iv) Automatic Deluge and Drencher Installations.

(b) Systems/Installations based on foam:

(i) Automatic foam installations using low expansion foam;

(ii) Automatic foam installations using medium expansion foam;

(iii) Automatic foam installations using high expansion foam.

(c) Systems/Installations using CO_2:

(i) Automatic CO_2 installations (High Pressure Type);

(ii) Automatic CO_2 installations (Low Pressure Type).

(c) Systems/Installations using dry powder:

(d) Systems/Installations based on clean gaseous extinguishing agents:

(i) Automatic Halon extinguishing systems;

(ii) Automatic Halon Alternative extinguishing systems

7.5.2. Definitions

1. Extinguishing agent: The substance contained in a fire-extinguishing system, when discharged on to the fire, is intended to produce extinction.

2. Risk: A measure of an insurer's probable liability, determined by the standard of a building, its usage and the quality of its fire protection.

3. Hazard: A particular area or activity in which a danger of fire can occur, e.g. paint spraying plant, cotton pickings and carding machinery or heat-treatment bath.

4. Storage hazard: The general dangers of storage of goods, having regard to their fire grading, flammability, method of packing, storage etc.

5. High-racked storage: A storage in which goods are held on high racking so that they are accessible for loading and withdrawal, usually by mechanical means.

6. Process hazard: A hazard associated with an industrial process involved in the manufacture or treatment of an end-product.

7. Underground fire hydrant: An assembly contained in a pit or box below ground level, and comprising a valve and outlet connection from a water supply main.

8. Pillar fire hydrant: A fire hydrant whose outlet connection is fitted to a vertical component projecting above ground level

9. Foam inlet: Fixed equipment consisting of an inlet connection, fixed piping and a discharge assembly, enabling the Fire Service to introduce foam into an enclosed compartment.

10.Ring main system: A water main that encircles a building, or series of buildings or other associated fire risks, and that feeds hydrants, internal rising mains, etc.

11.Dry rising main: A vertical pipe installed in a building for fire-fighting purposes, fitted with inlet connections at Fire Service access level and landing valves at specified points, which is normally dry but is capable of being charged with water, usually by pumping from Fire Service appliances.

12.Wet rising main: A vertical pipe installed in a building for fire-fighting purposes, that is permanently charged with water from a pressurized supply and fitted with landing valves at specified points.

13.Landing valve: An assembly comprising a valve and outlet connection from a wet rising main or dry rising main.

14.Classification of occupancies (for sprinkler systems): The division of occupancies into classes and sub-classes, according to the hazard they present. These classes and sub-classes are:

(a) light hazard;

(b) ordinary hazard (divided into group I, group II, group III special);

(c) high hazard (divided into process risks and storage risks)

15.Sprinkler: A device that seals an aperture in the pipe work of a sprinkler system, that operates automatically at a predetermined temperature and discharges water in a regular pattern over the area below it.

16.Wet system: A sprinkler system that is intended for use in locations where the ambient temperature is always above the freezing point of water. The sprinkler pipe work is charged with water in the operational condition.

17. Dry system: A sprinkler system that is capable of being used in any normal ambient temperature. The sprinkler pipe work is charged with air in the operational condition.

18. Alternate system: A sprinkler system that may be used either as a wet system, where freezing temperatures do not occur, or as a dry system in conditions where freezing temperatures may occur, or where part of the system may be exposed to them.

19. Pre-action system: A sprinkler system in which the sprinkler pipe work is normally charged with air at a low pressure up to the sprinklers, and in which the alarm valve is opened in response to an electric signal from a separate detection system. When the alarm valve opens, the water from the supply compresses the air in the pipe work and approaches close to the sprinklers. On sprinkler operation, the water discharges without delay from the opened sprinklers.

20. Water spray system: A system, similar in principle to a sprinkler system, that is designed to extinguish flammable liquid risks, or to provide cooling to an exposed area likely to be subjected to intense heat radiation from a neighbouring fire. Spray systems range in size from very small to very large.

21. Deluge system / Installation: An installation fitted with open spray nozzles controlled by a single deluge valve and operated on the actuation of automatic fire detectors so that the entire area is sprayed with water or foam as the case may be. The installation can be controlled manually also. This is generally used to protect large buildings against large flammable liquid spillages, eg., Aircraft hangars, Oil processing areas, Tanker loading bays etc.

22. Slop over: The condition that occurs when a water spray (or foam) is applied to the surface of a burning liquid that has developed a hot zone beneath the surface at a temperature in excess of 100^{o}C. On passing through this zone, the water boils and expands suddenly, causing some of the flammable liquid to pour over the rim of the tank.

23. Boil over: A more severe condition than slop over, in which the hot zone is sufficiently deep to reach the water that has drained to the base of the tank, so that a large part of the contents of the tank are expelled violently when the water boils.

24. Bund fire: A fire in flammable liquid fuel that has leaked into the bund area surrounding a flammable liquid storage tank.

25. Design density of discharge: A measure of the average quantity of water falling per unit area per minute from a sprinkler system in full operation, over an assumed maximum area of operation. Expressed as a rainfall, i.e. mm/min.

26. Assumed maximum area of operation: The maximum area over which a sprinkler system in full operation is required to maintain the design density of discharge. With each class and sub-class of sprinkler system, there is a related design density of discharge and assumed maximum area of operation.

27. Liquefiable natural gases (LNG): Those flammable gases that can be retained as a liquid/vapour mixture in pressure vessels, but vaporize on release to atmospheric pressure.

28. Liquefiable petroleum gases (LPG): Those flammable gases derived from the hydrocarbon series, e.g. methane, propane and butane that can be retained as a liquid/vapour mixture in pressure vessels, but vaporize on release to atmospheric pressure.

29. Total flooding: The discharge of a gaseous extinguishing agent into an enclosure, to a concentration sufficient to extinguish fire throughout the entire volume of the enclosure.

30. Local application: The discharge of a gaseous extinguishing agent at local areas of risk, to a concentration sufficient to extinguish fire at those local areas.

31. Recommended extinguishing concentration: The concentration of a gaseous extinguishing agent necessary to ensure extinction of flaming combustion throughout a protected enclosure. The value of the recommended concentration depends on the type of agent used and the nature of the combustible.

32. Inerting concentration: The concentration of a gaseous extinguishing agent necessary to ensure that combustion cannot occur throughout a protected enclosure. The inhibiting concentration is usually higher than the recommended extinguishing concentration. It depends on the type of agent used and the nature of the combustible.

33. Modular total flooding systems: Those systems comprising one or more units released simultaneously within an enclosure, to give a known total rate of discharge and concentration of the gaseous agent. They may or may not be piped systems.

NOTE: If they are piped systems, then the permissible pipe sizes and pipe lengths, and the number and type of fittings and nozzles have to be specified by the manufacturer.

34. Engineered total flooding systems: Those piped systems fed from a centralised tank or cylinder storage tank to give a known total rate of discharge and concentration of the gaseous extinguishing agent within the enclosure.

NOTE: They require individual design and calculation to determine flow rates, total discharge time and the nozzle locations and nozzle pressures to ensure the best arrangement to suit the type and distribution of combustibles within the enclosure.

35.Local application systems: Those systems in which the gaseous extinguishing agent is retained in a centralized supply tank or cylinder bank, and is fed through a piped system to nozzles located to discharge simultaneously on to specific areas of risk.

36. Manual hose-reel systems: Those systems in which the gaseous extinguishing agent is retained in a centralised supply tank or cylinder bank, and is fed through a piped system to manual hose reels located at specific points adjacent to the main areas of risk.

37. Foam branch: A similar device to a foam branch pipe, except that it does not induce the air, since the foam has been made further upstream at an in-line generator, and reaches the branch as expanded foam.

38. Foam monitor: A similar device in principle to the foam branch or foam branch pipe, but mounted on a swivelling base, so that its greater output can be discharged without reaction on the operator. The base unit may be fixed at one place, or may be trolley mounted or vehicle-mounted.

39. Foam pourer: A device for discharging made foam on to the top of flammable liquid in a storage tank. The pourer is usually fed from a foam riser, and is bolted through the wall of the tank to the top so that it can discharge on to the flammable liquid surface.

40. Surface application: The application of made foam to the surface of a flammable liquid to form a blanket.

41. Sub-surface application: The application of made foam beneath the surface of a flammable liquid, so that it floats to the surface and spreads on it to form a foam layer.

NOTE: Also called base injection, although the injection point may not be right at the base of the tank.

42. Semi sub surface application: The application of made foam to the surface of a flammable liquid in a storage tank through a flexible plastics stocking that, on injection of foam, unrolls and floats to the surface so that its sealed end is burned off and releases the foam directly at the surface, without it having to have contact with the flammable liquid.

43. Engineered systems: Piped systems from a centralised cylinder storage bank. They are individually calculated and designed to give the required flow rates to each of the individual discharge nozzles, which are located to suit the nature and distribution of the combustible.

44. Modular systems: Systems that comprise one or more storage units that all discharge simultaneously through their own outlet nozzle, the pressure and flow rate of which is predetermined. They may or may not be piped systems.

NOTE. If they are piped systems, the permissible pipe sizes and pipe lengths, and the number and type of fittings and nozzles have to be specified by the manufacturer for each unit.

45. Water hammer: If water flow in a pipe is shut off suddenly, the kinetic energy possessed by the moving water is instantaneously converted into pressure energy which results in a sudden shock and generation of pressure waves through the column of water. This is known as water hammer.

46. Jet reaction: When water is projected from a nozzle, a reaction equal and opposite to the force of the jet takes place at the nozzle, and the latter tends to recoil in the opposite direction to the flow. This is known as the jet reaction (if the size of the nozzle is doubled, the reaction increases to four times, making it much more difficult, or impossible, for one man to hold the branch).

47. Explosion: Is a physical or chemical change resulting in the sudden, violent release of energy heat, light, gaseous products and shock waves, or combinations of these are normally produced. Chemical explosives may either deflagrate or detonate.

48. Implosion: Is a special case of failure of a sealed evacuated vessel / container as a result of differential pressures.

49. Explosives: Are chemical substances or combination of chemical substances which are liable to explode due to heat, spark, friction or percussion. Explosion often produces a shock wave, and evolves large quantities of heat, sound and flash.

50. Detonation: Are violent explosions with shock waves which travel at sonic or supersonic velocities (sonic velocity is 300 m / sec). The detonation of a high explosive is always accompanied by brisance or shattering effect.

51. Deflagration: A form of rapid burning accompanied sometimes with a mild explosion. Eg. burning of propellants (low explosives).

7.5.3. HYDRANT SYSTEMS / INSTALLATIONS

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

7.5.3.2. Hydrant Systems can be of two types:

- **(a) External 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; and
- **(b) Internal Hydrant System,** installed in buildings or structures to be protected

7.5.3.3. The basic requirements of any hydrant systems are:

- (a) Water reservoir or source of water supply (for supply of water for fire fighting purposes);
- (b) Pump(s) for imparting energy to the water (for conveying water through pipe lines, and to make water available at the required pressures for fire fighting purposes);
- (c) Pipelines, which may be laid underground or above ground, for conveying water under pressure to the required places;

(d) Hydrants (which are the outlets installed on the pipelines at strategic locations on the water mains for drawing water, using delivery hoses, for fire fighting purposes.

7.5.3.4. External Hydrant Systems:

(a) 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'.

(b) The guidelines regarding the 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'.

(c) The capacity of pumps required for these systems have to be worked out based on 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, and subject to a minimum of one. The static fire fighting pumps should conform to the requirements given in IS:12469-1988, 'Pumps for Fire Fighting Applications'

(d) Pressure requirements of systems
The pressure for systems are normally designed based on practical considerations and specific needs. A minimum residual pressure 1.5kg/cm^2 (20psi) should usually be maintained at hydrants delivering the required fire flow.

In some foreign countries, a separate system designated **'high pressure system'** is maintained under the control of the fire department which is utilised for fire fighting purposes only. For instance, in San Francisco, US, a high pressure system has been provided which has a fire flow of **20,000 gpm at 250 psi** delivered to most of the principal mercantile districts. All the pipes are of heavy cast iron, tar coated and lined, and tested to **450 psi.** The system was provided primarily because **an earthquake can put the regular public water system out of service.** A few other cities in US also have provided similar systems.

(e) Indian scenario

(i) In other developed countries, well maintained hydrant water mains (which may be either a combined system for domestic as well as for fire fighting purposes, or separate fire fighting water mains, as in some cities) do exist in all cities and towns. Fire service vehicles, on a fire call, report to the scene, connect up to the hydrants, draw water from them, and carry out fire fighting operations, sometimes even for several hours. These fire fighting mains are capable of providing non-stop fire flow of even upto **20,000 gpm** or more, which may be required for tackling major fires.

(ii) As compared to the above in India, we do not have such reliable hydrant water mains even in our metropolitan cities, not to speak of towns. No doubt, in some major cities, there are hydrants available even now in some roads and streets. These hydrant mains were installed during the pre-independence periods, and many of them are either un-serviceable, or not presently traceable due to constructional changes in between. In practice, they cannot be taken in to account for availability for fire fighting purposes. Consequently, most of our city fire brigades are forced to maintain a large fleet of heavy Water Tenders / Tankers for replenishment of their fire fighting vehicles. This arrangement is no substitute for having regular fire fighting water mains, which can only guarantee continuous supplies of water for fire fighting purposes.

(iii) The existing water supply arrangements for our cities and towns are generally based on the formulae recommended in the Manual on Water Supply and Treatment issued by the Ministry of Works and Housing, Govt. of India, sometime back. According to this, no separate provision is made in city water supply for fire fighting purposes while calculating per capita consumption of water. However, the system, in some of the cities, is designed to meet broadly the following requirements:

- Minimum size of distribution main is kept as 100 mm (as against 150 mm in many foreign countries)
- For fire fighting purposes, at least 4 streams, each capable of delivering 450 lpm for about 4 hrs. should be available within reasonable distance 'with pressure' of 1kg/cm^2 to 1.5 kg/cm^2. In major towns this may be increased to 6 to 8 streams (In foreign countries like USA the fire fighting water mains are of much larger diameter and capable of handling bigger fire flow rates for operation of 25 streams or more, each of 900 lpm, and added

pressures ranging from $5 kg/cm^2$ to $8\text{-}10 kg/cm^2$, even for a city of population of 1.5 to 2 lakhs. The fire fighting operations may continue for several hours also without any interruption).

- As per the Manual, the following amounts of water are to be provided in the service reservoirs for fire fighting.

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

(f) Pressure and flow in mains

(i) The pressure of water flowing in the water mains can be expressed either in kg/cm^2 or bars (1atmosphere = 14.7psi or 101.325 kN/m^2 or 1.013 bar) (1 bar = $100kN/m^2$), 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.** 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.

(g) A distribution system for water supplies generally consists of:

(i) Water mains (trunk, secondary and service mains)

(ii) Service mains (used for supply to premises from the streets)

(iii) Service reservoirs (including overhead tanks, water towers etc.)

(iv) Booster pumps (at intermediate points where the length of the mains is excessive)

(h) Water Mains-Broad Features

- Increasing the pipe diameter increases water flow. The relative increases are indicated as under:

Size of pipe, inches	Relative capacity
6	1.0
8	2.1
10	3.8
12	6.2
14	9.3
16	13.2

- Pipe systems should be arranged in loops wherever possible. This allows hydrants and other connections to be fed from at least two directions and greatly increases the water flow without excessive friction loss.
- In course of time the internal cross section of cast iron pipe may be reduced or its interior surface made coarse, because of tuberculation, incrustation, or sedimentation. The addition of cement lining usually retards or prevents such deterioration.
- Plastic pipes (approved unplasticised PVC class 4 pipes are being installed increasingly and are immune from tuberculation and corrosion problems).

- Ductile iron pipes have the corrosion resistance of cast iron and almost the same strength and ductility of steel, and is now being used in place of cast iron.
- Cathodic protection methods are widely used for the external protection of iron and steel water mains. Cathodic protection is a technique of imposing direct electric current from a galvanic anode to the buried pipe line.
- Buried pipe needs a coating to protect against soil corrosion.
- Forces acting on pipe laid in the ground are mostly internal static pressure of the water; water hammer; load from the back fill, and load and impact from passing trucks and other vehicles.
- All pipe lines should be subjected to hydrostatic pressure tests, at not less than 1.5 times the working pressure for not less than 2 hrs. minimum period.

(j) Fire Hydrants

(i) Fire hydrants provide the means of drawing water from the water mains for fire fighting. 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:

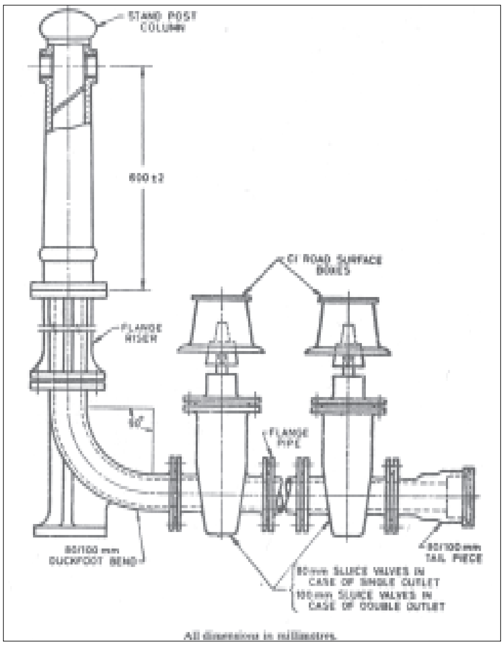


Fig-27 Stand-post type Hydrant

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 fire fighting 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 fire fighting operations can be carried out without delay.

(iv) Underground type of hydrants (Sluice Valve Type)-General Requirements

- These hydrants are placed underground alongside the water mains on a short branch, water flowing horizontally past the sluice valve

- The hydrant consists of three main castings, the inlet piece which is connected to the pipe, the sluice valve itself and the duckfoot bend leading to the outlet.
- For operating the hydrants certain hydrant fittings are required such as hydrant stand pipe, hydrant cover key, hydrant key, water iron, hydrant bar etc.
- For locating the hydrants, prominently marked hydrant plates are provided on the ground surface.

Note: Typical figures of the underground sluice valve type of hydrant and hydrant box are shown below:

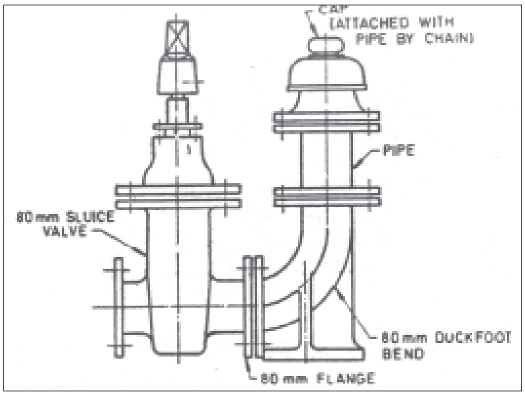


Fig-28 Underground Hydrant-Sluice valve type

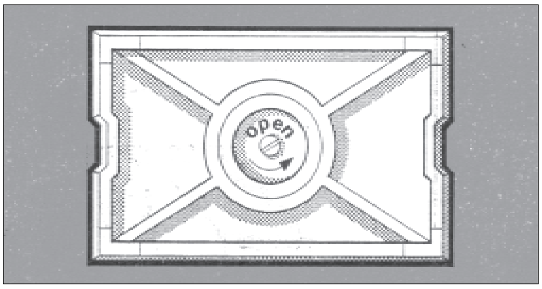


Fig-29 Typical Hydrant Box

Note: In case double headed hydrant stand pipes are used, the dimension of the sluice valve as well as the hydrant connection will have to be of 100 mm diameter in order to provide the required fire flow through the hydrant.

(k) Other factors to be taken into consideration in the provision and use of external hydrant systems:

- Minimum size of mains should be not less than 150 mm;
- Underground mains should be laid not less than 1m below ground level;
- Above ground mains should be adequately supported at regular intervals not exceeding 3.5m;
- The fire hydrant mains should always be laid in rings or loops;
- Adequate number of shut-off valves (isolation valves) should be provided at strategic locations in the system for the purpose of isolating any portion for maintenance, repairs etc.
- Fire fighting mains in industrial premises should not be utilised for any other purpose such as process use etc.,
- Normally in cities and towns, hydrants should be provided at intervals of 100m, but this can be varied according to the risks in the area;
- In case of industrial premises, the intervals for hydrants can be 30m for high hazard occupancies, 45m for moderate hazard occupancies and 60m for light hazard occupancies.
- Hydrants should be readily accessible to fire appliances and for fire fighting operations;
- No portion of a protected building should be more than 45 m from an external hydrant;
- For systems in cities and towns hydrant inspection should be carried out at intervals not exceeding one month, and for industrial establishments, once every week;
- Testing of pressure and output in different areas covered by the system should be carried out atleast every quarter. (details of the tests and maintenance of the systems are given in IS:13039-1991, 'Code of Practice for Provision and Maintenance-External Hydrant Systems'.
- For high hazard occupancies, the hydrant system shall be so designed that when half the aggregate pumping capacity is being discharged at the farthest point, and the other half in the most vulnerable area enroute, a minimum running

pressure of 5.25 kg / cm^2 is available at the former point and rate of flow of water does not exceed 5 m / sec. anywhere in the system;

- For ordinary / light hazard occupancy, the pressure requirement at the most remote point can be restricted to 3.5kg/cm^2.
- Minimum output of hydrants is generally accepted as 1125 lpm (250gpm) at a minimum pressure of 5.25 kg/cm^2;
- Water monitors fixed at strategic points in the hydrant system can be of various sizes with various outputs as given below:

Size of monitor inlet	Size of monitor outlet (nozzle dia)	Output(lpm)
63mm	32mm	1750
75mm	38mm	2580
100mm	45mm	3500

- Pump Capacities of Hydrant Systems(for private systems only):

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

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

Note: In an extra high hazard industry, like Reliance Petroleum Ltd., in Jamnagar, the fire fighting pumps are each of the following capacities:

290	17400	1044 (3828gpm)

7.5.3.5. Internal Hydrant Systems

(a) 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 fire fighting purposes;

(ii) Rising mains, down comer mains or external mains to feed water from the source to the required point under pressure;

(iii) Fire fighting 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.

(b) The main features and requirements for the internal hydrant systems are listed below:

- The capacities of the underground static water tanks/ terrace tanks vary according to the fire risks involved in the occupancy;
- Internal hydrants form part of any of the following systems- (i) Dry-riser system, (ii) Wet-riser system, (iii)Wet-riser-cum -down-comer system, and (iv) Down-comer-system
- 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;
- A wet riser system remains charged throughout so that by connecting delivery hoses, fire fighting 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 fire fighting pump installed in the building. However, a fire service inlet is also provided for charging it from fire service appliances. 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.

- The down comer system is connected to a terrace tank through a terrace pump;
- 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;
- The internal hydrant system should conform to IS:3844 - 1989, "Code of Practice for Installation and Maintenance of Internal Frie Hydrants and Hose Reels on Premises". The hose reel should conform to Type-A of IS:884-1985, "First-aid hose-reel for fire fighting";
- 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;
- For bigger systems, it is desirable to instal a small pump of approx. 180-300 lpm capacity, with pressure switches for automatic start and stop, which is known as jocky pump;
- The system should be tested before use for a minimum pressure of 7kg/cm^2 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, and also in Fire Protection Manual (12th eddition -1998) issued by Tariff Advisory Committee (TAC).

7.5.4. AUTOMATIC SPRINKLER SYSTEMS

7.5.4.1. 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 fire fighting 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 lay out of a typical sprinkler installation is given below:

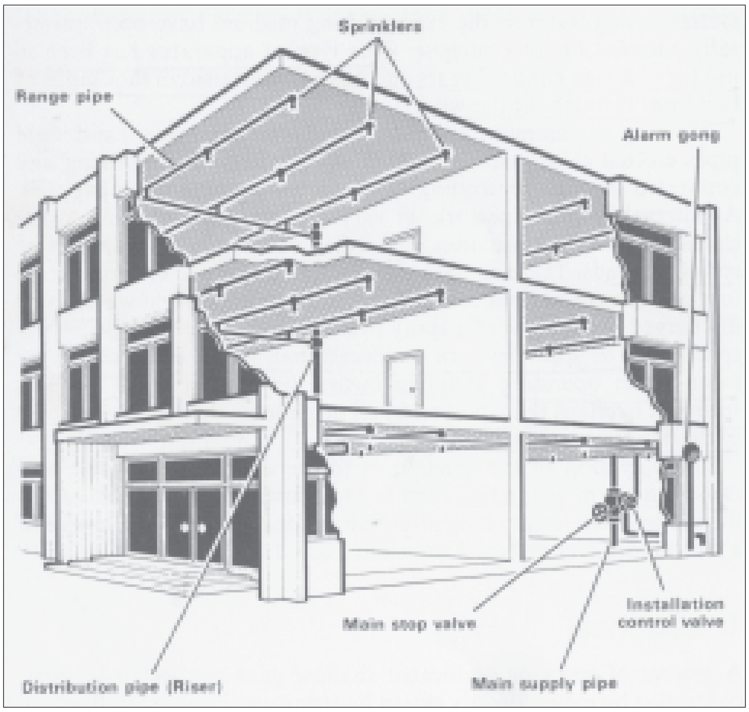


Fig-30 Layout of a Typical Sprinkler Installation

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 minimise 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 recognises 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 eg., 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.

7.5.4.2. 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. Sprinkler heads then operate individually.

7.5.4.3. 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 as 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

7.5.4.4. 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

7.5.4.5. Sprinkler Heads:

Their operation can be divided into two main types:

(i) Those in which the operating medium is **fusible solder**; and

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

(iii)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.

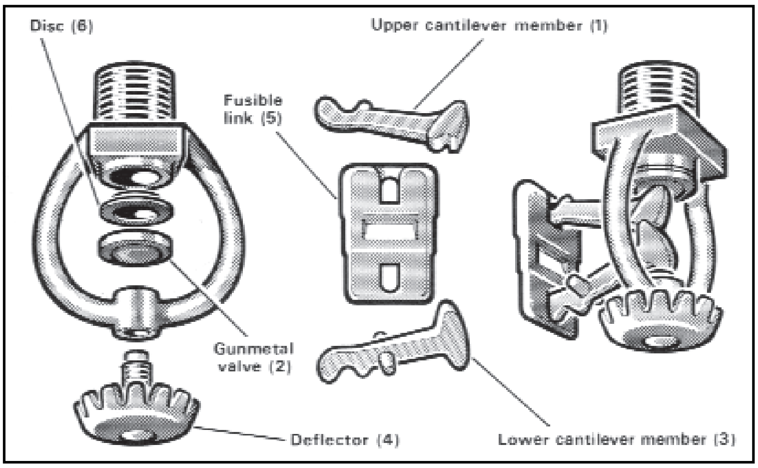


Fig-31 A typical fusible solder type sprinkler head showing component parts

(iv) The solders used with automatic sprinklers are made of alloys of metals like tin, lead, cadmium etc.

(v) Fusible bulb type: The second type of operating element of the sprinkler head utilises 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.

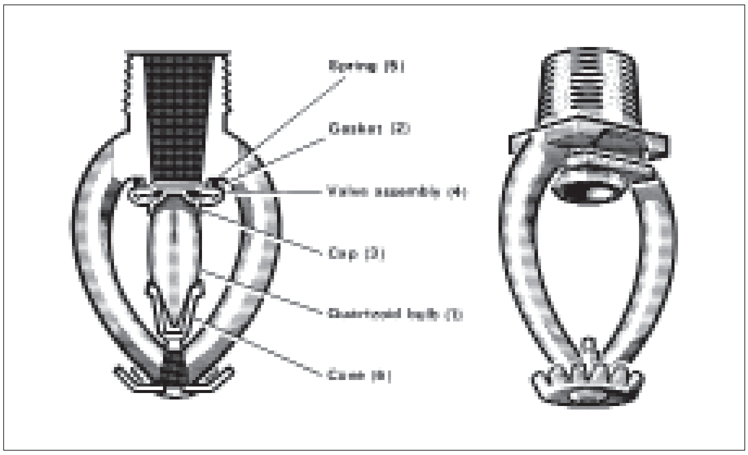


Fig-32 A typical fusible bulb type sprinkler head showing component parts

7.5.4.6. Temperature Ratings of Automatic Sprinklers:

Automatic Sprinklers have various temperature ratings that are based on standardised 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 colour coded for easy identification. Temperatures and colours 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.

7.5.4.7. Types of Sprinklers

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

(a) 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.

(b) Spray pattern: This operates with a hemispherical discharge pattern below the deflector with no water being directed upwards.

(c) 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.

(d) 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.

(e) Dry upright pattern: These are the same as pendent type sprinklers.

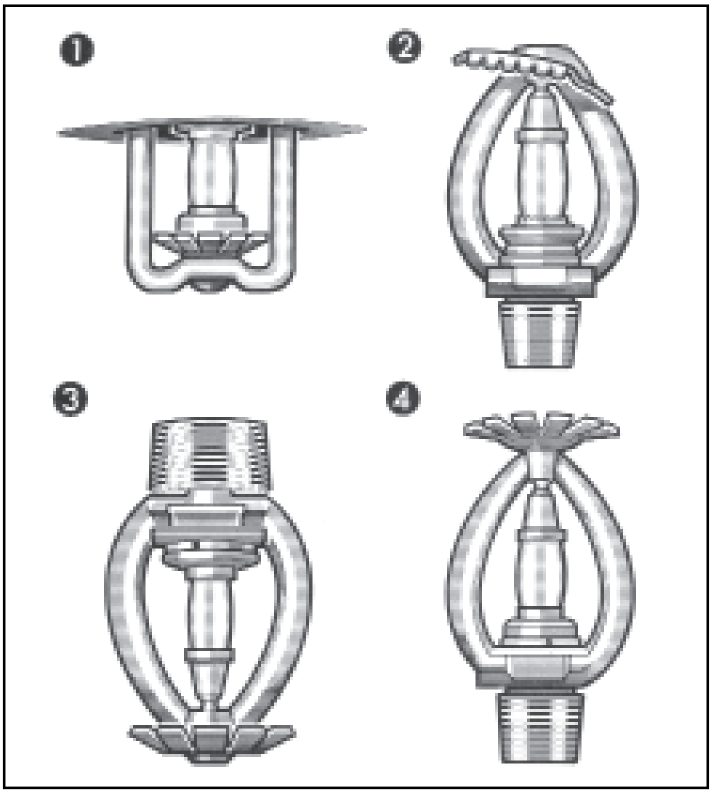


Fig-33 Types of sprinklers (bulb type)

(1) Ceiling flush pattern (2) Sidewall pattern

(3) Pendent type (4) Dry upright type

7.5.4.8. Sprinkler Water Supplies:

The water supplies for the sprinkler system must have adequate and reliable pressure and flow as per Sprinkler System Codes / Rules. Use of salt or brackish water is not permitted. The supplies may be by (i) Town's mains, (ii) Elevated reservoirs, (iii) Gravity tanks, (iv) Automatic pump supply or (v) Pressurised tanks. Apart from primary water supply, secondary water supply arrangements should also be made as stand by.

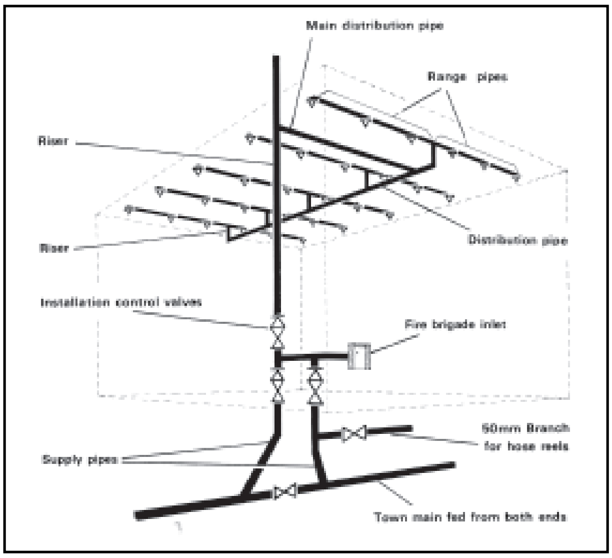


Fig-34 Diagramatic lay out of pipework of a sprinkler installation.

7.5.4.9. 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

7.5.4.10. 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 upto $36m^2$.

7.5.4.11. Other important facts / features regarding Sprinkler Systems:

(i) Design density of the system means the minimum density of discharge (in mm/min.) of water, for which a sprinkler installation is designed, determined from the discharge of a specified group of sprinklers in lpm divided by the area covered in m^2 .

(ii) Each system has to be hydraulically designed to provide an approx.density of discharge over an assumed maximum area of operation.(no. of sprinklers likely to operate) in the highest and remote areas to be protected.

(iii) High rise system: Is a sprinkler system in which the highest sprinkler is more than 45 m above the lowest sprinkler/sprinkler pumps, whichever is lower.

(iv) Low rise system: Is one in which the highest sprinkler is 45 m or less from ground level or sprinkler pumps.

(v) Design point: A sprinkler installation is planned on the basis of a design point. This means the maximum number of sprinklers that may be operated at one time in case of fire. Though an installation may have 500 or even 1000 sprinklers, the design point may be only 25. This practically means that the installation is capable of dealing with a fire where upto 25 heads are operated.

(vi) Work done at Factory Mutual showed that convective heat generally supplies more than 80% of the heat sprinklers need for activation.

(vii) Sprinklers can only be effective if they activate before the fire gets past them.

(viii) It has been reported that in buildings where sprinkler systems have been installed the chances of fatal occupant casualties and property losses per fire are reduced to about two-thirds, compared to buildings where sprinklers have not been installed.

(ix) When sprinklers do not produce satisfactory results, the reasons usually involve one or more of the following:

- Partial, antiquated, poorly maintained or inappropriate systems;
- Explosions or flash fires that overpower the system before it can react, and;
- Fires very close to people who can be killed before a system can react.

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

(xi) In our country also, TAC and Insurance Companies encourage the installation of sprinkler systems in buildings by giving substantial reduction in insurance premiums(even upto 50%) for buildings so equipped.

(xii) **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.

7.5.4.11. 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) (see Note);

(h) dressing room, scenery docks, stages and stage basements of theatres;

(j) in hotels, hospitals, industries low and moderate hazard, mercantile buildings of height 15 m or above;

(k) in hotels below 15 m, if covered area at each floor is more than 1000 m^2;

(l) 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

(m) 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.

7.5.5. WATER SPRAY SYSTEMS

7.5.5.1. General

(i) Water Spray System is a special fixed pipe system connected to a reliable source of pressurised 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.

(ii) 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).

(iii) 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).

(iv) 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.

(v) The type of water spray required will depend on the nature of the hazard and protection required.

(vi) 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.

(vii) 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.

7.5.5.2. 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'.**

(a) 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. (eg: 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.

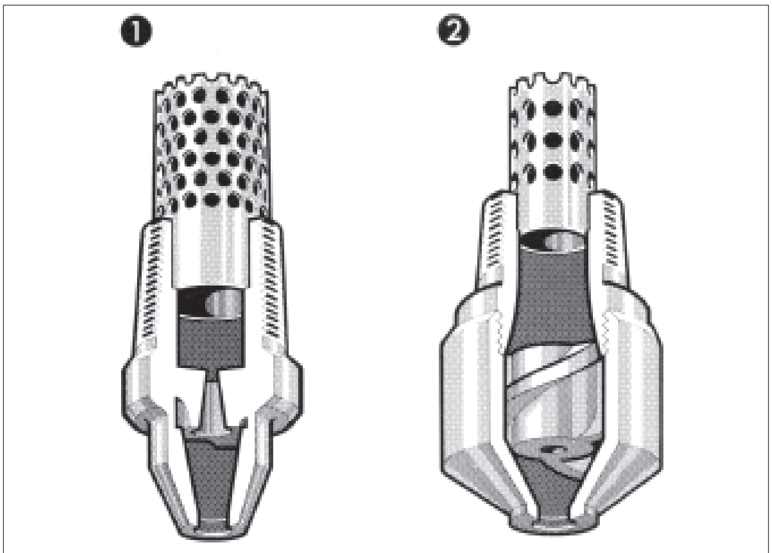


Fig-35 Two types of High Velocity Water Spray projectors

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.

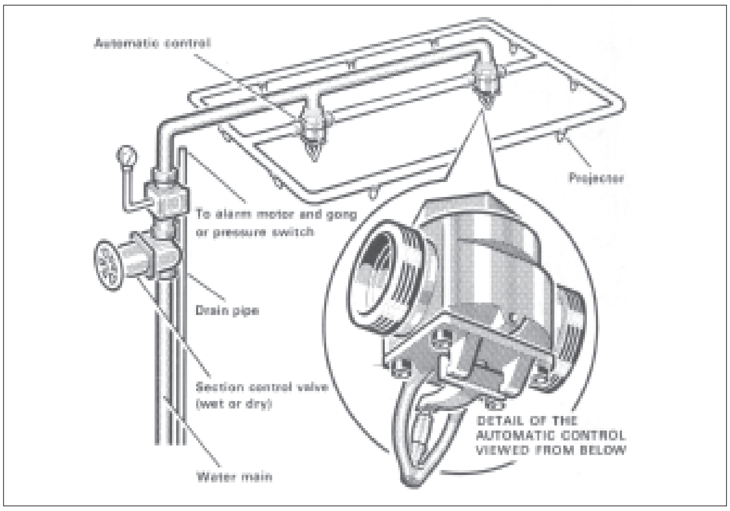


Fig-36 Automatic Water Spray projector system

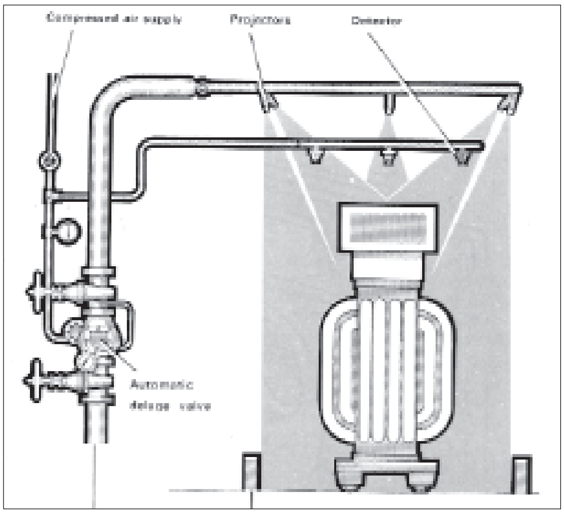


Fig-37 High Velocity Water Spray System for Transformer Protection

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.

(b) 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^{o}C) and also for fire extinguishment of water miscible liquids (polar solvents, alchohols etc.). It gives protection to tanks, structures, equipments etc. by cooling, by controlled burning of flammable liquids and also by dilution of explosive gases.

(ii) These systems are similar in operation and lay out to the high velocity systems.

(iii) Operation can be done automatically as well as manually.

(iv) Application rates for water spray systems are as follows:

- For extinguishment -- 8.1 lpm to 20.4 lpm/m^2 of protected surface;
- For fire control -- not less than 20.4 lpm / m^2 (for protection of pumps, glands other critical areas)
- For exposure protection (for cooling) -- not less than 10.2 lpm/m^2

7.5.6. AUTOMATIC DELUGE INSTALLATIONS:

7.5.6.1. 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. A diagram showing a typical system with component parts is given below.

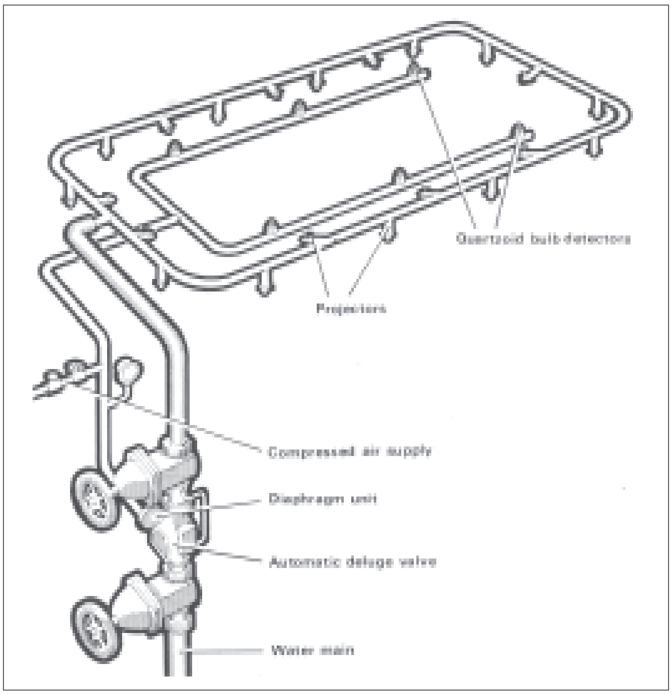


Fig-38 A typical deluge system

7.5.7. AUTOMATIC DRENCHER SYSTEMS

7.5.7.1. 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.

7.5.7.2. 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).

7.5.7.3. 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.

7.5.7.4. 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

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

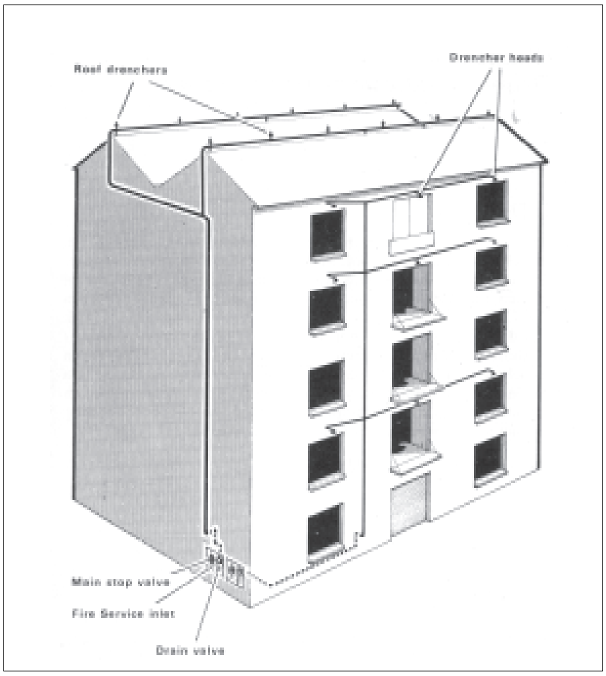


Fig-39 A typical drencher system

7.5.8. Foam Extinguishing Systems / Installations

7.5.8.1. (a) General:

(i) The general characteristics of foam as an extinguishing agent have already been dealt with under para 6.2.

(ii) A foam system consists of an adequate water supply that can be pressurised, 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.

(iii) 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.

(iv) 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 vapour 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.

7.5.8.2. Foam extinguishing systems are of three types:

(a) Low expansion foam systems;

(b) Medium expansion foam system; &

(c) High expansion foam systems.

7.5.8.3. Foam Generation Methods:

The foam production process assumes three separate operations - foam concentration proportioning process, foam generation process and foam distribution methods.

7.5.8.4. 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 pre mixing 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%.

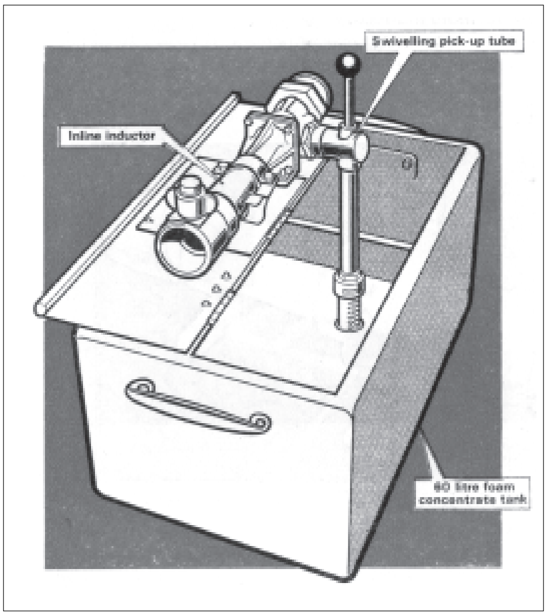


Fig-40 A typical Inline Inductor

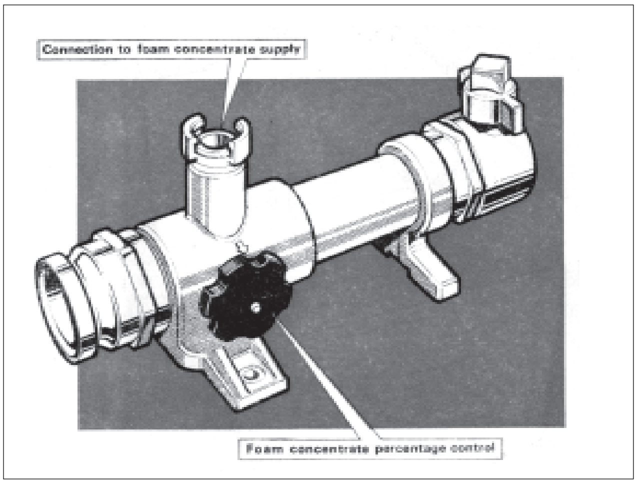


Fig-41 Inline Variable Inductor with control knob for regulating foam concentrate induction rate

- **By pass Induction:** This method combines the best features of self induction and inline induction devices.
- **Round-the-Pump Proportioner:** This involves installation of the inductor in a by-pass line between the discharge and suction sides of the fire pump. It can also be built in permanently in the fire appliance.

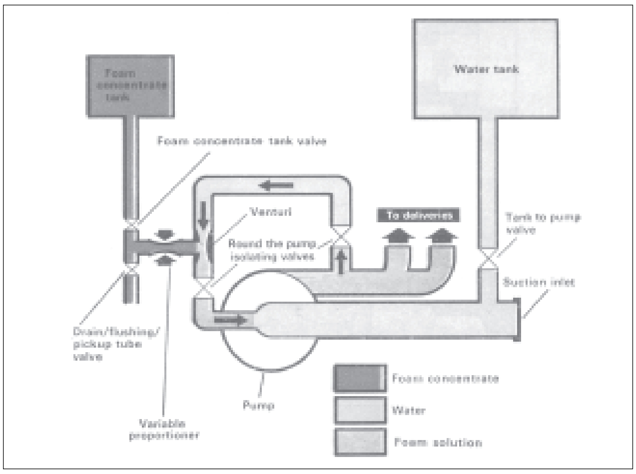


Fig-42 Diagrammatic lay out of Round-the-Pump Proportioner

(c) **Pressurised foam proportioning:** (Displacement Proportioner) This arrangement is suitable for both large and small systems.

(d) **Specialised foam making systems,** as in the case of Aviation CFTs, Refinery Foam Tenders etc.

7.5.8.5. Low expansion Fixed Foam Extinguishing Systems:

in the case of Aviation CFTs, Refinery Foam Tenders etc.

(a) Low Expansion foam may be applied directly to the surface of the burning liquid (surface application) or may be applied in the case of tank fires, below the surface so that they float to the surface under their own buoyancy (sub-surface application). Low expansion foams may also be applied by a semi sub-surface method. For gasoline and light crude oils, AFFF should be used.

b) General

The general requirements of a foam extinguishing system have already been explained in 7.5.8.1. Self contained systems are those in which all components including water and foam concentrate are contained within the system. Such systems often have water and foam concentrate stored as a premix solution in a tank which is pressurised by compressed air when operated or the foam concentrate can be stored and pressurised separately.

c) Limitations of Low Expansion Fixed Foam Systems:

- They are not suitable for extinction of running fuel fires.
- They are ineffective or dangerous to use on flammable liquids with temperatures in excess of 100^{o}C, particularly where the liquids in the tanks are of considerable depth;
- Most Aqueous Film Forming Foams (AFFF) are not suitable for use on water-miscible flammable liquids. For these specially stabilised foam concentrates are used;
- Foams are not suitable for use on fires involving gases or liquefiable gases with BP below 0^{o}C, or cryogenic liquids; they are not suitable for use on materials which react violently with water;
- They should not be used on energised electrical equipment;
- Their compatibility with dry chemical powders and certain wetting agents have to be verified before use.

- Only AFFF can be used in pre-mixed condition upto one year. Protein base foams are not suitable for this type of use.
- Simultaneous use of water jets or sprays may adversly affect a foam blanket.

(d) System Design

(1) General: The following points should be taken note of:

- Full details of the flammable liquid its storage, handling and location need to be known before any foam system is considered for installation.
- The most suitable foam making concentrate(P, FP, AFFF or FFFP as the case may be) in the appropriate concentration;
- The most suitable solution application rate;
- Most suitable equipment for making and delivering foam;

Note: The selection may depend upon the available water pressure;

- System operating time;
- Quantity of foam concentrate required for extinction;
- Most suitable proportioning method(s);
- Pipework sizes and pressure losses;
- Water supply, requirements, quantity, quality and pressure so that suitable pumps may be selected;
- System operation and any fire or gas detection equipment;
- Any special considerations such as the use of electrical equipment in areas where flammable vapours may be present;
- Reserve foam concentrate supply;
- Flushing Requirements.

Notes: 1) Provision should be made in the design for flushing with clean water after use of any lines.

2) Water supply mains, both underground and above ground, should be flushed thoroughly at the maximum practicable rate of flow, before connection is made to system piping;

3) Foam system can be operated manually or automatically, depending on the type and location of the risk;

4) Where automatic operation method is adopted, a manual override should also be provided;

5) All pipework should be subjected to a hydrostatic pressure test at 14 bars or 1.5 times the maximum pressure anticipated, whichever is greater, for a period of 2hrs.

7.5.8.6.Types of Foam Systems:

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

(i) Installed, fixed or semi-fixed;

(ii) Portable, and

(iii) Mobile.

(b) Installed System

(i) 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 favourable circumstances, over proportioning device to the foam maker(s) which protect the hazard.

(ii) Semi-fixed: Has steel pipework from outside the bund wall (or similar location) upto 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.

(iii) **Portable Systems:** Includes portable foam producing equipment that can be carried manually and connected via fire hose to pressurised water / pre-mixed solution supply to produce foam jets / sprays.

(iv) **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).

7.5.8.7.(a) Possible Advantages of Monitors and Foam Branches:

(i) Foam can be projected under favourable circumstances, over considerable distances and to significant heights.

(ii) Portable and mobile monitor systems housed protected from weather, are more likely to be kept in a serviceable condition, will be unaffected by explosion or flame exposure before fire fighting commences, and should be available for use in all parts of the complex to be protected. They may also be set up in the most favourable upwind position.

(iii) Oscillating monitors discharge foam evenly over very large areas, automatically

(iv) Fixed monitors may be remotely controlled from considerable distances, thus rendering them suitable, for example, in oil jetty protection and fire tug use.

(b) Possible Limitations of Monitors and Branches:

(i) Foam discharge may be affected by any wind and fire updraught resulting in discharge outside the affected area.

(ii) Tanks having ruptured roofs with only limited access for foam are not easily extinguished by monitor application from ground level.

(iii) Uniform foam distribution may not be achieved easily.

(iv) Fixed automatically-operated monitors applying foam horizontally into a fire area may be obstructed by equipment positioned temporarily.

(v) Portable foam branch pipes are not suitable for the primary protection of storage tanks of over 9m diameter and 6m height.

(c) Minimum Application Rates for Low Expansion Foams in Monitor or Foam Branchpipe Systems

Foam Concentrate	Flammable Liquid	Minimum Application Rates(l/m2/min.)	
(1)	(2)	(3)	(4)
Fluoroprotein(FP) or Flurochemical(AFFF)	Hydrocarbon	4	6.5
Protein (P)	Hydrocarbon	6.5	8

Notes

1. For tanks containing volatile fuels with flash point below 40°C it may be necessary to increase this rate of application

2. For tanks containing foam destructive liquids this method of application may not be suitable.

3. Allowance should be made for loss due to wind or fire up-draught when extinguishing storage tank fires.

(d) Minimum Discharge Times for Low Expansion Foams in Monitor or Foam Branchpipe Systems:

Risk	Equipment Type	Fuel Flash Point	Minimum Discharge Time(Min.)
(1)	(2)	(3)	(4)
Indoor and Outdoor spills	Fixed monitors fixed foam branchpipes.	All	10
	Mobile/Portable monitors and foam branch pipes	All	15
Tanks containing liquid hydro-carbons	All	Less than 40°C, for example: gasoline; greater than 40°C,for example, Kerosene	60

(e) Care should be taken when applying foam to high viscosity liquids such as burning asphalt, heavy oil, etc. when heated to 100°C and above.

(f) The water draining from a foam can cool the flammable liquid slowly, but if the drainage is too rapid, there is a considerable risk that the drained water will boil within the hot oil, thus producing dangerous frothing and even slop-over of the tank contents.

(g) While low expansion foam is not considered an effective agent for extinguishing three dimensional running flammable liquid fires, it can control the pool fire beneath the running fire, leaving control of the running fire to other means like dry powder fire extinguishers.

(h) With some flammable liquids the water spray distributed by foam sprayers can provide effective fire control as in high flash point hydrocarbon.

7.5.8.8. FIXED FOAM POURER SYSTEMS (SURFACE OR TOP APPLICATION) FOR FIXED ROOF TANKS

(a) General

This covers the systems which are designed to apply foam through pouring devices, and to provide primary protection for outdoor atmospheric flammable and combustible liquids in fixed roof tanks including covered floating roof tanks. These systems are intended for use in tank farms, oil refineries and chemical plants, and are usually operated manually. Tanks containing liquids with flash points above 60°C do not normally need to be protected by fixed foam systems unless these liquids are heated to their flash points.

(b) Fixed Foam Pourer (Foam Discharge Outlet)

Equipment is designed to discharge foam onto the top portion internal wall of a tank, so that it will flow down gently onto the surface of the flammable liquid without undue submergence of the foam or agitation of the surface. Some pourers are designed to discharge the foam tangentially in order to create a circular motion, and thus promote foam distribution.

(c) Foam Chamber (Vapour Seal Box)

Incorporates equipment designed to prevent tank vapour enter ing the foam pipework systems, while allowing the foam to enter the tank without undue resistance when required.

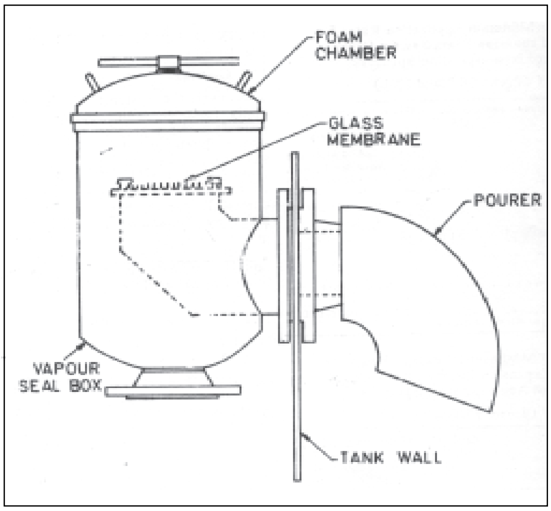


Fig-43 Foam chamber and pourer with vapour shield

(d) It has to be borne in mind that there is a risk of the pourers getting damaged due to explosion or fire exposure.

(e) Minimum Application Rates for Low Expansion Foam Systems Using Fixed Foam Pourers

Foam Concentrate	Flammable Liquid	Minimum Application Rate (l/m2/min.)
All types (1)	Hydrocarbon	8 1pm

NOTES

1. When foams are used on volatile fuels with flash points below 40°C the above rates may have to be increased

2. Products such as isopropyl alcohol, butyl alcohol, methyl isobutyl ketone, methyl methacrylate monomer and mixtures of watermiscible liquids in general may require higher application rates. Protection of products such as amines and anhydrides which are particularly foam destructive require special consideration.

3. It is often necessary to use special designs of pourer giving very gentle foam application, in order to extinguish ‘alcohol’ type fires.

(f) Minimum Discharge Times for Low Expansion Foam Systems Using Fixed Foam Pourers

Risk	Minimum Discharge Time	
	Protein (P) (Minute)	Flouroprotein (FP) Flourochemical (AFFF) (Minute)
Indoor and outdoor spill protection Tanks containing liquid hydrocarbons:	10	10
Flash point below 40°C Gasoline etc.	55	45
Flash point above 40°C Kerosene etc.	30	30

(g) Minimum Number of Foam Pourers for Flammable Liquid Storage Tanks (Fixed Roof)

Tank Diameter(m)	Minimum Number of Foam Poureres
Up to 24	1
Over 24 to 36	2
Over 36 to 42	3
Over 42 to 48	4
Over 48 to 54	5
Over 54 to 60	6

(h) For tanks over 60 m in diameter, at least one additional foam pourer should be added for each additional 460m2 of flammable liquid surface, located to give even foam distribution. Central sub-surface application may be used to give protection to the central area of the fuel surface.

(i) Fixed foam pourers should be equipped with an effective and durable seal, frangible under low pressure to prevent entry of vapour into the foam pourer and pipe lines. Access should be provided to permit inspection and maintenance, including replacement of the vapour seals.

7.5.8.9. FIXED FOAM POURERS FOR OPEN TOP FLOATING ROOF TANKS

(a) General

(i) This covers fixed foam pourers for the primary protection of open top floating roof tanks. Tanks of this design have a good fire record and normally do not require fixed protection. But if fixed protection is pecified, it need only be for the rim seal area.

(ii) Floating roof seals may be of the pantograph type or may be a tube seal with metal weather shield. Foam should be discharged into the seal area behind a foam dam secured to the floating roof, or should be injected below the pantograph seal, or behind the metal weather shield into the rim seal area in the case of tube seal designs.

Note: Portable foam branches are also suitable for extinguishing rim fires in floating roof tanks.

(iii) Possible Advantages

- Total foam output reaches the rim seal area.
- Using foam pourers and a foam dam, the equipment is simple and requires only moderate maintenance.
- Foam is applied gently without severe mixing with the fuel.

(iv) Possible limitations

- Where foam is injected below the pantograph or weather shield a foam generator might not be capable of operating against the pressure required to force foam around the rim seal area.
- Where foam is injected into the rim seal area, special pipework is needed to conduct foam from outside the shell onto the roof area. This needs to be hinged or jointed to allow for movement of the roof, and has to be protected or designed to withstand the effects of a rim seal fire.
- Adverse winds and obstructions projecting through the fuel surface may reduce the effectiveness of the system and allowance should be made in the rate of application of foam.

(b) Systems involving the use of a Foam Dam:

Foam Dams should be fitted where foam is discharged above the seal area. They should also be fitted for systems where foam is injected below the weather shield of a tube seal design, if the distance between the top of the tube seal and the top of the roof is less than 150mm. In such cases, the dam should be installed on top of the roof adjacent to the weather shield. Systems should be designed to deliver not less than 12.5 1/m^2/minute based on the area of the annular ring between the foam dam and tank shell.

(c) Where foam dams are not provided, the system should be designed to deliver not less than 20 lpm/m^2 of foam. The system should be capable of operation for at least 20 mins.

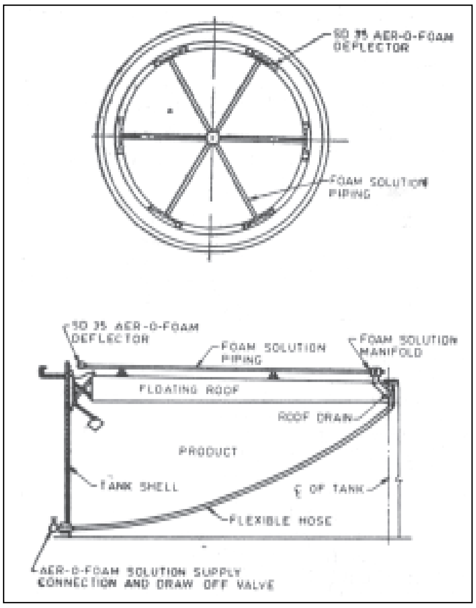


Fig-44 Foam system installed on the floating roof top

7.5.8.10. SUB SURFACE FOAM SYSTEMS

(a) General

(i) This covers systems for the protection of fuel storage tanks, by which foam is injected at the base of the tank with sufficient pressure to overcome the head of fuel. A special foam inlet pipe may be used.

(ii) This type of protection is suitable for fixed roof tanks, but it is not suitable for floating roof tanks with or without fixed roofs.

(iii) Sub-surface application is not suitable for the protection of water-miscible fuels and only fluoroprotein and AFFF type foam concentrates are suitable for this purpose.

(iv) The system is essentially simple and, being at ground level, is less likely to be damaged by fire or explosion.

(v) The circulation of cold fuel from the base of the tank to the burning surface caused by the rising foam stream can be utilised to assist extinction and to dissipate hot fuel layers at the burning surface.

(b) Possible Limitations

(i) Sub-Surface systems are not suitable for water-miscible fuels.

(ii) Sub-surface systems are not suitable for the protection of floating roof tanks because the roof will prevent complete foam distribution.

(iii) With some fuels, where there has been a long preburn prior to the application of foam, a hot zone may exist near the burning surface at temperature in excess of 100°C. In order to avoid frothing and slop-over, continuous application of foam should be avoided in the initial stages. Intermittent application of the foam can induce circulation of the fuel in the tank, thereby bringing the cooler layers of fuel to the surface. The foam injected intermittently will disperse without sufficient steam formation to produce frothing.

(c) Number of Foam Injection Points for Low Expansion Foams in Sub-surface Systems

Tank diameter (m)	Volatile Products (Flash point below 40°C)	Non-volatile Products Flash point above 40°C)
Up to 24	1	1
Over 24 to 36	2	1
Over 36 to 42	3	2
Over 42 to 48	4	2
Over 48 to 54	5	2
Over 54 to 60	6	3
above 60 m add one extra inlet for each additional ara of	460m2	700m2

7.5.8.11. SEMI SUB-SURFACE SYSTEMS

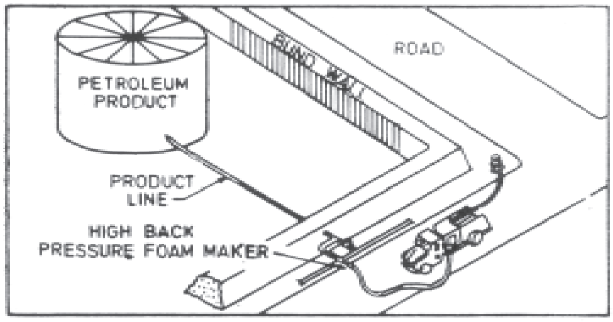
(a) General

(i) This covers systems from which foam is applied to the surface of oil storage tanks via a flexible hose rising from the base of the tank. A special container within the tank houses the hose and is connected at the base of the tank to an external foam generator capable of working against the maximum product head. This type of protection is suitable for fixed roof tanks but is not normally considered appropriate for floating roof tanks with or without fixed roofs.

(ii) With large tanks, the semi sub-surface units can be arranged to produce an even distribution over the fuel surface.

(iii) Protein, fluoroprotein or AFFF concentrates may be used.

(iv) Semi sub-surface systems may not be suitable for the protection of floating roof tanks, because the roof will prevent distribution.



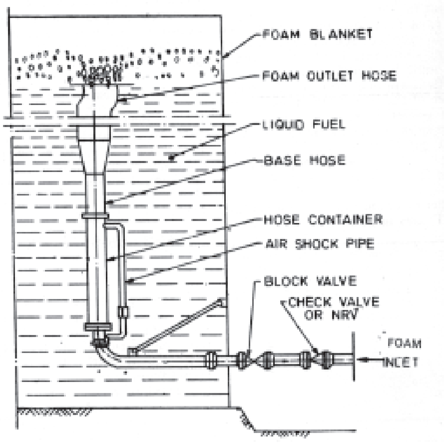


Fig-45 Layout of semi subsurface foam system

7.5.8.12. SUPPLEMENTARY PROTECTION FOR STORAGE TANKS

(a) Each foam branchpipe should be designed to give a solution flow rate of at least 500 1/min. Additional foam concentrate should be provided to permit operation of all extra branchpipes simultaneously with the primary means of fire protection and for the minimum discharge duration specified in Table below.

(b) Minimum Number of Supplementary Branchpipes and Duration of Discharge.

Diameter of LargestTank (in m)	Mini. Number of Foam Branchpipes with Manifold with each Hydrant	Min. Discharge Time (minute)
Up to 10	1	10
Over 10 and up 20	1	20
Over 20 and up 30	2	20
Over 30 and up 40	2	30
Over 40	3	30

(c) Hydrants

For fixed piping systems in addition to the primary means of protection, and the supplementary protection specified supplementary hydrants should be provided for use with portable foam monitors or portable foam towers in the event that a fixed discharge outlet on the primary protection system is damaged. In lieu of a foam hydrant a water hydrant may be used in conjunction with suitable foam producing equipment. Each hydrant should be located between 15m and 75 m from the shells of the tanks being protected by the associated primary system.

The flow from hydrants should be sufficient to support portable equipment to be used.

7.5.8.13. BUND PROTECTION SYSTEM

(a) This covers systems which apply foam to the bund area around tanks. These areas should be considered as spill fires.

7.5.8.14. 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:

- Total flooding,
- Local application, and
- Portable.

(iii) Medium expansion foam generators are of the 'aspirator' type and are mostly used for local and portable type applications.

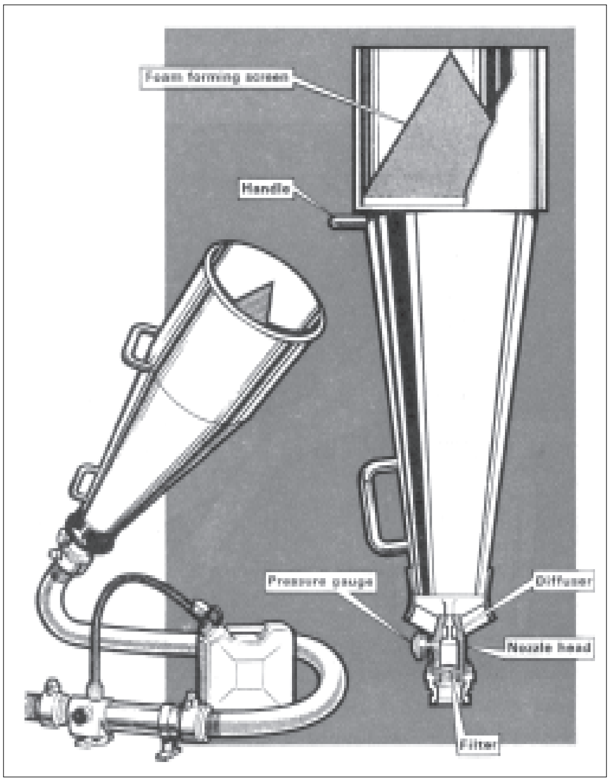


Fig-46 A typical medium expansion foam generator (iv)The 'blower' type generator is normally designed for production of high expansion foam. In this the foam solution is discharged onto a screen through which air is blown by a fan or a blower. As the air passes through the screen which is wetted with 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.

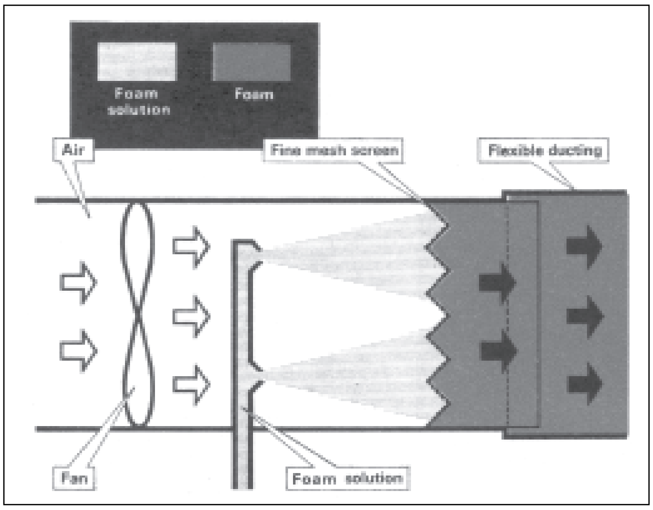


Fig-47 Principles of operation of a high expansion foam generator

(v) Basically, medium and high expansion foam systems are used to control or extinguish surface fires in flammable and combustible liquids and solids, and deep-seated fires involving solid smouldering 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 vapour cloud.

(vii) Total flooding system may be used in enclosures surrounding the hazard to be protected like walls, basements, ship's holds, mines, cable tunnels, high-rack storages etc.

(viii) It is important that leakage of the foam from the enclosures protected is avoided. Windows and doors in such premises should be designed to close automatically, with provisions for high level venting of the air in the enclosure which is displaced by the foam.

(ix) Generally, the minimum depth above the hazard should be about 0.6m (2 feet). For high expansion foam system, the minimum 50 % drainage time should be approximately 8 min.(1 litre 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 life line with them.

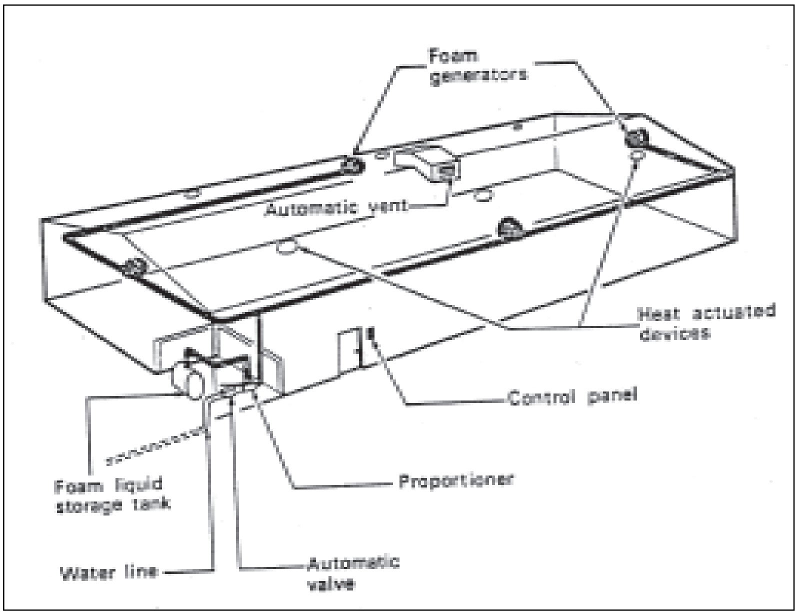


Fig-48 Typical High Expansion Foam System for Warehouse-

7.5.9. CO^2 EXTINGUISHING SYSTEMS / INSTALLATIONS

7.5.9.1. General

(i) CO^2 is suitable for extinguishing the undermentioned types of fires:

- Fires involving smouldering carbonaceous solid materials (Class A fires);
- Fires involving flammable and combustible liquids (Clas B fires);
- Fires involving combustible gases, except where explosive atmospheres are likely to develop (Class C fires); and
- Fires involving live electrical apparatus and installations.

(ii) CO_2 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.

7.5.9.2. There are two types of CO_2 extinguishing systems:

(i) High Pressure System:

This installation consists of a battery of one or more cylinders of CO_2 interconnected by a manifold, and feeding into a high pressure distribution pipework. Special discharge nozzles are fitted in the pipework, and on operation of the installation, the gas is discharged into the protected space with considerable noise.

(ii) Low Pressure System:

In this system the gas is stored in a refrigerated tank at a temperature of $-18^{o}C$ and at 20 bars pressure. The tank is connected by pipework to the protected spaces with discharge nozzles sited at strategic points on the pipework.

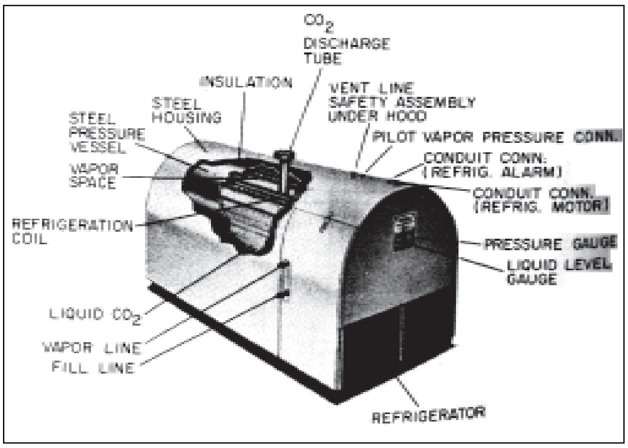


Fig-49 Low pressure CO_2 Storage Unit

7.5.9.3. Methods of Application:

There are two basic methods of applying CO_2 in the fire extinguishing systems:

(i) Total Flooding: In these systems the CO_2 is applied through nozzles to develop a uniform concentration of CO_2 in the protected enclosure. The minimum concentration used in the total flooding system is 34% CO_2 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%.

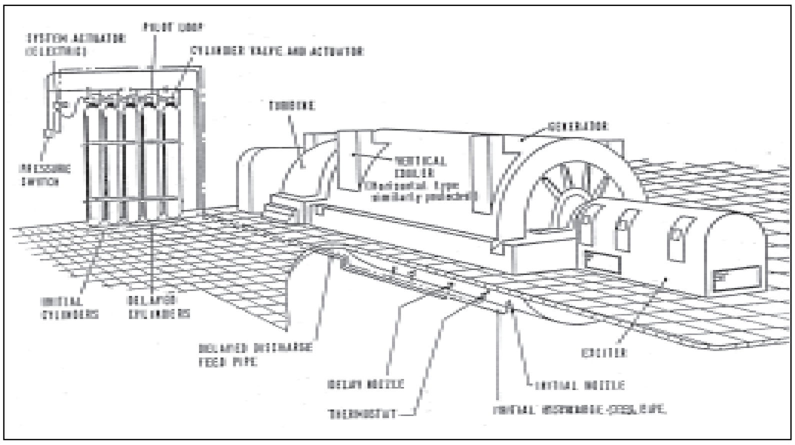


Fig-50 CO_2 Total Flooding System protecting turbo generator

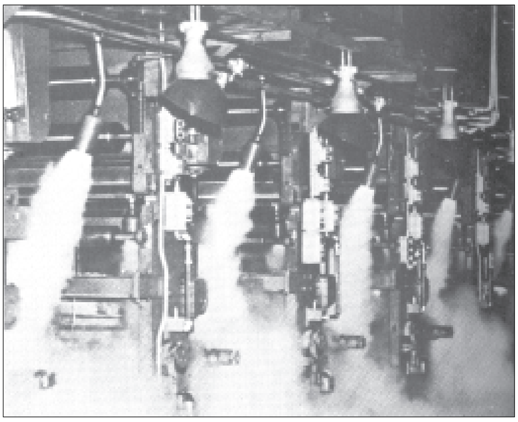


Fig-51 A CO_2 Extinguishing System that has been activated

(ii) Local Application: In this system CO_2 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

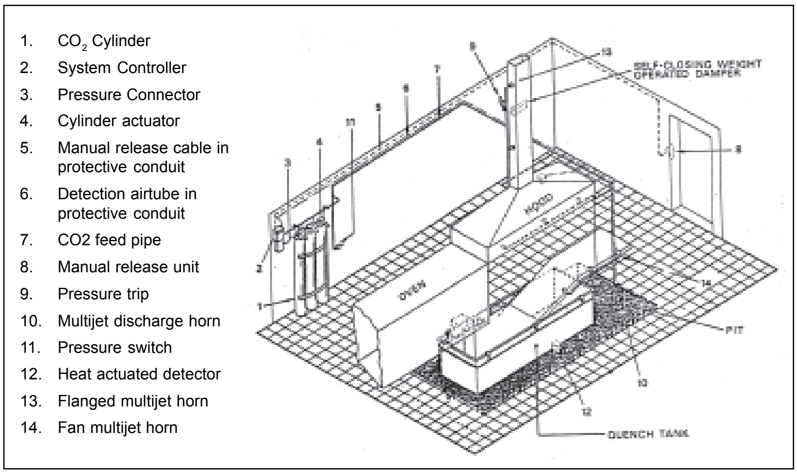


Fig-52 CO_2 Local Application System protecting quench tank

(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 was up to 30 mins.)

MINIMUM CARBON DIOXIDE CONCENTRATIONS FOR EXTINGUISHMENT

Material	Theoretical minimum CO_2 concentration (%)	Minium design CO_2 Concentration (%)
Acetylene	55	66
Acetone	27 (see Note 2)	34
Aviation gas grades 115/145	30	36
Benzol benzene	31	37
Butadiene	34	41
Butane	28	34
Butane-I	31	37
Carbon disulfide	60	72
Carbon monoxide	53	64
Coal gas or natural gas	31 (see Note 2)	37
Cyclopropane	31	37
Diethyl ether	33	40
Dimethyl ether	33	40
Dowtherm	38 (see Note 2)	46
Ethane	33	40
Ethyl alcohol	36	43
Ethyl ether	38 (see Note 2)	46
Ethylene	41	49
Ethylene dichloride	21	34
Ethylene oxide	44	53
Gasoline	28	34
Hexane	29	35
Higher paraffin hydrocarbons $C_N H_{2m} + 2M-5$	28	34
Hydrogen	62	75
Hydrogen sulfide	30	36
Isobutane	20 (see Note 2)	36
Isobutylene	26	34
Isobutyl formate	26	34
JP 4	30	36
Kerosene	28	34
Methane	25	34
Methyl acetate	29	35
Methyl alcohol	33	40
Methyl butene-I	30	36
Methyl ethyl ketone	33	40
Methyl formate	32	39
Pentane	29	35
Propane	30	36
Propylene	30	36
Quench, lubrication oils	28	34

(iv) Hand Hose Lines: This can be used for total flooding or local application, and is adopted to supplement fixed system or portable equipment

7.5.9.4. System Design:

(a) Total Flooding System:

(i) The enclosure construction shall be such as to prevent leakage of gas;

(ii) Openings and ventilation systems should be closed or shut down automatically with the activation of the discharge, and remain shut;

(iii) Where openings cannot be shut, additional CO_2 quantities should be provided;

(iv) CO_2 total flooding systems can be successfully used for protection of vaults, enclosed machines, ducts, ovens etc. and their contents

(b) Design Quantity:

This should be determined on factors like:

- Room size;
- Material to be protected;
- Particular risks;
- Openings that cannot be closed;
- Ventilation systems which cannot be shut down;
- Temperature of protected area;
- Likelihood of spread of fire from one compartment to another;
- Chances of fire occurring in more than one space at the same time.

(c) Types of fires which can be extinguished by CO_2 total flooding system are:

(i) Surface fires involving in flammable liquids, gases and solids(most suitable for total flooding systems); and

(ii) Deep-seated fires involving in smouldering materials. The extinguishing concentration should be maintained for a sufficient period so that re-ignition can be prevented.

(d) The system should be designed taking into account the atmospheric correction factor.

(e) The theoretical minimum CO_2 concentration for extinguishment of surface fires of some common liquids and gases are shown in the Table overleaf:

(f) The requirements of CO_2 for deep seated fires is based on tight enclosures. After reaching the design point, the concentration should be maintained for not less than 20 min.;

(g) Additional qualities of CO_2 should be provided to compensate for any special conditions;

(h) Rate of application: The minimum design rate of application should be based on the quantity of CO2, and the maximum time to achieve the design concentration is as follows:

- For surface fires, the design concentration should be achieved within one minute;
- For deep-seated fires, the design concentration should be achieved within 7 min.

(i) For enclosed rotating electrical equipment, a minimum concentration of 30% should be maintained for not less than 20 min.

(j) High pressure storage temperatures can range from $-18^{O}C$ to $54^{O}C$.

(k) The hazard protected should be isolated so that fire will not spread outside. The entire hazard should be protected.

(l) The quantity of CO_2 required for local application systems should be based on the total rate of discharge needed to blanket the area, and maintenance of the discharge to ensure complete extinguishment.

(m) For systems with high pressure storage, the quantity of CO_2 should be increased by 40%, since only the liquid portion of the discharge is effective.

(n) Duration of Discharge: The minimum effective discharge time should be 30 sec. , which may be increased to compensate for any hazard condition.

(o) The system should have sufficient number of nozzles to cover the entire area protected.

(p) The system should generally be designed for automatic operation, with manual override.

(q) The system should have indicating and alarm devices as given below:

- Automatic visual warning with coloured indicator lights to indicate:
- Manual control;
- Automatic control;
- CO_2 discharged.

(r) Other automatic devices designed to be installed are to:

- Operate door closing devices;
- Close openings in ventilating ducts;
- Switch off ventilation system;
- Operate fire screens;

7.5.9.5 Safety Requirements:

(a) The CO_2 discharge can create serious hazards for personnel, such as reduced visibility and suffocation. Suitable safeguards should be provided to ensure prompt evacuation and to prevent entry into such areas.

(b) Before entry into protected spaces, the automatic release of the system should be isolated, and the lock-off control activated. The minimum safety precautions for the system are.

- Inhitbit switch and time delay;
- Safety inter-lock; and
- lock-off valve.

(c) Since discharge of liquid CO_2 can produce electrostatic charges, CO_2 systems installed in explosive areas should be provided with metal nozzles which should be properly bonded and earthed.

(d) Adequate lighting with directional signs should be provided to ensure quick occupant evacuation.

(e) The audible and visual alarms should activate a few minutes before the operation of CO_2 installation.

(f) Warning and instructional signs should be positioned at the entrance to the protected area;

(g) Premises protected with Co2 installation should display a distinctive symbol (as shown below) as a warning of the presence of CO_2 .

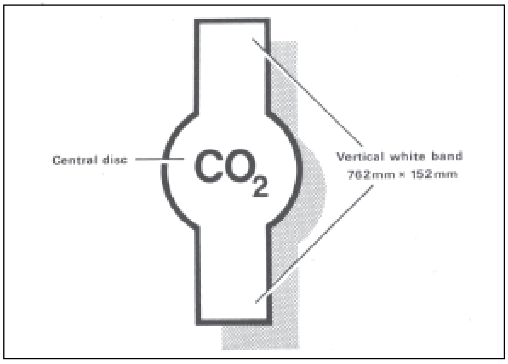


Fig-53 Standard warning symbol of a CO_2 Installation

7.5.9.6. Acceptance Tests:

The completed CO2 system should be subjected to the following tests before acceptance:

(a) Full Discharge Test; as per standards;

(b) Where a full discharge test is considered not necessary by the competent authority, the following procedure should be followed:

(i) Subject the distribution system to a hydrostatic pressure test of 1.25 times the calculated pipework's maximum developed storage pressure at 55°C, followed by purging the system.

(ii) Subject the protected area to an enclosure integrity test.

7.5.10. Dry Chemical Extinguishing Systems / Installations:

7.5.10.1. General

(a) The characteristics etc. of dry chemical powder as an extinguishing agent have already been covered under para 6.7. 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 cleaningup 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.

7.5.10.2. 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.

7.510.3. 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.

(a) Fixed Systems:

These consist of a supply of dry chemical, an expellant gas, an actuating mechanism, fixed piping and nozzles through which the dry chemical can be discharged into the hazard area. Fixed dry chemical systems are of two types: total flooding and local application.

(i) Total flooding: In total flooding systems, a pre determined amount of dry chemical is discharged through fixed piping and nozzles into the protected area. Total flooding is applicable only when the risk is totally enclosed, or when all openings can be closed automatically. Only where no re-ignition is anticipated can total flooding be resorted to.

(ii) In local application system, the nuzzles are arranged to discharge directly into the fire. The principal use of the local application systems is to protect open tanks of flammable liquids. Here again, re-ignition possibilities have to be considered.

(iii) Hand hose line systems consist of a supply of dry chemical and expellant gas with one or more hand hose lines to apply the dry chemical on to the fire. The hose stations are connected to the agent container directly or through piping. These systems are quite useful for protection of gasoline loading racks, flammable liquid storage areas, diesel and gas turbine locomotives, and aircraft hangars.

7.5.10.4. System Design:

(a) Usually, dry chemical system consists of dry chemical and expellant gas storage tanks, piping / hose to carry agent to the fire areas, nozzles to discharge the agent into the area and automatic and / or manual actuating devices.

(b) An engineered system needs individual calculations and designs to determine the various factors necessary for the system.

(c) On the other hand, in a pre-engineered system (also called as a package system), the quantity of dry chemicals, pipe sizes, number of fittings, number and types of nozzles etc. are pre-determined by fire tests. Pre-determined systems are frequently used for kitchen ranges and hoods, including deep fat fryers. Care has to be exercised to ensure that only alkaline dry chemicals(sod. bi-carbonate, pot. bi-carbonate etc.) are used in these cases, and ABC or multi purpose dry chemical (mono ammonium phosphate) should never be used.

(d) Expellant gas used for dry chemical systems is normally dry Nitrogen. But for smaller systems, dry air or CO_2 can be used.

(e) Extreme care has to be taken to ensure moisture-free storage for dry chemical as well as for expellant gas. Once the powder loses its free flowing characteristics, it should be discarded.

(f) For automatic operation systems, manual controls should also be provided as an alternative.

(g) Suitable safety alarms should be sounded before actuation of the systems.

(h) Generally, controlled discharge type of nozzles are preferred for the system.

(i) The efficacy of the system, to a large extent, depends on the proper design and construction of the pipings, fittings and nozzles.

(j) Quantities of dry chemicals and rates of flow for the systems should also be carefully calculated.

(k) In case one system is designed to cater for 2 or 3 hazard areas, suitable directional valves and controls will have to be incorporated into the system so as to enable the system operation to be directed to the particular area affected by fire.

7.5.10.5. Reserve Supply: A fully charged reserve unit permanently connected to the system will be desirable as reserve supply for the system so that immediate re-commissioning of the system will be possible.

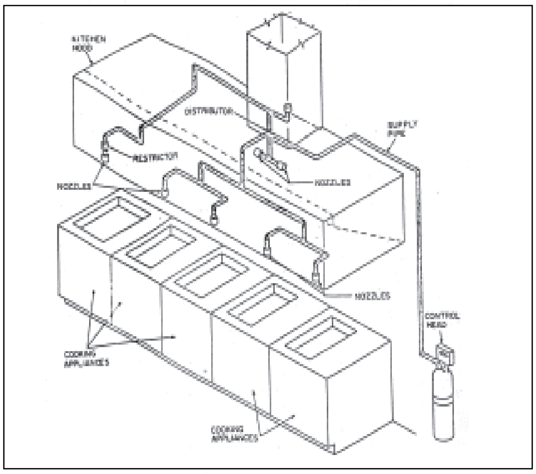


Fig-54 Dry Chemical Extinguising System (for protection of cooking range)

7.5.10.6. Maintenance, Inspection and Test Procedures:

(i) Routine inspection system should be carried out every month;

(ii) The quantity of dry chemical should be checked every six month;

(iii)The amount of expellant gas should also be checked every months.

(iv)Inadvertant mixing of different base dry chemicals can initiate dangerous reactions, generating CO2 gas and double de-composition products which may result in equipment failure or loss of discharge capability.

(v) Nozzles should be examined to see that they are free of obstructions and in good operation condition.

(vi)System actuating devices, like detectors, fusible links, thermostats etc. should also be inspected for trouble free operatlion.

(vii) Care has to be exercised by periodical inspections to ensure that the dry chemical powder inside the containers always remains dry.

(viii) Every time, after discharge, all piping and nozzles in the system should be blown clear.

7.5.11. HALON FIRE EXTINGUISHING SYSTEMS / INSTALLATIONS

7.5.11.1. General

(a) Halons(Halogenated Extinguishing Agents) are hydrocarbons in which one or more hydrogen atoms have been replaced by halogen atoms: fluorine, bromine, chlorine or iodine. This combination with halogens not only renders these agents non-flammable, but imparts flame extinguishment properties also. Halons are used both in portable fire extinguishers and in extinguishing systems.

(b) Halons were first introduced into commercial use during the 1960s, which posessed exceptional effectiveness in fire extinguishing and explosion prevention and suppression. These agents are clean, electrically non-conductive, and leave no residue (coming under the category of clean agents). This unique combination of highly desirable properties led to these agents being selected for a wide range of fire protection applications.

(c) Halons which are commonly used as fire extinguishing agents are:

  (i) Halon 1301 - Bromotrifluoromethane - Chemical formula - CF_3Br,

  (ii) Halon 1211 - Bromochlorodifluoromethane - Chemical formula - CF_2BrCl, and

  (iii) Halon 2402 - Dibromotetrafluoroethane - Chemical formula - $C_2F_4Br_2$.

(d) Halon 1301, which is a gas at room temperature, has been used widely in fixed systems throughout the industrial, commercial, marine, defence and aviation industries. Halon 1211, a vapourising liquid at room temperatures, was preferred for use in portable fire extinguishers, and to a limited extent in extinguishing systems for unoccupied areas. Halon 2402, a low boiling liquid, has primarily been used in the defence, industrial, marine and aviation sectors in Russia and other former Soviet Union countries, and to a limited extent in Indian Navy.

(e) In the early 80s, as a result of research studies, it was revealed that certain substances, including halons, were responsible for catalytic depletion of the stratospheric ozone layer. In fact, it was found that the Ozone Depletion Potential(ODP) of the halons was much higher than other substances involved. The ODP for Halon 1301 has been found to be 13 times more than CFC (Chloro Flouro Carbon) whose ODP was reckoned as 1. The ODP for Halon 1211 was found to be 3 times more than CFC.

(f) On account of the coming into force of the international agreement known as Montreal Protocol on substances having ODP, production of the Halons ceased in the developing countries by 1 January 1994, and will be phased out in the developing countries also by the year 2010.

(g) Many Halon systems still remain in use throughout the world and, therefore, the specification standards concerning these fire fighting agents and their systems still continue to be relevant. However, the development as well as utilisation of Halon alternative agents are currently in progress worldwide. Apart from the Halon extinguishing systems which are in existence currently, Halon extinguishing systems continue to be used for critical applications. Recycled Halons, recovered from less critical applications, are now providing the source of supply for specialised applications such as defence equipment, aviation use and explosion prevention / suppression applications that remain dependent on Halons.

7.5.11.2. (a) Halon extinguishing agents achieve flame extinguishment primarily by inhibiting flame chain reactions (a process known as chain breaking). Among the Halogens, bromine is much more effective in this process than chlorine or fluorine. In total flooding systems, the effectiveness of the Halons on flammable liquids and vapour fires is quite phenomenal. Rapid and complete extinguishment is obtained with low concentrations of agent. A comparative statement of flame extinguishment values for Halon 1301 and Halon 1211 are shown below:

	Average Percent by Volume of Agent in Air Required for Flame Extinguishment	
Fuel	Halon 1301	Halon 1211
Methane	3.1	3.5
Propane	4.3	4.8
n-Heptane	4.1	4.1
Ethylene	6.8	7.2
Benzene	3.3	2.9
Ethanol	3.8	4.2
Acetone	3.3	3.6

(b) Toxicity: As per research studies conducted in the US, the approx. lethal concentration (ALC) for 15 min. exposures to Halon 1301, Halon 1211 and Halon 2402 have been found to be 83%, 32% and 13% by volume respectively. Experience and testing have shown that personnel may be exposed to Halon 1301 in low concentrations for brief periods without serious risk. However, on application on fires(of temperatures approx. above 482^{o}C), Halons usually produce decomposition products like hydrogen fluoride (HF), hydrogen bromide(HBr), bromine(Br) etc., which can prove lethal.

7.5.11.3. Total flooding systems:

(a) Halon 1301 total flooding systems are usually installed for protection of computer rooms, electrical switchgear rooms, magnetic tape storage walls, electronic control rooms, storage areas for high value stores, books etc., machinery spaces in ships, cargo areas in aircraft, processing and storage areas for highly flammable liquids etc. Halon 1301, by virtue of its lower toxicity, higher volatality and better fire extinguishing efficiency, offers particular advantage for use in total flooding systems.

(b) Halon 1301 total flooding systems should not be used in concentrations greater than 10% in normally occupied areas.

(c) Minimum design concentrations of Halon 1301 for flame extinguishment for a few fuels are shown below:

Fuel	Minimum Design Concentration % by Volume
Acetone	5.0
Benzene	5.0
Ethanol	5.0
Ethylene	8.2
Methane	5.0
n-Heptane	5.0
Propane	5.2

(d) Halon 1301 design concentrations required for inerting purposes is slightly higher than the design concentrations for extinguishment, as is the case with other extinguishing agents also. The design concentration required for inerting certain fuels are shown below:

Fuel	Minimum Conc.% by Volume*
Acetone	7.5
Benzene	5.0
Ethanol	11.1
Ethylene	13.2
Hydrogen	31.4
Methane	7.7
n-Heptane	6.9
Propane	6.7

7.5.11.4. Local Application Systems:

Local application systems are meant for protection of hazards which have no fixed enclosure around them. Individual hazards within confined spaces may be protected by this method. In this method, the discharge nozzle is directed at the surface or on the object to be protected. Hence, the design of the nozzle has an important role to play in this system. The discharge velocity and rate must be suitable to penetrate the flame and produce extinguishment.

7.5.11.5. Specialised Systems:

These are widely used to protect aircraft engine nacelles, racing cars, military vehicles, emergency generator motors etc. The important characteristic of a specialised system is that it can be applied only to the specific hazard for which it was designed and tested.

7.5.11.6. Maintenance of Halon Extinguishing Systems:

(a) Since the age of most of the existing Halon extinguishing systems may range anything from 10 to 20 years or more, it is essential, in the interests of operational efficiency of the systems, and safety of personnel concerned, that stringent inspection and maintenance schedules for these systems are formulated and implemented.

(b) Some of the features to be borne in mind in this regard are as follows:

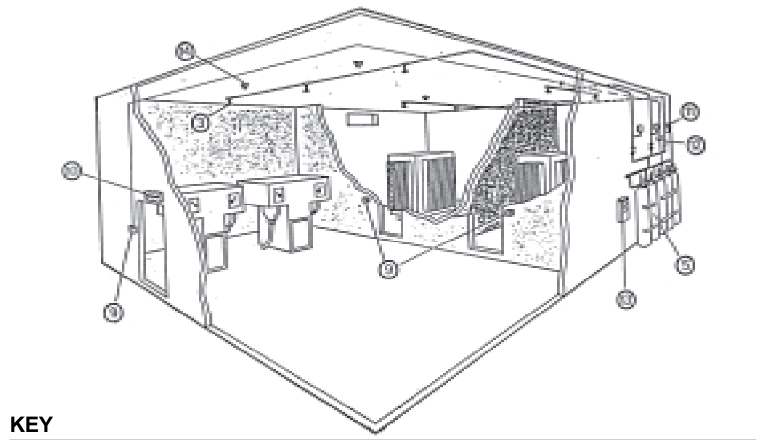
- The system should be visually inspected for evidence of corossion or other damage, at least every six months;
- The storage containers must be checked for loss of agent as well as loss of pressurising gas by suitable methods, at least every six months. Liquid level indicators, if available, are to be preferred for checking the quantity of agent, rather than weighing, which is more cumbersome and time-consuming;
- At least annually, the operational characteristics of the systems should be re-tested by knowledgeable and qualified persons;
- It should be ensured that inadvertent Halon release does not occur due to fault in service or maintenance procedures;
- Enclosure integrity tests should be carried out at least once a year.

(c) Recycling of Halons:

(i) It is quite likely that in the existing Halon extinguishing systems, either the agent quantity must have been reduced, or the agent quality must have been adversely affected. Recycling of Halons is important to avoid atmospheric release, as well as to cater to the need for protection of essential applications.

(ii) Halon cylinders and valves contain a liquified compressed gas. Further, the Halon cylinder valves are designed to accommodate the high flow rates required for fulfilling the discharge time of less than 10 sec. Consequently, Halon cylinders have the potential to cause serious damage, injury, or death. Before a Halon cylinder is removed from the system retaining brackets, the cylinder valve must be made safe and anti-recoil device placed in the discharge opening. Several incidents of damage, injury and fatality have occurred from failure to take these precautions (as per documented evidence).

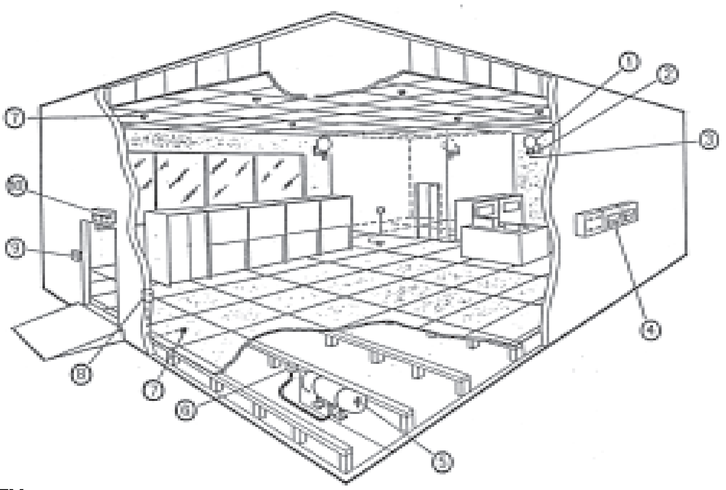
(iii) It is important that whenever any users contemplate de-commissioning of any Halon extinguishing system due to age of the system or for other reasons, the manufacturer of the equipments as well as the installer besides any other designated authority should be contacted for necessary technical advice and assistance.



KEY

(1) Spherical Halon container (2) Wall bracket (3) Discharge nozzle (4) Control Unit (5) Halon containers (6) Electrical connector (7) Smoke detectors 8) Detector 'operated' lamp 9) Break Glass manual release (10) Remote indiacation box (11) Pressure Switch (12) Direction valve (13) System actuator (14) Pneumatic heat detector (15) Control head (16) Release head.

Fig-55 Halon Total Flooding System for oil-filled switchgear & transformers



KEY

(1) Spherical Halon container (2) Wall bracket (3) Discharge nozzle (4) Control Unit (5) Halon containers (6) Electrical connector (7) Smoke detectors 8) Detector 'operated' lamp 9) Break Glass manual release (10) Remote indiacation box (11) Pressure Switch (12) Direction valve (13) System actuator (14) Pneumatic heat detector (15) Control head (16) Release head.

Fig-56 Halon Modular Total Flooding System protecting electronic data processing equipment and tape storage rooms

7.5.12. HALON ALTERNATIVE EXTINGUISHING SYSTEMS / INSTALLATIONS

7.5.12.1. 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 has been posing several challenges and problems for the 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 vapourise readily and leave no residue. 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:

- Hydrobromofluorocarbons(HBFC);
- Hydrofluorocarbons(HFC);
- Hydrochloroflurocarbons(HCFC);
- Perfluorocarbons(FC or PFC); and
- Fluoroiodocarbons(FIC)

Their common characteristics are:

- Electrical non-conductivity;
- Are clean agents which vapourise readily leaving no residue;
- Are liquefied gases;
- Can be stored and discharged from typical Halon 1301 hardware(except HFC 23);
- All use nitrogen super pressurisation 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:

(i) Inergen - IG - 541(mixture of N_2 52%, Argon(A) 40% and CO_2 8%

(ii) Argonite - IG - 55 (mixture of N_2 50% and A 50% and

(iii) Argon - IG 01 (A) 100%

(iv) Nitrogen - 100%

These are clean agents stored as pressurised gases and, hence, require substantially greater storage volume. They are electrically non-conductive, form stable mixtures in air, and leave no residue.

7.5.12.2. 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, ie., by inhibition of free radicals, or breaking chain reaction. Other replacement agents primarily extinguish the fires reducing the flame temperature by a combination of heat of vapourisation, 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

7.5.12.3. (a)Table-1 showing the New Technology Halon Alternatives, as given in one HTOC document is reproduced overleaf:

(b) Table-2 showing the physical properties of Halocarbon Gaseous Agents for Fixed Systems is given in page 154.

Table-I New Technology Halon Alternatives

Table-2 - Physical Properties

Total Flooding Gaseous Alternatives	
Halocarbons	**Composition**
HCFC:	HCFC Blend A, HCFC 124
HFC:	HFC-23, HFC-125, HFC-227ea, HFC-236fa
PFC:	FC-3-1-10, FC-2-1-8
FIC:	FIC-13I1
Inert Gases	
Nitogen:	IG-10
Argon:	IG-01
Nitrogen/argon blend:	IG-55
Nitrogen/argon/CO2 blend:	IG-541
Water Mist Technologies	**Manufacturer**
Single Fluid, Low/Moderate Pressure (3 - < 50 bar)	Grinnell, Kidde, GW Sprinkler, and Total Walther
Single Fluid, High Pressure (> 50 bar)	Marioff, Reliable, Ultra Fog, Semco, and Unifog
Dual Fluid Systems	Securiplex, ADA Technologies, Kidde and Ginge Kerr (BP)
Flashing Liquid Systems	MicroMist Ltd.
Inert Gas Generators	**Manufacturer**
	ICI and Primex
Fine Particulate Aerosols	**Manufacturer**
	Kidde, Powsus, Spectrex, Russian Research Institute for Applied Chemistry, Soyz Association, Intertexnolog Assoc., and Dynamit-Nobel
Streaming Agents	**Composition**
HCFC:	HCFC Blend B, HCFC Blend E, HCFC-124
HFC:	HFC: HFC-227ea, HFC-236fa
PFC:	PFC: FC-5-1-14

Table-2

Physical Properties - Halocarbon Gaseous Agents

Generic Name	Trade Name	Chemical Composition		Group	Stored Agent State	Vapour pressure bars @ 20° C	k1, m^3/kg (9)	k2, $m^3/kg/deg$ C (9)	Vapour Density @ 20° C (kg/m^3)	Liquid Density @ 20° C (kg/m^3)
Halon 1301	BTM	CF_3Br		Halon	LCG*	12.90	0.1478	0.00057	6.283	1,572
HCFC Blend A	NAF S-III	Component	Weight %	HCFC	LCG*: 91.5% LIQ**: 8.5%	8.30	0.2413	0.00088	3.862	1,200
(HCFC-22)		$CHClF_2$	82%							
(HCFC-124)		$CHClFCF_3$	9.50%							
(HCFC-123)		$CHCl_2CF_3$	4.75%							
(isopro penyl-1-methyl-cyclohexane)		$C_{10}H_{16}$	3.75%							
HCFC-124	FE-24	$CHClFCF_3$		HCFC	LCG*	3.30	0.1575	0.00066	5.858	1,373
HFC-23	FE-13	CHF_3		HFC	LCG*	41.83	0.3164	0.00122	2.934	807
HFC-125	FE-25	CF_3CHF_2		HFC	LCG*	12.10	0.1825	0.00073	5.074	1,218
HFC-227ea	FM-200	CF_3CHFCF_3		HFC	LCG*	3.91	0.1269	0.00052	7.283	1,407
HFC-236fa	FE-36	$CF_3CH_2CF_3$		HFC	LCG*	2.30	0.1413	0.00057	6.549	1,377
FC-2-1-8	CEA-308	$CF_3CF_2CF_3$		PFC	LCG*	7.92	0.1171	0.00047	7.904	1,320
FC-3-1-10	CEA-410	C_4F_{10}		PFC	LCG*	2.84	0.0941	0.00034	9.911	1,517
FIC-13I1	Triodide	CF_3I		FIC	LCG*	4.65	0.1138	0.00050	8.078	2,096

LCG* = Liquified Compressed Gas

LIQ** = Liquid

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(c) Table-3 showing Minimum Extinguishing Concentrating and Agent Exposure Limits of Halocarbon Gaseous Agents is given below:

Table-3

Minimum Extinguishing Concentrations- Halocarbon Gaseous Agents

Generic Name	Trade Name	Heptane Extinguishing Concentration vol% (1)	Minimum Class B Fire Design Conc. vol% (1)	Inerting Methane/Air Design Conc. vol%	NOAEL vol% (2)	LOAEL vol% (2)
Halon 1301	BTM	3.2	5.0	4.9	5	7.5
HCFC Blend A	NAF S-III	9.9	12.0	20.1	10	>10
HCFC-124	FE-24	6.7	8.0	Not Reported	1	2.5
HFC-23	FE-13	12.5	18.0	22.2	50	<50
HFC-125	FE-25	8.1	9.7	Not Reported	7.5	10
HFC-227ea	FM-200	6.6	7.9	8.8	9	10.5
HFC-236fa	FE-36	6.1	7.3	Not Reported	10	15
FC-2-1-8	CEA-308	7.3	8.8	9.8	30	>30
FC-3-1-10	CEA-410	5.9	7.1	8.6	40	>40
FIC-13I1	Triodide	3.0	3.6	7.15 propane	0.2	0.4

(d) Toxicity: 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).

For Halocarbon agents, these levels are usually driven by the cardio-sensitisation level of the agent. It has been recommended that Halon replacement agents should not normally be used at concentrations above the NOAEL in occupied areas. Use of agents upto the LOAEL has been permitted in occupied areas if adequate time delays and pre-discharge alarms are provided and time required for escape was short(HTOC). New recommendations are under proposal:

(e) Environmental Factors: (i) As far as Halon Alternative Clean Agents are concerned, the primary environmental factors to be considered are:

- Ozone Depletion Potential(ODP);
- Global Warming Potential(GWP); and
- Atmospheric Life Time (ALT)

(ii) 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.

(iii) Table 4 showing the Environmental Factors for the Halocarbon Gasceous Agents, and Table-5 showing the Toxicity, Storage and the Environmental Factors for INERT Gases are shown at pages 158 & 159 respectively.

(f) 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:

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

Table-5 - Inert Gases

Generic Name	IG-541	IG-55	IG-01	IG-100
Trade name	Inergen	Argonite	Argotec	NN100
Agent exposure limits				
Max unrestricted agent concentration, vol% (2)	42.8	42.8	42.8	42.8
Max restricted agent concentration, vol% (3)	52.3	52.3	52.3	52.3
Other				
In Relation to Halon 1301				
Mass Required (Class A)	2.2	2	2.8	2
Cylinder Storage Vol.	~10 (5)	~10 (5)	~10 (5)	~10 (5)
Environmental factors				
Ozone depletion potential	0	0	0	0
Global warming potential, 100 yr.	n/a	n/a	n/a	n/a
Atmospheric Life Time, yrs.	n/a	n/a	n/a	n/a
System Features				
Nominal Discharge Time, seconds	60	60	60	60
Cylinder pressure, bar	150 or 200	150 or 200	180	180 or 240

- 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.

7.5.12.4. Explosion Inerting:

(a) Explosion inertion is an important application area of total flooding fire suppressants. The inerting concentration of an agent is the concentration required to prevent unwanted pressure increases in a premixed fuel/air/agent mixture subjected to an ignition source.

(b) Explosion suppression systems employ rapid delivery of the agent following very early detection of an ignition. Such systems employ significantly higher agent quantities (than flame suppression or inertion) delivered at higher rates. The total agent delivery time is on the order of 1min. Suppression of detonations requires substantially higher agent concentrations

7.5.12.5. Clean Agent System Design:

(a) Detection and Actuation System is a critical and integral part of a clean agent system design. The detection system should be designed to actuate the system, with appropriate predischarge alarms. This is particularly important, since thermal decomposition products of halocarbon clean agents are a concern.

(b) The enclosure's integrity should be sufficient to prevent (i) preferential agent loss during discharge, and (ii) excessive agent /air mixture loss after discharge to ensure adequate hold time.

(c) All openings, including doors, ventilators etc. must be secured prior to discharge, in conjunction with the detection and alarm system. System installation in rooms with unenclosable openings should not be attempted with these agents

(d) Minimum design concentrations for Halon 1301 were set by the cup burner extinguishing concentration plus a 20% safety factor. A minimum Halon 1301 design concentration of 5% was also established for all applications.

(e) In so far as clean agents are concerned, the minimum extinguishing concentrations as determined by the cup burner method must be established. Following this by the system manufacturer, full-scale third party approval testing should be conducted using the manufacturer's hardware on n-heptane, wood crib, and selected flammable liquids. Details of these tests will be available in relevant standards.

(f) It is gathered that consideration is being given to the need for raising the safety factor from 20% to 30%. The move for increasing the safety factor to 30% resulted from a combination of theoretical analysis and fire testing.

(g) The use of Halon alternative agents must be consistent with applicable environmental regulations.

(h) The selection of an agent should be made on its fire performance characteristics, agent and system space and weight concerns, toxicity(particularly for use in unoccupied areas) and the availability of approved system hardware.

(i) In the background of relative lack of experience with systems employing these new agents, extreme care and attention should be given in the selection of system, and aspects like design, installation, inspection, testing and maintenance of the systems.

7.6. GRAPHIC SYMBOLS FOR FIRE PROTECTION PLANS:

7.6.1. While making out Fire Protection Plan Drawings certain stan dard graphic symbols are required to be used for identifications of various fire protection equipment and systems recommended for incorporation in the Fire Protection Plans of the premises concerned. All those concerned with the design, construction of buildings and installation inspection and maintenance of the fire protection systems and equipment and the implementation of the Plan in its entirety are required to be well conversant with these symbols. These graphic symbols, as stipulated in IS:12407-1988, “Graphic Symbols for Fire Protection Plans”, are reproduced at Annex I for information and guidance.

7.7. FIRE PROTECTION - SAFETY SIGNS

Safety signs pertaining to fire protection/means of exit have come to be universally accepted and adopted as international standards, particularly in the Tourism leisure (Hotels) and Aviation Industries. These have come to be adopted for Assembly buildings like Cinema Theatres, Auditoriums etc., IS 12349-1988, “Fire Protection-Safety Signs” is also reproduced at Annex J, for information and guidance.

■

CHAPTER -5- FIRST AID FIRE FIGHTING EQUIPMENT

8.1 General

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

(b) In the 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.

(c) Portable fire extinguishers are specially designed for the purpose of tackling fires in their incipient stage, and they are now very commonly used for the same purpose. Infact, they are now considered as the first line of defence in fire fighting operations, and has assumed the front position among the fire protection measures for all types of occupancies as well as fire risks.

(d) 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.

(e) Apart from portable extinguishers, which are of comparatively smaller size, there are bigger size of extinguishers which are trolley-mounted and could be pulled to the desired spot. These bigger sizes of extinguishers also come under the broad term of first aid fire fighting equipment.

8.2 Types of Extinguishers:

(a) Portable fire extinguishers can be divided into 5 categories according to the extinguishing agent they contain:

(i) Water type extinguishers;
(ii) Foam extinguishers;
(iii) Dry powder extinguishers;
(iv) CO_2 extinguishers; and
(v) Halon / Halon alternative type extinguishers.

(b) They can also be grouped into categories according to their method of operation. Extinguishers can be operated by the use of air or gas pressure in the upper part of the container, which forces the extinguishing medium out through a nozzle. They can also be operated using a cartridge containing an inert gas (normally CO_2) under pressure. When the cartridge is pierced, the gas which comes out of the cartridge drives out the extinguishing medium. In other types, the pressurising agent (air or inert gas) is stored inside the upper portion of the extinguisher itself, and therefore the body of the extinguisher remains permanently pressurised. 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.

(c) Water(gas cartridge) type extinguisher:

(i) In this pressure is released from a cartridge which is stored inside the body of the extinguisher. The cartridge is pressurised with CO_2 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.

(ii) The liquid capacity of the extinguisher, when filled to the specified level, is 9 litres.

(iii) 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.

(iv) On operation, the water jet should give an effective throw of not less than 6m for a minimum period of 60 sec., and at least 95 % of water in the extinguisher should be discharged.

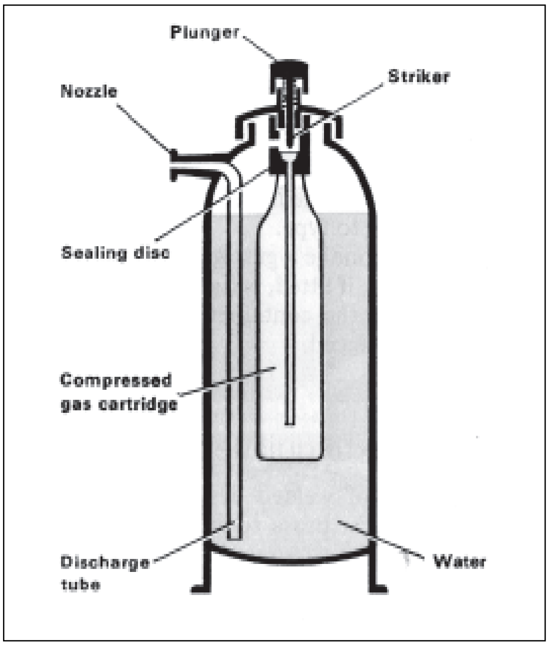

Fig-57 Water(Gas Cartridge) type extinguisher

(d) Water(Stored Pressure) Extinguisher:

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

(ii) Operation is performed by withdrawing the safety pin, depressing the valve lever and directing the water jet by means of the hose.

(iii) As this type of extinguisher is permenantly pressurised, it can only be opened for inspection after discharged.

(iv) The normal capacity of this extinguisher is also 9 litres.

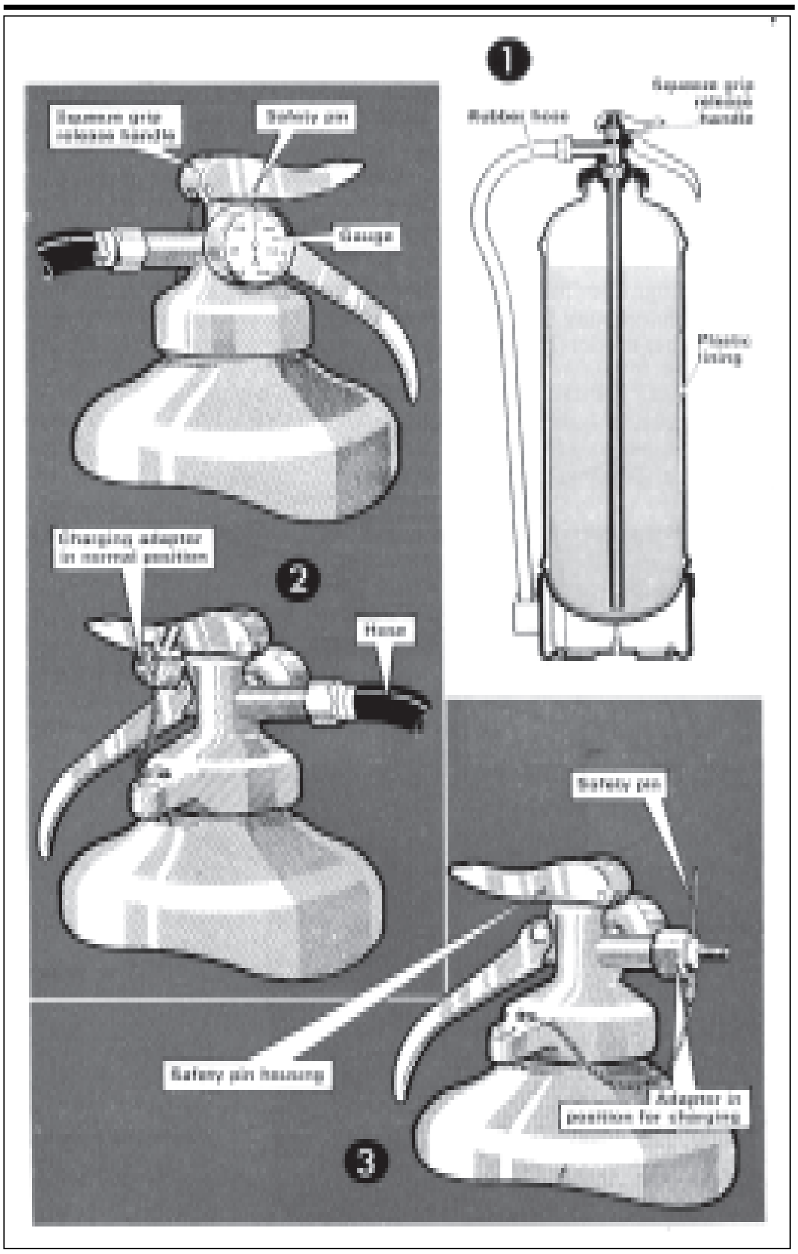

Fig-58 Water(Stored Pressure) type extinguisher

(e) Mechanical Foam Extinguisher (9 L):

(i) The extinguisher is filled with pre-mixed foam solution(AFFF)

(ii) Foam extinguisher can either be of the stored pressure type, or gas cartridge type.

(iii) The operation of these types is similar to what has been stated under the water type extinguishers.

(iv) The figures of the two types are shown below:

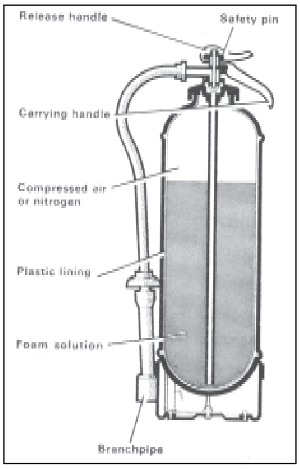

Fig-59-A Mechanical Foam Extinguisher (Stored Pressure Type)

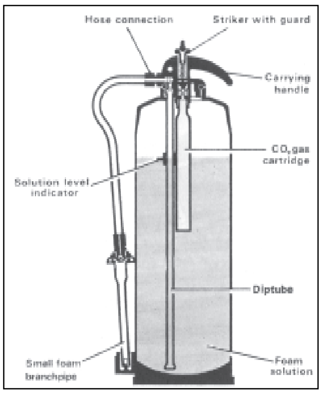

Fig-59-B Mechanical Foam Extinguisher (Gas CartridgeType)

Fig-60 Method of Operation of Foam Extinguisher

(f) Dry Powder Extinguisher:

(i) 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.

(ii) As already stated under Extinguishing Media chapter, 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.

(iii) Dry Powder Extinguisher(stored pressure type): 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 overleaf:

Capacity of Fire Extinguisher kg	Minimum Period Which Throw of Jet Will be Maintained s	Maximum Period Discharge at Least 85 % of Contents s	Range or throw of Jet m
0.5	5	8	Not less than 1.5
1 and 2	6	12	Not less than 4
5 and 10	15	25	Not less than 4

1) From nozzle to centre of pattern of discharge.

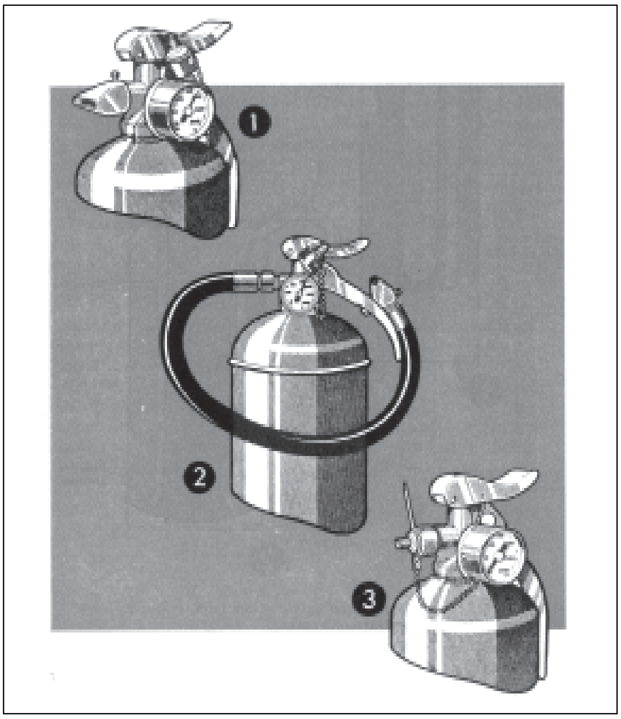

Fig-61-A Dry Powder Extinguisher(Stored Pressue) type

(iv) Dry 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.

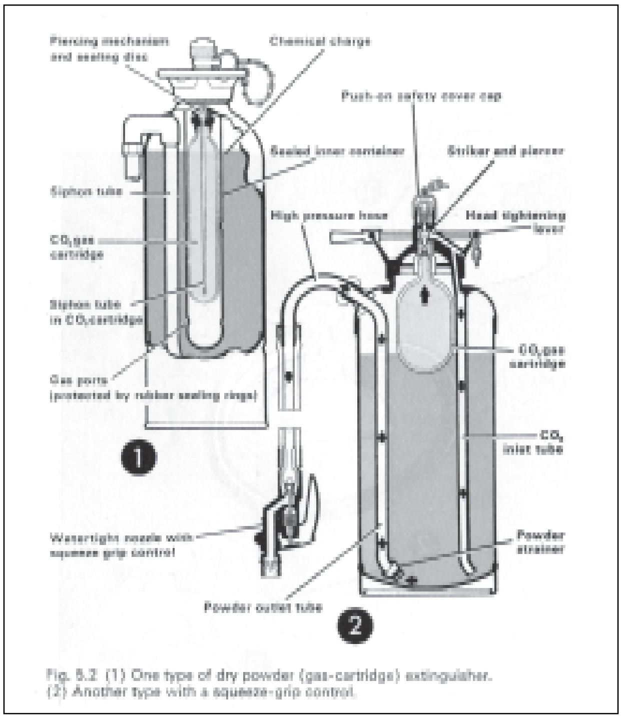

Fig-61-B Dry Powder Extinguisher(Gas Cartridge) - two types

(g) CO_2 Extinguisher: The main features of this extinguisher are:

- It consists basically of a high pressure cylinder;
- The 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 etc. of various types are given overleaf:

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

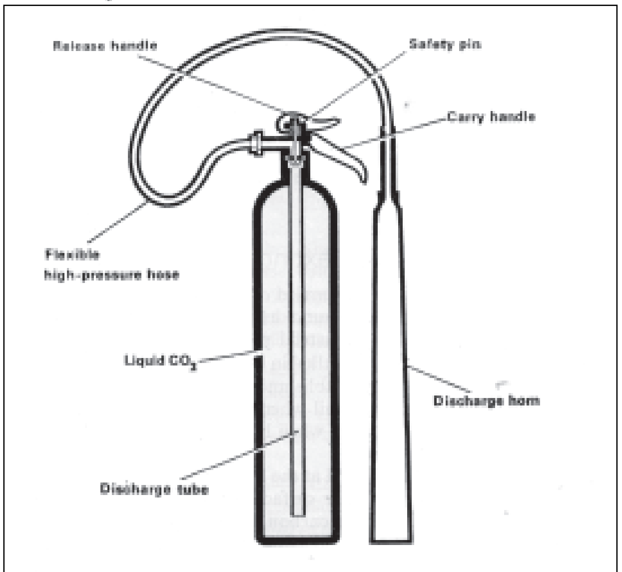

Fig. 7.1 A carbon dioxide extinguisher showing the piercing mechanism, control valve and discharge horn.

Fig-62 CO_2 Extinguisher

Hazards of CO_2 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

(vi) Halon Extinguishers:

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

(vii) Soda Acid & Chemical Foam Extinguishers have already been phased out, and their IS withdrawn.

8.3. Selection and Installation of Extinguishers:

8.3.1.The most important considerations while selecting extinguishers are the nature of the area to be protected, and the nature of the hazard involved. 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.

8.3.2. Detailed instructions regarding selection, installation and maintenance of first-aid fire extinguishers are contained in IS:2190 - 1992 (which is under revision). It is essential that all users (at least organisations) should be quite familiar with these instructions, so that maximum advantage can be gained for promotion of fire safety standards for their own benefit.

8.4. Inspection and Maintenance of Fire Extinguishers:

8.4.1. An inspection is a quick check that visually determinds that the fire extinguisher is properly placed and will operate

8.4.2. 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 repressurising the extinguisher, where necessary.

8.4.3. Detailed instructions regarding periodical maintenance, hydrostatic pressure testing, and refilling of extinguishers are given in IS:2190-1992 which should be scrupulously followed.

■

SECTION 5 - BUILDING FIRE HAZARDS

9.

9.1. General

Building, whether used for living, working, or for other purposes, forms an integral and major constituent of human habitat. Based on occupancy, buildings come under one or the other of the following general classifications - Residential, Educational, Institutional, Assembly, Business, Mercantile, Industrial, Storage and Hazardous.

As a sequel to the all round socio-economic progress our country has been making, there had been enormous increase in the number of buildings of all classifications, including high-rise buildings, especially in the urban areas. With the technological advance on all fronts, not only the factor of susceptibility but the complexity of fires, explosions and other hazards which these 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 services in evolving better and improved methods of design and fire protection in order to mitigate such losses.

Any laxity in the control of these hazards in the buildings can lead to mass disasters.

9.2. Fire hazards in buildings: An overview

Right from the history of mankind, fire has been a constant threat to human habitations and instances are several when cities or a major part of them had been raced to the ground by conflagrations. Some of these disastrous fires during the last few centuries like:

- The Great Fire of London in 1666,
- Great Fire of New Orleans in 1788,
- The Great Bombay Fire in 1803,
- The Great New York Fire in 1835,
- Sansfransico Fire in 1851,
- Chicago Fire in Oct . 1871. etc.,

are well known, not only for the immense loss of life and destruction of property they had caused to mankind, but also for the fact that they eventually led to the origin of the metropolitan fire services in these cities.

The susceptibility of buildings to fire depends on several factors like:

- Type and size of building,
- method of construction,
- combustibility of materials of construction,
- the type of occupancy,
- age of the building,
- degree of fire resistance,
- the type of building services,
- 'fire load' of the building,
- fire prevention, and fire protection arrangements of the building,
- and scores of others, including **the human factor**. However, for purposes of analysis of the various fire hazards in buildings it is common to divide these hazards into:

(i) Internal hazards- which arise inside the building and which concern the safety of the occupants (**Personal Hazard** or more widely known as **Life Hazard**): and which concerns the safety of the structure and the contents; and

(ii) External hazards - which arise as a result of fires in surrounding property (**Exposure Hazard**)

The relative degree of each of these hazards will vary according to the type of occupancy of the building - An Assembly occupancy will be having predominently life hazards, whereas a Storage occupancy will have primarily a damage hazard, ie., hazard to the structure and contents.

9.3 Relationship of Building Fire Hazards with Life Safety:

The most important of these hazards which deserves the highest consideration is the **life hazard**, as everybody's concern is to save and protect lives from fires. As a fire develops, smoke, heat and toxic gases build up over time to create an environment leading to a critical level when survival of life becomes impossible. The lead time for this can be very short, and will vary according to the material on fire, the combustion products produced, and the physical and mental characteristics of the exposed individuals which govern their endurance to withstand the adverse environments.

It has been seen that such untenable conditions can develop in a room fire within an incredibly short time of two to three minutes, If unchecked. Therefore, it is this short interval of time, and more precisely, the interval between detection and the critical level of human survical, that is available to the occupants for effecting escape, or for taking some action to overcome the fire. This is the reason why lot of emphasis is laid on the need for early detection of fire conditions especially when life hazard is involved.

9.4. Toxic Hazards from Fire

It has been the experience that the primary hazard to humans in a building fire is from smoke and toxic gases. Nearly three-fourths of all building related fire deaths are from inhalation of the smoke and toxic gases produced in fires rather than from exposure to flame or heat. Many new materials used in building construction, like different kinds of plastic materials, are the worst culprits in production of highly toxic gases such as carbon monoxide (which is produced even during fires involving conventional materials), hydrogen cyanide, sulfur dioxide, hydrogen chloride, oxides of Nitrogen, etc. Death can result from oxygen deprivation in the blood stream caused by replacement of oxygen (02) in the blood haemoglobin by CO - The latter can combine with haemoglobin at a rate of about 210 times more readily than does O2 - The danger is enhanced by evolution of large quantities of carbon-di-oxide (Co2) which contributes to increased breathing rates. A concentration of CO of approx. 5000 ppm (0.5%) can be fatal in 2 to 3 mins, and 10,000 ppm (1%) in about 1 minute! In a confined smouldering fire more quantities of CO are likely to be present as compared to a freely burning fire in a well ventilated room.

Hazards of Smoke:

The main danger from smoke is that it reduces visibility and consequently the occupant may not be able to identify escape routes and utilise them. Many people find it difficult to move about if the visibility is reduced by smoke to say 10m. It has been shown from full scale room fire tests conducted by NBS, for determining smoke density and CO, levels, that the smoke density (OD/M) at 1.5 m level rose from 0.2 at 200 sec. to 1.2 at 215 sec. with fir plywood **as compared to a smoke density level of 0.043 OD/M prescribed for escape routes**, and the production of CO rose from 1% at 160 sec. to approx. 4% at 200 sec., and 6% at 390 sec. (as compared to the TLV of 100 ppm or .001%). The thermal products of combustion account for nearly 25% of fire deaths. In addition, burn injuries, which far outnumber the fatalities, can not only cause pain and disfigurement, but may result in serious, long-term complications also.

9.6 Fire and Damage Hazards to the Building:

The other internal hazard arising from fires within the building is the damage hazard or the hazard to the building structure and contents. Many factors can have a bearing on this form of internal hazard such as:

- The type of building construction,
- Fire resistance of the elements of structure,
- Combustibility of materials of construction,
- Unbroken large spaces,
- Fire load of the building,
- Open vertical and horizontal shafts,
- Bad house-keeping and storage practices,
- Unsafe processes,
- Non-availability of fire doors and other types of fire barriers
- Inadequate fire fighting/fire protection measures,
- Unsafe building services,
- Unfavourable human elements etc.

Here again, you will find that the damage hazard will largely depend on the type of occupancy, and can vary from low hazard in office or business premises to high hazard in storage or hazardous occupancies. Many of the fire outbreaks have been attributed to acts of omission or commission by humans. Although it will be beyond the scope of this Handbook to go into the details of each one of these factors, a few among them, are being highlighted here, which have been proving as serious threats to fire safety of buildings.

Unbroken large spaces, especially for Industrial occupancies, had been the cause of serious fires in the past. The internal subdivision of a building into compartments predetermines the escape arrangements as well as the fire spread. In an uncompartmented building the whole of the occupants and the contents of the building have to be considered at risk in the event of fire. A few serious fire outbreaks which are glaring examples of this lapse are:

(i) General Motors, Livonia, fire in August 1953, which had an undi vided area of approx. 1.5 million sq. ft. besides a bituminous roof - The building was classified as non-combustible-Loss $50 m.

(ii) Jaguar Car Coy., Coventry, U.K.on 12th Feb. ‘57

(iii) Mc Cormick Place, Chicago on 16 Jan. ‘67, which was used as an Exhibition Hall - Loss $ 52.5 m.

(iv) Boston Grocery Warehouse on 5 Aug. ‘69 with an undivided area of 11 acres - Loss $ 15m.

It is not hard to find this type of construction in some of our factories also. For instance, an important defence production establishment has an unbroken area of 11 across under one single roof!

Even in buildings where care has been taken to divide such large areas into compartments, the danger of fire spread can still be there because of **open doors, unenclosed stairways and shafts, unprotected penetrations of fire barriers, and non-fire stopped combustible concealed spaces.**

The last named, namely **concealed spaces,** had been responsible for a good no: of large loss fires. Buildings may have a wide variety of concealed spaces above false ceilings, under floors, behind walls, in utility chases etc., Fires in such concealed spaces are seldom promptly detected and are difficult to handle when once detected. Vertical concealed spaces, like **service shafts,** can act as a flue in spreading fire and hot gases. In one of the tests conducted at Brooklyn, New York, temperatures in excess of 815^{o}C were recorded at the top of a 10 m. shaft after 1 min. of starting of a fire at the bottom. Similarly, movement of flame through a non combustible ceil-ing plenum space was supposed to be the cause of horizontal spread of fire in New York Plaza fire.

9.7. Fire Hazards from Building Contents

Outbreak of fire is more to be expected to originate in the contents of the building rather than the structure itself. The degree of hazard is usually determined by the combustion characteristics of the contents, the fire load and the types of processes or operations conducted in the building. The hazard of the contents will also govern the rate of spread of fire, the smoke propagation, as well as the possibility of explosion.

9.8. Fire Load and Fire Effects

Fire load in a building has a significant influence in severity and duration of a fire. In a normal building the fire load includes the combustible contents, interior finish and elements of construction. **Fire load is a measure of the maximum heat that would be released if all the combustibles in a fire area burned.** But it is now proved that fire load as a sole determinant of fire severity of damage potential is wrong, as prevailing ventilation also plays a significant role in determining the fire behaviour. The present view, as pointed out by Dr. Badami [Founder & Head of Fire Research Division CBRI, Roorkee], in one of his articles, is that the fire severity and, therefore, the fire damage that may be expected, are influenced by 3 independent factors of the fire during its fully-developed period, viz., (i) duration (2) average temperature, and (3) effective heat flux. These factors are mainly governed by the fire load and ventilation. In well ventilated buildings with large windows, the fire burns readily and very high temperatures are created. **The duration and severity of fire mainly depends on ventilation and fire load.**

9.9. Exposure Hazard

Exposure hazard is an external fire hazard which a building is exposed to, since a building on fire can cause a fire hazard to other adjoining buildings or structures by exposing them to heat by radiation, convective currents, or to the danger from flying brands of the fire. The explosion hazard can also be from adjoining open storage yards. The degree of exposure hazard will depend on many factors like:

- Separation distances,
- Severity of the fire,
- Combustibility of exterior walls,
- The type and extent of fixed fire protection systems installed, if any,
- Wind direction,

- Width and height of exposing fire,
- openings in exposing wall, etc.

The exposure hazard has a direct relationship with fire spread, and can be instrumental in turning single building fire into a conflagration, given the required conditions.

9.10. Hazards from Interior Finish

As stated earlier, I**nterior finish is one of the three principal elements' which determine the fire hazard potential of a building.** This generally consists of those materials or combinations of materials that form the exposed interior surfaces of walls and ceilings. The materials used for interior finish in modern buildings are numerous, including a variety of wall coverings, the most commonly used being different kinds of plastics. This has been responsible for rapid fire spread and contributing to some of the worst fires. In countries like U.S. and U.K., regulations exist to check the indiscriminate use of cellular or foamed or other dangerous plastic materials for interior finish. Interior finish plays an important role in the occurrence of **"flash-over"**. This phenomenon is caused by thermal radiation feed-back from the ceiling and upper walls heated by the fire, which gradually heats the contents of the fire area. When all the combustibles in the space have become heated to their ignition temperatures, simultaneous ignition of all the contents occurs, and the fire becomes a fully developed one. Combustible interior finish was found to be the main cause for the tragic fire outbreaks in:

- Joelma Bldg. Sao Paulo in Feb. '74,
- Coconut Grove Night Club, Boston, inNov. '42;
- Beverley Hills Supper Club, Kentucky, in May '77;
- and most typical of all, the Stardust Disco, Dublin, fire in 1981, all of which took a heavy toll of lives.

9.11. Hazards from Building Services

Building services include:

- Electrical installations,
- Heating,
- Ventilation,
- Air conditioning,

- Refuse disposal,
- Plumbing,
- Communications,
- Transportation and conveyance systems.

Unless these services and utilities are properly designed and installed, they can lead to fire outbreaks in buildings, or cause fire and smoke spread, and even hamper fire control and evacuation operations. Realising their potential hazards and also their utility, designers prefer to adopt a carefully planned and integrated system of building services which can reduce the fire hazards to the minimum, and also help in mitigation of the fire effects. It is the vertical and other shafts, which are used for passing these services through floors, walls or other partitions, which are often neglected from fire protection point of view, and which present considerable fire hazards. It has been found that although the fire itself may be confined to the compartment of origin, it is extremely difficult to prevent spread of heat, smoke and gas beyond the compartment through the air conditioning system. There have been several fire incidents to bear out this point. The New York Hilton Hotel fire in Dec. '65 is one case, where the fire had originated in the 2nd floor, but smoke and gases spread through the A/c system upto the 28th floor, forcing evacuation of all the 3000 occupants of the building below the 29th floor. The State Bank of India, Bombay, fire in Jan. '72 is yet another case.

9.12. Explosion Hazards in Buildings

Explosion hazards in buildings are mostly associated with industrial or hazardous occupancies, especially in plants handling or processing flammable gases/ chemicals or explosive substances, including dusts. They can cause devastating damage, death and destruction. They may or may not be accompanied by fire damage, although fire is a principal cause of accidents involving explosive materials. Explosions are probably the most destructive industrial accidents (the Flix Borough Plant explosion and fire on 1st Jan. 1974 is a unique instance as illustration) calling for the most carefully planned and designed explosion damage control measures. Explosion protection systems, in addition to explosion prevention measures, should be considered for equipment, housings, rooms and buildings associated with manufacture, handling, processing and storage of such materials which have an explosion potential.

9.13. Hazards from Building Collapses

Besides fire and explosion hazards, another very important hazard which buildings are subjected to is the likelihood of collapse of a structure due to various reasons like old age of the building, effects of blast or strong winds, earthquake, or due to fire or explosion effects. The collapse of structural building elements can be a serious hazard to occupants and have often caused large number of casualties of persons inside, as well as to fire fighters during fire fighting and rescue operations. In our country there had been number of collapses of buildings in the recent past, some of which are enumerated hereunder:

1) August '83- Akashdeep multi-storyed bldg. Bombay collapsed in which over 20 died and rescue operations went on for 2 weeks or so. One of the reasons for the collapse, besides the building being old, was its nearness to railway track and possible consequent structural instability caused due to vibration during frequent rail movements.

2. Sept.12, '83-Bangalore - Residential building collapsed in which the number of persons who died were as high as 114. It was a 9 -storey building, and rescue work continued for one month!

3. Aug. 13, '85-The worst ever house collapse in Bombay - Killing 43 people, including 18 children. Fire brigade rescued 100 people (35 injured). 45 who died were living on the 2 upper storeys of the 80 year old building, and ground floor was occupied as shops and presses. The building was surveyed only 3 weeks earlier, and passed. The cause of the collapse had been surmised as the walls getting weakened over the years by constant vibrations caused by power looms located immediately behind.

4. In Surat on 9-7-1981, a four storeyed RCC building - housing Shantinath Silk Mills collapsed following a boiler explosion. Nearly 200 firemen, helped by many other workers, toiled for many days in the rescue work. 98 dead bodies were recovered and 105 injured casualties were rescued within 5 days.

5. 15-10-85 - Roof collapse of the auditorium in Dhaka - Bangladesh - At least 74 died and 28 injured, mostly students, who were watching a night TV programme.

6. 14-12-91 - Surat - Mukesh Dyeing Mills fire followed by building collapse (Night) - 3 dimensional fire due to leaking oil from a boiler - 20 Firemen, including a Fire Officer and 2 others got killed.

7. 29-6-95. S. Korea - A 5 storey Dept. Store, crowded with shoppers collapsed. killing over 100 & injuring nearly 1000. Over 900 were treated in hopitals. Rescue work hampered due to lack of equipment.

9.14:Arson and Incendiarism

The cases of building fires and explosions deliberately caused by miscreants have been on the increase the world over. In fact, in the developed countries, this has been showing an alarming rising trend causing great concern to all. It is gathered that the fire protection experts of these countries will be meeting soon in the one of the European countries for discussing this problem.

9.15. Fire Hazards during Building Construction

During building constructions also the fire hazards are predominant, particularly because of the fact that hardly any fire prevention measures are observed during this stage by the contractor and their workers. Besides, the management also seldom ensures proper observance of the fire protection measures during construction work. There are provisions in the National Building Code and some of the municipal Building Bye-laws which make it incumbent on the contractor to observe fire safety precautions and to appoint a fully trained official who should be present at the work spot throughout for ensuring compliance with all fire safety measures.Detailed guidelines on this are given in NBC part 7, Constructional Practices and Safety.

9.16. NBC Part-4 Provisions

Detailed guidelines and norms regarding types of building construction, structural fire protection requirements, fire zoning, exit requirements, fire safety and fire protection requirements in general, as well as for all the nine different types of occupancies, special fire safety and fire protection requirements for multi-storey buildings (above 15 in. ht.), guidelines for selection of fire detectors, fire protection considerations for venting in industrial buildings, and the guidelines for fire drill and evacuation procedures for high-rise buildings, are given in Part IV of the NBC. However, they should be recognised only as minimum requirements consistent with reasonable public safety, but not necessarily as criteria for complete safety or ideal conditions.

9.17. Need for an Integrated Approach on Fire Safety

In the present days, it is perhaps impractical to totally eliminate all fire hazards from buildings, and thus bring about optimum fire safety, However, it is possible to relate the use and amount of combustibles to a common datum in an attempt to balance the fire risks among different types of building construction and different occupancies. While formulating a fire protection scheme for any premises, it will be necessary to have an **integrated approach** to the problem starting right from the design stage, thereby ensuring that adequate and suitable fire protection measures, both active and passive, are incorporated while finalising the design of the occupancy. It has to be borne in mind that the ability of the fire service to contain or extinguish a fire is considerably reduced if the fire spread is faster than it could be controlled effectively, because of lack of proper fire safety design and constructions of the building.

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SECTION 6 - LIFE HAZARDS IN BUILDINGS AND MEANS OF ESCAPE / EGRESS / EXIT

10.1. Fire and Life Safety

A building on fire poses a life hazard problem to the occupants of the building, which has potential to develop into a major life loss catastrophe, due to several reasons, including inadequate fire and life safety measures incorporated in the building.

As a fire develops in a building, smoke and heat build up to create an environment which is dangerous to life. The progress of the deterioration of the environment is beyond prediction, since there are great many variables involved, many of which are beyond control. Most fires develop slowly at first when conditions of human survival are comparatively safe. However, depending upon the nature of the fire and the surroundings, the intensity of the fire increases sharply creating serious survival problems.

When the products of combustion reach a certain level of accumulation, the fire will be detected, either by persons around or by automatic fire detectors.

As mentioned earlier, when the environment deterioration reaches the critical level, life hazards to occupants in the building assume serious proportions. The interval of the time between detection and criticality is the time available to undertake or initiate life saving measures. These measures may include various actions like activation of manual or automatic equipment for fire fire suppression , or evacuation of occupants.

10.2. Factors affecting Life Safety of Occupants.

The most difficult component of life safety to evaluate is the occupant population at risk in the building and, therefore their susceptibility to fire and fire products are to be assessed correctly to evolve a safe evacuation plan for them. The characteristics of the building occupants to be taken into account are their age, mobility (including physical handicaps, disability, illness etc.), alertness or awareness (which may be influenced by alcohol and narcotics, or whether they are awake or asleep), familiarity with the lay out of the premises, their standard of training in evacuation drills, occupant density in the premises, and their amenability to disciplinary control.

Regular occupants of a particular building are likely to have better familiarity and knowledge about the premises as against casual or transient visitors to the building. Occupant density in the building is also quite relevant due to the fact greater the number of people in a given area, greater is the potential loss of life. Studies have shown the relationship of occupant density with speed of movement in case of forced evacuation, which may lead to panic conditions

Any uncertainty as to the location or adequacy of means of egress, the presence of smoke or fumes and the stoppage of travel towards the exit, such as may occur when one person stumbles and falls on stairs, may be conducive to panic. Danger from panic is greater when a large number of people are trapped in a confined area.

10.3. Nature of Fire in Buildings

Every building shall be so constructed, equipped, maintained and operated as to avoid undue danger to life and safety of the occupants from fire, smoke , fumes or panic during the survival time available for escape.

10.4. Growth and Spread of Fire and Smoke

The fire growth stage is the most important to life safety. It is in this stage that the space or room of fire origin eventually becomes uninhabitable, making human survival difficult. It is for this reason that fire detection and action to protect or rescue the occupants have to be speedily initiated during this stage itself. Materials burning near a wall will have a faster rate of fire growth than materials burning in the centre of the room. This is because of the re-radiation from the heated walls to back to the burning fuel.

When a fire spreads across the ceiling heat build up throughout the room becomes faster, eventually leading to 'flashover'. Occupants survivability becomes impossible at this point. The spread of smoke and fire to the other parts of the building exposes the occupants in these areas also to survival problems. Building features such as vertical shafts, ducts, plenums, void spaces and even windows can all contribute to spread of fire and smoke. Large complex structures such as multi-storeyed shopping malls, atrium buildings etc. require thorough planning and design for smoke control measures.

10.5. Means of Escape Requirements

Safe exit for the occupants in a building on fire, requires a safe path of escape from the fire in the shortest possible time. This path, which should be as short as possible, and easily negotiable, should be ready for use in case of emergency

For ensuring the life safety of occupants from a fire, the following are the requirements in general:

- Provision of adequate No. of properly designed, unobstructed means of exit of adequate capacity which are available at all times;
- Availability of alternative means of exit for use, if the already chosen one is inaccessible due to fire, heat, smoke and toxic gases;
- Protection of the entire rescue path against fire, heat, smoke and toxic gases during the egress time based on occupant load, travel distance and exit capacity;
- Adoption of compartmentation and other adequate passive fire protection measures to ensure the safe egress/evacuation of the occupants in case of fire;
- Provision of adequate and reliable fire alarm system in the building to alert the occupants;
- Provision of refuge areas where total evacuation of occupants is not contemplated;
- Adequate illumination and marking of the means of egress;
- Formulation organisation and practice of effective evacuation drill procedures.

10.6. Design Considerations of Means of Exit

Designing a means of egress involves more than numbers, flow rates and densities. Good exits facilitate everyone to leave the fire area in the shortest possible time by prompt and efficient use of them. If the fire is discovered promptly and occupants alerted also equally promptly, early evacuation can be done. However, **evacuation times are directly related to the fire hazard; higher the hazard, shorter the exit time.**

Provision of two separate means of exits for every floor including basements is a fundamental requirement, except in very few deserving cases.

In general, life safety from fire requires the following principles to be adopted:(Some of these may have already been covered earlier):

- Sufficient number of unobstructed exits of adequate capacity and properly designed, with easy access;
- Safeguarding of exits against fire and smoke during the length of time they are designed for use;
- Availability of alternate exit and means of access to it, in case one exit is unusable due to fire;
- Sub division of areas to provide sufficient areas of refuge for occupants where evacuation may be delayed;
- Adequate protection of vertical openings to minimize hazards from fire and smoke;
- Efficient fire alarm systems for alerting occupants and others concerned in case of fire;
- Adequate lighting of exits and rescue paths;
- Adequate exit indication signs to help evacuation;
- Ensuring trouble free evacuation through the escape route by safeguarding of equipment and vulnerable areas from fire and smoke hazards;
- Fully rehearsed exit drill procedures to ensure orderly and smooth exit;
- Institution of panic control measures;
- Control fire hazards from interior finish material

10.7. Exit Requirements - General

The details of some of the means of exit or egress or escape is a continuous path of travel from any point in a building or structure to the open air outside at ground level. It consists of three constituents which are:

(i) the exit access;
(ii) the exit ;
(iii) the exit discharge

The main requirements for the means of exit consisting of the three constituents as given above are:

- All means of exit, including staircases, lift lobbies and corridors, shall be adequately ventilated;

- Exits not properly ventilated can cause suffocation to people being evacuated because a large number of people would be present in such enclosed place with no natural ventilation till they get out of it and reach open air;

- Every building meant for human occupancy shall be provided with exits sufficient to permit safe escape of occupants, in case of fire or other emergency;

- An exit may be a doorway, corridor, passageway(s) to an internal staircase, or external staircase, or to a verandah or terrace(s), which have access to the street, or to the roof of a building or a refuge area. An exit may also include a horizontal exit leading to an adjoining building at the same level;

- Every exit, exit access or exit discharge shall be continuously maintained free of all obstructions or impediments to full use in the case of fire or other emergency.

- Even if adequate exits are provided at the initial stage, often at the time of renovation/alteration, knowingly or unknowingly, people do not give same attention to exit requirements. In view of the above this requirement assumes great significance.

- No building shall be so altered as to reduce the number, width or protection of exits to less than that required.

- People escaping from areas filled with fire and smoke will be all anxiety to reach open air where they can breath normally and become tension-free at the earliest.

- All exits shall provide continuous means of egress to the exterior of a building or to an exterior open space leading to a street.

- Exits shall be clearly visible and the route to reach such exits shall be clearly marked and signs posted to guide the occupants of the floor concerned. Signs shall be illuminated and wired to independent electrical circuits on an alternative source of supply. The sizes and colour of the exit signs shall be in accordance with established international practice.

- Normal colour used for exits is green. Illumination of exits and exit route signs, even when electricity is turned off, is very important to ensure orderly evacuation of occupants without chaos.

- The floors of areas covered for the means of exits shall be illuminated to values not less than 10 lux at floor level.

- This should cover all portions of exit access, exits and exit discharge.

- Fire doors with 2 hour fire resistance shall be provided at appropriate places along the escape route and particularly at the entrance to lift lobby and stairwell, where a funnel or flue effect may be created inducing an upward spread of fire, to prevent spread of fire and smoke.

10.8. Lifts and Escalators as Means of Exit

According to Clause 4.2.2. of Part-4 of NBC, "Lifts and Escalators shall not be considered as exits".

(i) This requirement has been made because of the following reasons. In case of failure of electricity, lifts and escalators tend to suddenly stop in between floors trapping the occupants of the lift, and creating chaotic conditions. Moreover, there had been instances, in India as well as abroad, when even under no-fire conditions there had been malfunctioning of the lifts, and the trapped victims had to be rescued through the intervention of the fire services. Under fire conditions, the chances of failure of the lifts and escalators are much more, and instances are many when trapped victims, including some fire service personnel, got killed inside the lifts due to fire and smoke.

(ii) Also, if lifts are not properly fire seperated by fire resistant shafts / lift lobbies and fire doors at every entrance, they create a stack effect carrying the fire from floor to floor.

10.9. Lifts and Escalators for Emergency Evacuation

Lift Evacuation Strategy-Modern Trends

(a) Building Codes throughout the world had all along been advocating the traditional **'evacuation by stairs'** policy in fire affected buildings, especially, for high rise buildings. Years of experience have brought to focus certain facts arising from the use of staircases for evacuation in high rise buildings:

- Even normally healthy persons are liable to feel fatigued after about 5min. of going down stairs. (Research done in Hong Kong found that people begin to suffer fatigue when they have climbed down about 18 storeys or so).
- Such fatigue can lead to the persons getting dizzy, or slipping on the stairs, etc.
- Research has found that it takes about 12 to 14 mins. to get down to the ground level using stairs from the 42nd floor of a high rise building, provided the travel is performed without a break.
- From buildings over 100 storeys in height, evacuees may need about 5 to 6 rest stops while coming down from the topmost floor to the ground level. Hence, including the time spent for the rest stops, it may take approx. about 40 to 45 min. for any one to reach the ground level from the top storey, which prolonged duration is not acceptable from any point of view.

(b) After the 11 Sept. 2001, WTC incident, many felt that had adequate Emergency Escape Lifts(EELs) were available at WTC, perhaps many more lives could have been saved.

(c) Past experience combined with research studies conducted during the last two decades, has led to the development of a new concept of **'Emergency Elevator Evacuation System'** in the developed countries.

(d) Incidentally, British Standard, BS 5588. 'Fire Precautions in the Design, Construction and Use of Buildings, Part-5 Code of Practice for Fire fighting Stairs and Lifts', as well as Part-8, 'Code of Practice for Means of Escape for Disabled People' recommend the use of lifts/elevators in fire situations for evacuation of disabled persons, and also for fire fighters' use during fire fighting operations. The BS, as well as NFPA Codes, recommend the use of lifts under emergency situations, with provisions for special protection measures for this lift against fire, smoke and heat, plus provisions for fail-safe standby electrical power for operation of lifts, reliable two-way communication system for the lift cars and lift lobbies with fire control room etc. Further, an emergency lift control procedure is required to be developed for adoption in case of fire emergency.

(e) The elevator lobby for Emergency Evacuation Lifts(EELs) should have a capacity of not less than 50% of the occupant load of the area served by the lobby. The lobby spaces should also include 1 or 2 wheel chair space of 76cm x 122cm (30 in x 48in)for each 50 persons of the total occupant load served by that lobby. The EELs should be provided with fire fighters' emergency operation devices also.

(f) The new concept is becoming increasingly popular in many advanced countries.

(g) Incidentally, this new method has been incorporated in the design of the present-day tallest building in the world, ie., Petronas Twin Towers in Kuala Lumpur, Malaysia. Some of the main features of the emergency evacuation lift strategy incorporated in this super high rise building are:

- The twin towers have 29 double deck elevators, (each having a capacity of 22 persons) out of which certain double deck lifts are designed as fire lifts;
- The 'sky lobbies' on levels 41 & 42 will serve as refuge floors and staging area for egress from the upper levels(upto 80 storeys);
- The shuttle lifts(double decker lifts) provide express service between sky lobbies and ground levels;
- Pressurisation of sky lobbies;
- All lifts will be available for use in a phased evacuation mode in an emergency. Fire lifts are provided with emergency power supplies also.

10.10. Occupant Load

(a) Occupant load in a building or area is an important factor for determination of the number of exits required as well as for capacities of exits.

(b) The total capacity of the means of egress for any storey, balcony or other occupied space shall be sufficient for the occupant load thereof. The occupant load as arrived at from as indicated in Table 20 of NBC Part-4 is just for normal guidance and not to be taken as a firm requirement, since an unforeseen hazard might occur when an unusually large crowd is present.

(c) The occupant load in any building or portion of it shall be at least the number determined by dividing the floor area assigned to that use by the occupant load factor(floor area in m^2/ person) indicated in Table 20 of NBC Part-4. According to this Table, the occupant load factor or floor area in m^2/ person varies between the highest value of 0.6 m^2/ person for Assembly occupancy(D) with fixed/loose seats, dance floors etc., and 30 m^2/ person for Storage occupancy(H).

(d) Where fixed seating arrangements exist, as in theatres, conventions, lecture/entertainment/social functions etc. halls, certain problems do arise in the case of handicapped persons or people who require assistance for evacuation in the event of fire or other emergency. Likewise, unpredictable situations leading to panic, and sometimes to tripping down and stampede, may result in Assembly occupancies which have no fixed seating. Similar tragedies involving heavy casualties are possible (and had happened also) in huge Assembly gatherings in the open as in religious festivals and melas(Kumbh melas, for instance).

10.11. Capacities of Exits

The unit of the exit width, used to measure the capacity of any exits shall be 500mm. A clear width of 250mm shall be counted as an additional half unit. Clear widths less than 250 mm shall not be counted for exit width.

Note:- The total occupants from a particular floor must evacuate within two and half minutes. Size of the exit door/exit-way shall be calculated accordingly keeping in view the travel distance as per NBC.

(a) Exit capacity is usually computed on the basis of unit of exit width which, as per Part-4 NBC, is reckoned as 50cms(approx. 20 inches).

(b) The number of exits required for any occupancy is also arrived at based on this unit of exit width, on the assumption that body width of a normal person is 50cm and that much of minimum width is required for one person while passing through an escape route including stair cases, doors etc., which are components of means of egress or escape route.

(c) The Note is persumably based on studies conducted by the Grading Committee in UK on evacuation times taken in actual fires. The time $2^{1/2}$ minutes was taken as the time necessary for the total evacuation of one storey to a protected stair way and not to a final exit.

(d) The occupants per unit exit width to achieve this time for evacuation of total occupants from a floor will range from 25 to 50 persons for stairways. The reduction in the evacuation time to $1^{1/2}$ minutes for Type-2 construction and 1 minute for Type-3 construction is obviously because of the reduced fire resistance capability of these types of constructions, which necessitates more speedy evacuation of occupants to a place of safety.

(e) In the case of high rise buildings, the time needed to evacuate just the floors immediately at risk to a final exit, will be much longer.

(f) Results of research studies conducted abroad:

The unit of exit width is based on the 'body ellipse' concept, which was used in other countries for developing design of pedestrian systems. Studies show that most adult men measure less than approx. 520 mm(20.7 inches) accross the shoulder. The 'body ellipse' equals about 0.21m^2 (2.3 sq.ft.) which is an average person's maximum practical standing capacity of space.

- The design and capacity of passage ways, stair ways, doors and other components in the means of egress are related to the physical dimensions of the human body. People have a normal tendency to avoid bodily contact with others, especially while on the move. The movement of persons results in a swaying motion which varies with individuals, and also depending on whether the movement is on level surfaces, on stairs or in dense crowds. During movement on stairs or in dense crowds, the total body sway may reach almost 100mm(4 in) In theory. This indicates that a total width of about 760mm (30 in) would be required to accommodate a single file of persons going up or down stairs.

- London Transport Board had undertaken a research project on the movement of persons, and some of the conclusions from their Research Report No.95 will be of interest in this present context, which are listed below:

- crowding people into spaces less than $0.28m^2$ (3 sq.ft.) per person under non-emergency conditions may create a hazard;
- under the psychological stresses during a fire, such crowding could contribute to crowd pressures resulting in injuries;
- on level surface, an average walking speed of 76m/min. (250 ft./min.) is attained under free-flow conditions, with 2.3 m^2 (25 sq.ft.) of space available per person;
- speeds below 44m/min. (145 ft./min.) show shuffling, which restricts motion, leading to a jam point with one person every 0.18 m^2 (2 sq.ft.);
- restricted movement on escape route under fire conditions can lead to non-adaptive behaviour of occupants, especially when there is more than one person every $0.28m^2$ (3 sq.ft.);
- flow rates are directly proportional to width for exit ways over 1.2m (4 ft.) wide. It can be 50% greater in short passages less than 3.05m(10 ft.) than through a long passage of same width;
- travel down stairways (of over 1.2m width) was determined at 0.3m (21 persons/min./ft.) of width, whereas upward travel was reduced to 19 persons/min./ft. of width;
- proper egress design permits all occupants to reach a safe place before they are endangered by fire, smoke or heat;
- a 813mm (32 in) doorway is considered the minimum width to accommodate a person in a wheel chair.

10.12. Internal Staircases

The staircase shall be ventilated to the atmosphere at each landing with a vent at the top; the vent opening shall be of 0.5 m2 in the external wall and the top. If the staircase cannot be ventilated, because of location or other reasons, a positive pressure 50 pa shall be maintained inside. The mechanism for pressurizing the staircase shall operate automatically with the fire alarm. The roof of the shaft shall be 1 m above the surrounding roof. Glazing or glass bricks if used in staircase shafts shall have fire resistance rating of minimum 2 hours.

Venting or pressurisation of staircases provide smoke-free passage to people being evacuated who face danger of suffocation by smoke inhalation.

All buildings, which are 15 m in height or above, and all buildings used as educational, assembly, institutional, industrial, storage and haardous occupancies having area more than 500 sq. m on each floor shall have a minimum of two staircases. They shall be of enclosed type; at least one of them shall be on external wall of building and shall open directly to the exterior/interior open space or to an open place of safety. Further, the provision or otherwise of alternative staircases shall be subject to the requirements of travel distance being complied with.

Smoke moves from an area of higher pressure to one of lower pressure. Pressure differences may be caused by buoyancy from the fire. Every internal escape stair should therefore be a protected stairway.

Internal Stairs shall be constructed of non-combustible materials throughout.

In case internal stairs form a part of the escape route, they have to be treated as escape stairs and as a 'protected stairway' to enable them fulfill their role for safe evacuation of occupants during fire emergencies.

A staircase shall not be arranged round a lift shaft. Lift shafts tend to carry smoke and fire upwards People escaping through stairs downwards must be safe from such smoke and fire.

No combustible material shall be used for decoration / wall paneling in the staircase.

The exit sign with arrow indicating the way to the escape route shall be provided at a suitable height from the floor level on the wall and shall be illuminated by electric light connected to corridor circuits.

Floor indicator boards in the staircases help people getting down the stairs to know on which floor they are, and how far they are from the ground level where they will be safe from the fire. This also helps in reducing psychological pressure on them whilst being evacuated in case of a fire emergency.

No gas piping, ducting or electrical panels shall be laid in the stair way. These have fire hazard potential.

The lobby should have not less than 4m2 permanent ventilation, or protected from the ingress of smoke by a mechanical smoke control system.

Width of Staircase

Following minimum width shall be provided for staircases:

a)	Residential buildings (dwellings)	1.0m
b)	Residential hotel buildings	1.5 m
c)	Assembly buildings like auditorium, theatres and cinemas	2.0m
d)	Educational buildings up to 30 m in height	1.5 m
e)	Institutional buildings like hospitals	2.0 m
f)	All other buildings	1.5 m

10.13. Fire Lifts

This lift can be used even by building occupants except during fire emergencies. This is a lift designed to have additional protection with controls to enable it to be used under the direct control of the fire service during fires.

For fire fighting operations in high rise buildings, it will be almost impossible for fire fighters to carry their equipments to the upper floors of a tall building without the use of lift, which is much easier and quicker than carrying them up through stairs.

Fully automated fire lifts having minimum capacity for 8 passengers with emergency switch on ground level shall be provided. In general, buildings 15m in height and above shall be provided with fire lifts.

In case of fire only fireman shall operate the fire lift. In normal course, lift may be used by other persons.

In case of fire, firemen can commandeer the lift for their exclusive use. A switch in a glass fronted box marked ‘Fireman’s Switch’ placed at ground level and by operation of this switch firemen can recall the lift if it is in normal operation and utilise the lift for their use.

Each fire lift shall be equipped with suitable intercommunication equipment for communicating with the control room on the ground floor of the building

One fire lift per 2000 m 2 of floor area shall be provided.

Fire lift should be provided with a ceiling hatch for use in case of emergency, so that when the car gets stuck up, it shall be easily operable.

By opening the hatch, fire brigade may be able to rescue people trapped in lifts which have suddenly stopped in case of a fire.

The lift shall be so wired that in case of power failure, it comes down at the ground level and comes to stand-still with door open.

Automatic changeover from normal supply to generator supply is very important because the generator room may not easily be accessible in case of a severe fire.

The speed of the fire lift shall be such that it can reach the top floor from ground level within one minute.

10.14.Fire fighting Shafts

In U.K. Buildings more than 18m in height, or with a basement of more than 10 m below grade, have been provided with a fire fighting shaft. This is a protected shaft having facilities like fire fighting lifts, fire fighting stairs and fire fighting lobbies. These fire fighting shafts are designed to facilitate access of fire fighting personnel into high rise and other special hazard buildings. This facility enables the fire fighting personnel to reach the fire and conduct fire fighting operations without delay and in an efficient manner.

Doors shall be arranged to be opened readily from the egress side whenever the building is occupied.

Stair treads and landings shall be solid, without perforations, and free of projections or lips that could trip stair users.

Elevators shall be capable of orderly shut downs during earthquakes.

Handrails shall be provided within 760mm (30 in) of all portions of the required egress width of stairs and ramps.

10.15. External Stairs

It is desirable to provide external staircases in case of high-rise buildings. External stairs, when provided shall comply with the following:

- The flights and landings of an external escape stair should be of fire resisting construction;
- All external stairs shall be directly connected to the ground;
- No wall opening or window opens on to or close to an external stairs. Flames can leap out of such doors and windows in external walls of affected building hampering evacuation and fire fighting operations.
- The route to the external stairs shall be free of obstructions at all time.

10.16. Horizontal Exits:

(a) Horizontal exits are particularly useful during fire emergencies in hospitals (health care occupancies) for evacuation of bedridden patients or patients suffering from immobility. Adjoining compartments into which horizontal evacuation is done should also have a floor area sufficient to accommodate evacuees from the adjoining compartment.

(b) Sometimes, progressive horizontal evacuation may also have to be adopted depending on the emergency situation and the facilities available.

10.7. Illumination of means of exit

Staircase and corridor lights shall conform to the following.

(a) The staircase and corridor lighting shall be on separate circuits and shall be independently connected so that it could be operated by one switch installation on the ground floor easily accessible to fire fighting staff at any time irrespective of the position of the individual control of the light points, if any. It should be miniature circuit breaker type of switch so as to avoid replacement of fuse in case of crises

(b) Staircase and corridor lighting shall also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains.

One control switch at the ground level will help in putting on emergency lights for prompt illumination of escape routes. Miniature circuit breakers avoid frequent fuse replacement.

10.8. Refuge Areas

For buildings more than 24m in height, refuge area of 15 sq.m or an area equivalent to 0.3 sq.m per person to accommodate the occupants of two consecutive floors,whichever is higher, shall be provided as under.

For floors above 24 mt and up to 39 m - One refuge area on the floor immediately above 24 m.

For floors above 39 m- One refuge area on the floor immediately above 39 m and so on after every 15 m. Refuge area providedu in excess of the requirements shall be counted towards FAR.

The refuge area shall be provided on the periphery of the floor and open to air, at-least on one side, protected with suitable railings.

10.9. Ramps

Ramps shall comply with all the applicable requirements of stairways regarding enclosure capacity and limiting dimensions.

The slope of a ramp shall not exceed 1 in 10. Ramps with slopes greater than those recommended render them difficult to be used, particularly by physically handicapped elderly people and children, and hence this requirement.

Ramps in means of egress are required to be enclosed or protected. Further, they must have landings located at the top, at the bottom and at doors opening into the ramp

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SECTION 7 - FIRE SAFETY IN BUILDING DESIGN AND CONSTRUCTION BASIC PRINCIPLES

11. 1. General

The design of any building and the type of materials used in its construction are important factors in making the building resistant to a complete burn-out, and in preventing the rapid spread of fire and smoke which may otherwise contribute to the loss of lives and property.

Fire Load isthe measure of the maximum heat that will be released if all the combustibles in a fire area burned, Including wall linings, wooden or combustible partitions, linings/coverings on floors and ceilings.

The fire resistance of a building or its structural and non-structural elements is expressed in hours against a specified fire load which is expressed in kcal/m2, and against a certain intensity of fire. The fire - resistance test for structural elements shall be done in accordance with good practice.

Fire Resistance Rating is at times referred to as “Fire Endurance Rating” also. While the actual time is recorded in the nearest integral minuites, fire resistance ratings are given in standard intervals. The usual fire resistance ratings for all types of structural members, doors and windows are 15 mins., 30 mins., 45 mins., 1hr., 11/2 hrs., 2 hrs., 3 hrs., and 4 hrs.

The fire resistance of an element is the time in minutes from the start of the test until failure occurs under any one of the criteria set out below:

(a) Resistance to collapse (stability)

(b) Resistance to penetration of flame (integrity)]

(c) Resistance to temp. rise on unexposed face (insulation)

11.2 Types of construction

According to fire resistance, buildings shall be classified into four categories, namely, Type 1 construction, Type 2 construction, Type 3 construction and Type 4 construction. The fire resistance ratings for various types of construction for structural and non-structural members shall be as given in standard Tables in NBC Part-4

IS:1809-1979 deals with methods of testing structural members of different material for their fire safety. For fire resistance ratings required for various structural and non-structural members to be used for different classes of construction, please refer to standard Tables in NBC. Part-4.

The fire resistance is the time duration the member or assembly can withstand the fire test without failure. The usual fire resistance ratings for structural assemblies, members, doors etc. are: 1/2 hr., 1hr., 2 hrs., 3hrs. & 4 hrs. A 1hr. rating indicates that the assembly/ member can withstand the standard test for minimum 1 hr. without failure by any one of thefailure crieteria listed in the fire test protocol i.e. stability. Integrity and Insulation.

Perfect party walls have minimum fire resistance of 4 hrs. Combustible materials on the other side of the fire seperating wall can be segregated before the wall collapses, and the fire enters the segregated compartment. This reduces the overall damage and material losses.

Fire damage assessment / post fire structural safety assessment of various structural elements of the building and adequacy of the structural repairs can be done using the fire resistance ratings mentioned in the tables. Uses of these Tables is to assess the stability of building damaged by fire; before declaring a building damaged by fire which has undergone repairs, as safe

For buildings 15 m in height or above, noncombustible materials should be used for construction and the internal walls of staircase enclosures should be of brick work or reinforced concrete or any other material of construction with minimum of 2h rating. The walls for the chimney shall be of Type 1 and Type 2 construction depending on whether the gas temperature is above 200 c or less.

11.3 Steel Construction

Bare steel members if provided would collapse under fire conditions much earlier than other structural elements like walls, slabs etc. All supporting structural beams and columns of steel should therefore be enclosed in 5 cms (2 in) thick concrete or equivalent fire proofing material.

Encasement of structural steel members has been a very common and satisfactory method of insulating steel to increase its fire resistance. Encasement of structural steel members can be done utilizing concrete, lath and plaster, gypsum board or sprayed mineral fibres

Load bearing steel beams and columns shall be protected against failure / collapse of structure in case of fire. This could be achieved by use of appropriate methodology using suitable fire resistance rated materials.

11.4 Occupation of Buildings under Construction.

Classification of buildings under construction or repairs gets temporarly downgraded because of opening up of walls, roofs etc. A building or portion of building may be occupied during construction, repairs, alterations or additions, only if all means of exit and fire protection meaures are in place, and continuously maintained for the occupied part of the building Detailed Instructions on “Safety Against Fire and Fire Protection for Buildings under Construction” are given in Part-7 “Constructional Practices and Safety” under NBC, which is also currently under revision

11.5 Maximum Height

Every building shall be restricted in its height above the ground level and the number of storeys, depending upon its occupancy and the type of construction. The maximum permissible height for any combination of occupancy and types of construction should be necessarily be related to the width of street fronting the building, or floor area ratios and the local fire fighting facilities available.

Buildings above 15m. : Not permitted for occuppancies A1, A2, G3, Groups H & J

Buildings above 30 m: not permitted for Groups B, C, D & F

Buildings above 18 m: Not permitted for G-1 & G-2 Occupancies.

Buildings above 60 m: Not permitted for A3 & A4 Occupancies.

No height restrictions for buildings in A5, A6 & group E

Note: Classification of Occupancies and Groups under them are as given in NBC Part-4.

11.6 Open Spaces

The open spaces around or inside a building shall conform to the requirements of Part 3, NBC, Development Contro Rules and

General Building Requirements. For high rise buildings, the following additional provisions of means of access to the building shall be ensured:

The width of the main street on which the building abuts shall not be less than 12 m and one end of this street shall join another street not less than 12 m in width;

The road shall not terminate ina dead end ; except in the case of residential building, up to a height of 30 m.

The compulsory open spaces around the building shall not be used for parking; and

Adequate passageway and clearances required for fire fighting vehicles to enter the premises shall be provided at the main entrance; the width of such entrance shal lbe not less than 4.5m. If an arch or covered gate is constructed, it shall have a clear head-room of not less than 5m.

The approach to the building and open spaces on all its sides upto 6m width and the same shall be of hard surface capable of taking the mass of fire engine weighing upto 45 tonnes. The said open space shall be kept free of obstructions and shall be motorable".

" The main entrance to the plot shall be of adequate width to allow easy access to the fire engine and in no case shal it measure less than 6 m. If the main entrance at the boundary wall is built over, the minimum clearance shall be 4.5m. A turning radium of 9m. shall be provided for fire tender movement". If entrance gate is of lesser dimension , fire engine with their ladders cannot negotiate them incase of emergency.

Other Amenities

One Fire Station or Sub Fire Station within 1 km to 3kms. for every 200,000 population has been prescribed with the following requirements;

Area for Fire Station with essential residential accommodation - 1.00 ha;

Area for Sub Fire Station with essential residential accommodation - 0.60 ha"]

11.7. Mixed Occupancy

When any building is used for more than one type of occupancy in so far as fire safety is concerned, it shall conform to the requirements for the occupancies of higher hazard. Unless the high hazard area is separated by separating walls of 4th rating, the occupancies shall not be treaed individually.

A typical example of a mixed occupancy is a covered mall building, which is a single building enclosing a number of tenants and occupancies such as mercantile units, restaurants, entertainments and amusement facilities, offices, clinical laboratories etc. This can be a high rise building also.

In many of our cities, the number and variety of such mixed or multiple occupancies are increasing fast. A recent development is the growth of so-called “multiplexes”, which are in fact one multi-level building complex, having multiple occupancies like cinema theatre, shopping complex, hotel/restaurants, and may be a few other ancillary occupancies. The unusually high fire and life hazards in such multiplexes can well be imagined. Consequently, the design and construction of the building, as well as the fire protection and life safety measures incorporated in the building

11.8 Exposure Protection

Any neighboring buildings, particularly those of more than one storey, wil be subject to some degree of exposure hazard either from flying brands or radiation, or both, as a result.

Normally, window and ventilator openings in the higher building are protected by 6.25 mm (1/4 in) thick wired glasses in steel frames

11.9. Fireseals

This is a seal provided to close the opening or imperfection of fit or design between elements or components to eleminate the possibility of fire and smoke passing through them. These fire stops fill the openings around penetrating items such as cable trays, conduits, ducts, pipes etc. through the wall or floor openings.

Provision of non- combustible “sleeving” is also resorted to as an alternative to proprietary seals for penetration of pipes. Fire stopping materials include:

- cement mortar
- gypsum-based plaster
- cement or gypsum vermiculite/perlite mixes

- glass fibre, crushed rock, blast furnuace slag, or ceramic based products (with or without resin binders), and +. intumescent mastics

Not all of them will be suitable in every situation.

11.10 Transformers

If transformers are housed in the building below the ground level they shall necessarily be in the first basement in a separate fire resisting room of 4h rating.

The entrance to the room shall be provided with the fire- resisting door of 2h fire rating on both sides at the opening. A curb (sill) of suitable height shall be provided at the entrance in order to prevent the flow of oil from ruptured transformer into other parts of the basement.

The switch-gears shall be housed in a room separated from the transformer bays by a fire resisting wall with fire resistance of not less than 4h.

Oil filled transformers shall not be housed on any floor above the ground floor.

It becomes difficult to tackle transformer fires. If transformers are located above ground level, there is a danger from over flowing of the burning fuel to the floors below and even to the drains.

The oil filled transformers, shall be protected by an automatic high velocity water spray / system if the contents exceed 2000 litres of oil. Soak pits of approved design shall be provided.

A tank of reinforced cement concrete construction of adequate capacity for of accommodating the entire oil of the transformers shall be provided at a lower level to collect the oil from the catch-pit to the tank which shall be provided with flame-arrester

In case of transformer fires a soakpit is required for collection of the oil draining out at a safe distance, thereby removing the fuel from the fire scene.

11.11. Boiler rooms.

Boilers may be allowed in the basements away from escape routes.

The boilers shall be installed in a fire resisting room of 4h fire resistance rating, and this room shall be situated on the periphery *of the* basement.

Boilers when located in a 4 hr, fire resistant enclosure will ensure that any possible boiler explosion or fire effects are confined to the boiler enclosure and are not conveyed to outside. Provision of catchpit ensures that escaping burning fuel flowing out of a transformer on fire does not spread to other areas. Its location on the periphery ensures its easy isolation from other areas.

Entry to this room shall be provided with a door of 2h fire resistance.

The boiler room shall be provided with fresh air inlets and smoke exhausts directly to the atmosphere.

Smoke extraction and ventilation become very important in case of fires in boiler rooms which use fuels that can generate dense smoke.

The furnace oil tank for the boiler, if located in the adjoining room shall be separated by fire resistant wall of 4h rating. The entrance to this room shall be provided with double composite doors. A curb of suitable height shall be provided at the entrance in order to prevent the flow of oil into the boiler room in case of tank rapture.

All exterior openings in a boiler room or rooms containing central heating equipment if located below opening in another storey-or if less than 3m from other doors or windows of the same building, shall be protected by a fire resistant assembly/or fire stop. *Wherever combustible materials like wood, plywood etc. are used, they should be rendered fire resistant by fire retardant treatment.

11.12. Openings in separating Walls and Floors.

A doorway or opening in a separating wall on any floor shall be limited to 5.6 m2 in area with a maximum height/width of 2.75 m . Every wall opening shall be protected with fire-resisting doors having fire rating of not less than 2 h in accordance with accepted standards.

Opening 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 of not less than 2 h. The inspection door of all service shafts except electrical shafts shall have fire resistance of not less than 1 h. For electrical shafts they shall have fire resistance of not less than 2 hours (Bus-bar system shall be desirable.) Medium and low voltage wiring running in shafts/ducts, shall either be armoured type or run through metal conduits/pipes. Further, the space between the conduits and the walls/ slabs shall be filled in by a filler material having fire resistance rating of not than one hour.

In case the opening size exceeds 5.6m2, fire resisting doors designed to protect them need to be adequately strengthend. Normally doors with larger panel areas, tend to buckle in fire conditions.

11.13 Concealed spaces

Such spaces within a building such as space between ceiling and false ceiling, horizontal and vertical ducts, etc, tend to act as flues/ tunnels during a fire. Provision should, therefore, be made to provide fire stopping within such spaces.

11.14 Vertical Opening

In a building fire vertical openings like stairs and lift shafts acts as flues or chimneys conveying flames, hot gases and smoke vertically and serve as channels for easy spread to the upper levels. Hence, the need for enclosure or protection of such vertical shafts to prevenet fire spread to other areas and floors served by them.

Door openings at every floor level leading to staircases or lifts/lift lobbies should be protected by single fire doors for safe evacuation of occupants in case of fire emergency.

Every vertical opening between the floors of a building shall be suitably enclosed or protected, as necessary, to provide the following :

Reasonable 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

11.15 Compartmentation

Helps in limitation to the damage of building and its contents :

- Fires on one or two floors, or when spread over a large floor area, are extremely difficult to control and extinguish by manual fire fighting methods. Building designs with unprotected vertical openings, like open stairwells, large floor areas without separation walls, A/c duct work without dampers etc. provide avenues for fire spread vertically as well as side ways. Fire figting operations become difficult and prolonged as the fire propagation continues upwards as well as horizontally.
- Judicious ccmpartmentation of a building is considered as a primary method among passive fire protection measures. It helps to segregate a space that has a higher fire or life hazard than the surrounding area;
- Limit the size of the fire, thereby limiting the smoke generation and also facilitate fire suppression;
- To protect high value or critical areas or operations from a fire in the surrounding area (Eg: Computer rooms, control rooms, safe vaults, records room etc.)

11.16. Service Ducts/Shafts.

Service ducts and shafts shall be enclosed by waiis of 2 h and doors of 2 h, fire rating. All such ducts/shafts shall be property sealed and fire stopped at all floor levels.

A vent opening at the top of the service shaft shall be provided having between one-fourth and one-half of the area of the shaft. Natural venting of service shafts helps in smoke disposal thus making fire fighting and rescue operations easier.

Refuse chutes which are used for collection and disposal of the waste from the various floors constitute a potential source of fire due to accumulation of combustible waste. Provision of fire resistant doors at every floor level helps prevention of fire spread from floor to floor. Refuse chutes shall have openings at least 1 m above roof level for venting purpose Inspection panels and doors shall be tight fitting with 2 hours fire resistance.

11.17. Drains

Many a time, damage caused by water used in fire fighting has proved costlier than the fire damage itself, possibly because of the nature of the materials involved. It is therefore important that they have proper drainage arrangements in all the areas of the building. Similarly, it is equally important to have non combustible drain pipes for obvious reasons. The drain pipes should be provided on the external wall for drainage of water from all floors.

11.18 Fire stop or enclosure of openings in external walls

Total areas of windows and door openings in external walls of a building should not exceed 75% of wall area for stability of structure and for reducing exposure hazards to adjoining property.

Certain aspects, applicable to particular occupancies only, which may affect the spread of fumes and thus the safe evacuation of the building in case of fire are :

- Service equipment and storage facilities in buildings other than storage buildings;
- Residence or shop, when partly used as godown assumes altogether different proportion from fire safety point of view and needs to be dealt with differently.

11.19. Interior finish and decoration;

Interior finish materials like wall panellings, wooden floorings, or false ceilings play equally destructive role in aggravating loss of human lives and property in case of fire, and hence these must conform to class-1 flame spread characteristics.

Generation of large volumes of smoke and toxic gases seriously affect the life safety of the occupants.

The use of combustible surface finishes on walls (including facade of the building) and ceilings affects the safety of occupants of a building. Such finishes tend to spread the fire even though the structural elements may be adequately fire resistant, serious danger to life may result .It is therefore essential to take adequate precautions to minimize spread of flame on such walls, facade of building and ceiling surfaces.

The finishing materials used for various surfaces and decor shall be such that it shall not generate toxic smoke/fumes.

Interior finishes or linings, also provide a large unbroken surface over which flame spreads. The flame from the interior finish may release sufficient thermal energy for the formation of a hot gas layer which may become thick, attaining a temperature around 600°C, and starts descenting from the top. At this stage, all the combustible contents as well as the furnishings in the room may simultaneously get ignited, which is known as "flash-over" or full fire involvement. This can happen even in a few minutes.

Use of combustible interior finishes (interior linings) such as low density fibre board ceilings, wood panelling textile wall coverings, vinyl wall coverings, cellular polyurethane and polystyrene materials, and combustible floor coverings, had resulted in several heavy death toll fires in the past.

Interior finish affects the fire in four ways: (i) It affects the rate of heat build-up to a 'flash-over' condition (ii) It contributes to flame spread over the surface, (iii) It adds to the intensity of fire by contributing additional fuel, and (iv) It produces toxic gases and smoke that adds to life hazard and property damage. The fourth factor is the most important since it affects occupant life safety seriously.

The susceptibility to fire of various types of wall surfaces is determined in terms of the rate of spread of flame. Based on the rate of spread of flame, surfacing material shall be considered as divided into four classes as follows.

Class 1 surfaces of very low flame spread Class 2 Surfaces of low flame spread.

Class 3 Surfaces of medium flame spread Class 4 Surfaces of rapid flame spread Class 1 may be used in any situation.

Class 2 may be used in any situation, except on walls, facade of the building, staircase and corridors.

Class 3 may be used only in living rooms and bed rooms (but not in rooms on the roof) and only as a lining to solid walls and partitions; not on staircases or corridors or facade of the building.

Note- Panelling (lining) shall be permitted in a limited area. It shall not be permitted in a vestibule.

Materials of class-4 flame spread are the worst ones for use in buildings, and hence their use is to be strictly prohibited unless they are given proper fire retardant treatment. This is equally true for false ceilings and false floors also.

Class 4 materials shall not be used in kitchens, corridors and staircases. Some materials contain bitumen and, in addition to risk from spread of fire, emit dense smoke on burning. Such materials shall be excluded from use under these conditions and shall also not be used for construction of ceiling where the plenum is used in return air in air-conditioned buildings Class 4 materials shall not be used in kitchens, corridors and staircases.

When frames, walls, partitions or floors are lined with combustible materials, the surfaces on both sides of the materials shall conform to the appropriate class.

11.20. Wired Glass-The wired glass shall be of minimum half hour fire resistance rating.

Sashes and Frames- The Sashes or Frames or both shall be entirely of iron or other suitable metal such as stainless steel, securely bolted or keypad into the wall, except in case of panels in internal doors.

Setting of Glass- The panels of glass shall be set in rebates or grooves not less than 6.0 mm in width or depth, with due allowance for expansion, and shall be secured by hard metal fastenings to the sashes or frames independently of any cement or putty used for weather proofing purposes.

If the supporting frame work to hold wired glasses is of combustible nature, eg. of wood, the support would be lost in case of a fire .at a very early stage, and the wired glasses would fall off defeating the very purpose for which they are provided.

If the opening protected is more than 5m2 the glass loses its fire resisting property. It will give way soon, nullifying the very purpose for which it is installed.

Skylights

Wired glass for skylights or monitor lights shall comply with the following requirements:

Wired Glass for skylights or Monitor Lights- The wired glass for skylights or monitor lights shall be of minimum half hour fire resistance rating.

Frames and Glazing - The frames shall be continuous and divided by bars spaced at not more than 700 mm centers. The frames and bars shall be of iron or other hard material and supported on the curb either of metal or of wood covered with sheet metal. The toughened glass shall be secured by hard metal fastenings to the frame and bars independently of any lead, cement or putty used for weather-proofing purposes.

Materials used in louvers wherever provided shall be of minimum half hour fire resistance rating.

Glasses used in facade of high rise buildings

These shall have minimum of 1 hr fire resistance. If this is not observed, glasses will shatter and fly off in case of a fire, injuring pedestrians passing by on the surrounding streets.

11.21. HIGH RISE BUILDINGS-15 M IN HEIGHT OR ABOVE.

The definition of high rise building, viz., 15m in height or above, should be read in conjunction with the definition for 'Building Height'

Some of the outstanding problems which had been experienced by the fire services during fire fighting operations in high rise buildings are:

- External fire fighting and rescue difficult;
- Evacuation prolonged/difficult;
- Rescue and fire fighting mainly from within the building;
- Being fully airconditioned, traps heat and smoke during fires,
- Danger of flash overs; Smoke venting problems;
- Large number of occupants. Incase of fire, human behaviour unpredictable;

- Special care for physically handicapped;
- Special care to keep escape routes clear;
- Hazards from increasing use of plastic materials, interior finish decoration;
- Multi occupancy hazards, high fire loads;
- Inadequate water supplies;
- Indequatc/unserviceable fire protection systems and equipment.

11.22. Basements

Occupancies which are prohibited from being located in basements are either of high risk category, or an Assembly occupancy, making their evacuation in case of fire difficult due to smoke logging and also possible impediments to fire fighting operations.

Departmental stores, shops, storage of flammable oils and gases, banquet hall, auditorium, discotheque, restaurants etc, shall not be permitted in basements.

Basement shall not be permitted below the ward block of a hospital/ nursing home unless it is fully sprinklered.

A system of air inlets shall be provided at basement floor level and smoke outlets at basement ceiling level. Inlets and extracts shall be terminated at ground level with stallboard or pavement lights Stallboard and pavement lights should be marked **'SMOKE OUTLET' OR 'AIR INLET*** with an indication of areas served at or near the opening.

The staircase of basements situated at the periphery of the basement to be entered at ground level only from the open air. It shall communicate with basement through a lobby provided with fire resisting self closing doors of one hour resistance. If the travel distance exceeds the desired level, additional staircases shall be provided at proper places.

Each basement and basement compartment shall have separate smoke outlet duct or ducts.

Mechanical extractors for smoke venting system from lower basement levels shall also be provided. It shall also have an arrangement to start it manually. Mechanical extractors shall be designed to permit

30 air changes per hour in case of fire or distress call;

In ventilating ducts crossing the transformer area or electrical switchboard, fire dampers shall be provided.

All floors shall be compartmented with area not exceeding 750 m2 by a separation wall with 2 h fire rating.

High rise buildings shall be provided with lightning protection.

11.23. Fire Control Room

For all buildings 15m in height and above, there shall be a control room on the entrance floor of the building with communication system (suitable public address system) to all floors and facilities for receiving the message from different floors. Details of all floor plans along with the details of fire fighting equipment and installations shall be displayed in the fire control room. The fire control room shall also have facilities to detect the fire on any floor through indicator board connection to fire detection and alarm systems on all floors. The fire staff in charge of the fire control room shall be responsible for maintenance of the various services and the fire fighting equipment

It should have an area of 16m2 to 20m2, preferably on ground floor;

The Control and Indicating Equipment(Control Panel of the AFA system), power supply units and the fire protection ancillary panels(for automatic sprinkler system or other fixed fire protection system etc.) should be installed in the room;

It should have intercom and direct telephone facilities. Where possible, a direct hot line to local fire brigade should be provided;

It should have a mimic panel of the premises protected and details of all the fire protection systems installed;

The room should be air-conditioned and should have emergency lighting system.

11.24. House Keeping

To eliminate fire hazards, good house keeping, both inside and outside the building, shall be strictly maintained by the occupants and the owner of the building.

Good house keeping boils down to regular upkeep of the premises, keeping things in their places and regular waste disposal. Good house keeping reflects good management style and a strong desire to follow fire prevention practices.

11.25. Helipad

There had been several cases of major nigh rise building fires when many persons had collected on the roofs of the burning buildings because of non availability of staircases for escape due to smoke accumulation in the escape route. In many such cases they were rescued from the rooftop helipads using helicopter sorties.

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SECTION 8 - FIRE PROTECTION / FIRE SAFETY MANAGEMENT FOR VARIOUS CLASSES OF OCCUPANCIES

12.1. Fire Protection Management

Experience has proved that it will be too ambitious and impractical to expect that prevention of fires can be achieved 100% in all types of occupancies and situations, when several unpredictable factors, including vagaries of nature and acts of human commission and omission are bound to occur.

Nevertheless, all those concerned and responsible for enhancement of building fire safety standards continue their untiring effects to mitigate losses of lives and property due to fires. The best possible way to achieve this laudable objective is to develop an integrated system of balanced fire protection that combines the best of different design features of both active and passive fire protection systems for the buildings. This is what all framers and implementing agencies of national and local level Building Codes and Regulations, as well as the entire building construction community should aspire for.

12.2 Classes of Occupancies

All buildings, whether existing or hereafter created shall be classified according to the 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

12.3.Multiplexes

In many of our major cities, Multiple occupancies, or what are commonly known as “Multiplexes” are coming up, which are buildings having independent occupancies like Shopping Centre, Cinemas, Restaurants etc., simultaneously in one building complex. These multiple occupancies contain high fire and life hazard potential, and hence call for stringent fire prevention and fire protection measures.

Occupancy or Use Group: In the case of mixed occupancy, the actual occupancy classification of the building or premises will be on the basis of the principal occupancy class. A building need not necessarily be inhabited. Temporary structures need not be construed as buildings.

12.4.Change of Occupancies

Owner or the occupier shall apply in writing to the local authorities concerned for any alteration, modification, extension etc, of the building along with necessary drawings, specifications etc., and obtain necessary clearance for the same from the authorities concerned.

After completion of the work also, a Completion Certificate should be countersigned by the designated authorities after inspection.

12.5.Unsafe Buildings:

Unsafe Buildings are those which are:

(i) deficient in means of egress;

(ii) has a potential hazard from fire or natural or man-made threats;

(iii) dangerous to human life or public welfare by reasons of illegal or improper use, occupancy or maintenance;

(iv) non-compliance with the provisions of the applicable Codes:

(v) significantly damaged by fire or explosion or other natural or man-made cause;

(vi) incomplete buildings for which building permits have expired;

(vii) buildings having deteriorated structural elements or partially destroyed buildings;

(viii) unsanitary buildings

All unsafe buildings shall be considered to constitute danger to public safety and shall be restored by repairs or demolished or dealt with as otherwise directed by the Authority. “Notice shall require the owner or the occupier within a stated time either to complete specified repairs or improvements or to demolish and remove the building or portion thereof.”

The Authority may direct in writing that the building which in his opinion is dangerous, or has no provision for exit if caught fire, shall be vacated and protect the public by an appropriate fence or such other means as may be necessary.

13. General Guidelines for Good Fire Safety Management:

- Good Fire Safety Management involves and implies Good Life Safety Management also. Essentially Life Safety implies keeping the harmful effects of fire away from the occupants of the building, or vice versa, by keeping the occupants segregated from the harmful effects of fire, by adopting methods based on time, distance or shielding. Life Safety also depends to a large extent on the physical and mental characteristics of the occupants, as individuals and as a group.

- Fire Prevention, wherever and whatever is possible can also, to a great extent, make positive contributions to fire and life safety. However, it will be prudent to bear in mind that no fire prevention strategy can be totally effective.

- Good Fire Safety Management takes note of all these factors and adopts an **integrated systems approach** so as to achieve optimum results.

13.1. Staircases/Means of Egress

- In all cases the leading edges of all treads should be readily visible during both descent and ascent;

- Means of egress must permit unobstructed travel at all times;

- **Hand-rails:** It is worth noting that handrails are one of the most important components of a staircase, and therefore, its design should be such as to enable a comfortable grip and also to facilitate the hand to be slid along the rail without encountering obstructions while negotiating the stairs;

- One or two steps at a doorway are considered to constitute an accident hazard in emergency use, and hence should be avoided.

13.2. Smoke Control/Smoke Management

- Smoke Management includes all methods which are resoted to, either singly or in combination, to control smoke movement for assisting easier and more speedy means of egress for occupants, for assisting firefighting operations, and for reducing property damage. Compartmentation, dilution, airflow control, pressurisation, and buoyancy of smoke can be utilised alone or in combination for smoke management, to minimise the smoke hazard in building fires;

- For ensuring that products of combustion in a fire do not enter a smokeproof stair enclosure, the following guidance is provided;

"The smoke control system should ensure on a 97 percent basis for the geographical location of the building, that the atmoshphere of the smoke proof enclosure will not, during a period of 2 hours, including a quantity of air emanating from the fire area that is more than 1 percent of the volume of the stair enclosure" (NFPA 101)

13.3. Atrium Buildings: Need special attention with regard to design, fire protection and smoke control. Fire protection in such buildings are usually provided by combination of methods like compartmentation, ventilation, automatic suppression and smoke control. Products of combustion from a fire get diluted with air in large volume atria, and with proper ventilation their flow can be safety directed to the outside.

- Where vision panels and fire windows are provided, it has to be remembered that they may transmit heat by both conduction and radiation.

13.4. Special Structures and High-Rise Buildings: Special structures, including open structures, towers, underground and windowless structures, high-rise buildings, multiplexes etc; pose special problems with regard to fire and life safety requirements, and hence call for special considerations in design, lay-out and construction aspects. Best results are achieved by sound design and engineering judgement and common sense.

- Special attention needs to be given on component elements such as concealed combustible spaces, remoteness of exits, enclosure, illumination and marking of exits, controlled interior finishes, automatic suppression systems, smoke control systems, fire detection and alarm systems, containment of hazardous areas etc;

- These complex occupancies call for a well thought out fire engineering approach to achieve a satisfactory standard of fire and life safety.

13.5. Means of Escape: The design of a building shall be such that in an emergency the occupants in any part of the building should be able to escape safely without any external assistance, except in the case of physically challenged(disabled) people who have to be rendered assistance.

- It is the responsibility of the management of the premises to ensure that necessary facilities are provided in the building so that the occupants can evacuate the building in reasonable time in case of fire or other emergency.

13.6. Provision of barrier free environment for physically challenged people (physically disabled people) has been made mandatory in some of the Building Bye-laws and Development Control Regulations in the country. Provision for movement of disabled persons to areas of safety within the building (Refuge Areas) has also been included in these Regulations.

13.7. Certification Scheme: Since the fire performance of a system, products, components or structure is dependent on satisfactory site installation and maintenance, independent schemes for certification/accreditation and registration of installers and maintenance firms will have to be introduced in our country so as to ensure conformity with approved standards and codes, as well as for elimination of use of sub-standard products.

14. Fire Safety Management as applied to different occupancy groups are discussed below:

14.1. Residential Buildings(Group A)

- Good Fire Safety Management in homes call for strict and constant observance of all the common home fire safety rules for kitchen fire safety, gas fire safety, electrical fire safety etc;

- Every Residential occupancy, including residential homes and flats, should formulate a suitable fire escape plan so that every occupant in the building can promptly and safely evacuate the premises in the event of a fire or any other emergency. In the case of Dormitories, Hostels, Hotels etc., the evacuation plans have to be made out with extreme care as more number of occupants are involved;

- The fire escape plans have to be practised periodically by the occupants in the form of 'mock fire drills' so that the evacuation of the occupants in the building can be carried out promptly, smoothly and in an orderly manner avoiding panic and confusion which can lead to accidents and injuries;

- It has to be ensured that the exits and stairways of the building are always kept clear of all obstructions or hazardous materials;

- Where Residential and Non-Residential Occupancies co-exist, extreme care has to be taken in the design and construction of the premises so as to ensure that all essential fire and life safety requirements as per Codes are incorporated in the building;

- No dwelling unit of a Residential occupancy shall have its sole means of egress pass through any part of non-Residential occupancy in the same building;

- Interior finishes, including floor finishes in Residential occupancies, shall be of approved classes as per relevant Codes/ standards;

- Building Services, including lifts/escalators shall be of standard approved types as per relevant Codes/Standards.

- Rooms containing A/C plants, high-pressure boilers, transformers etc, having fire and explosion hazards, shall not be located directly under or adjacent to exits. Walls of enclosure for such rooms shall have minimum 4 hrs. fire resistance.
- Flammable liquids for household purposes shall be kept in tightly stoppered or sealed containers. Particular care has to be taken to avoid storage of low flash point flammable liquids like petrol in residential accommodation.
- No stove or combustion heater shall be located directly under or immediately at the foot of stairs or otherwise so located as to block escape.
- Kitchen exhaust ducts are hazardous since they convey hot and flammable gases and vapours. All kitchen exhaust fans, shall be fixed to an outside wall or to a duct of noncombustible material, which leads directly to the outside.
- All outdoor antennae shall be properly grounded and protected from lightning.
- Doors leading to rooms in which flammable liquids are stored or used shall be posted with a sign on each side of the door in 50mm high block letters stating - **'Fire door-Keep closed'** In addition, they must have the required fire resistance also.

14.2. Educational Buildings (Group-B)

- Educational occupancy is distinguished from Assembly occupancy in that in the former the same occupants are regularly present, and they are subject to discipline and control;
- All educational buildings of permanent nature shall be of Type I construction having external shell and load bearing elements of 4 hrs. fire resistance rating, while internal / non-load bearing walls shall have 2 hrs. fire resistance;
- All educational buildings not of permanent nature, may be of Type II or Type III construction as per IS 1642. All such semi-permenant buildings shall be restricted to ground and one upper floor only, and the floor area not exceeding 1000 m^2 on each floor;
- Type IV construction, as well as temporary structures, such as tents or with thatched construction, shall not be allowed for housing educational institutions;

- Basement, if constructed, should not be used for classrooms, laboratories, libraries or for assembly halls;
- Every clasroom with a capacity of 45 persons or more should have minimum two door exits;
- The occupant load of educational buildings or any individual story or section for determining the exits required shall be not less than one person per $4m^2$ of net area;
- There shall be at least two exits available from every floor area;
- All internal staircases, lift, lobbies and corridors should be adequately ventilated and illuminated;
- Emergency lighting in accordance with approved standards must be provided for all interior stairs and corridors and normally occupied areas;
- NO exit doorway shall be less than 1m. The height of door shall not be less than 2m;
- The doors shall open inwardly wherever the doors lead to corridors or open on landings leading to flight of stairs;
- Any building having area more than 500 m^2 on each floor, and 15 m or more in height, shall have minimum two staircases of enclosed type;
- Internal stairs shall be constructed of non-combustible materials throughout;
- The width of staircases shall not be less than 1.5 m for building up to a height of 30 m;
- **Educational buildings above 30 m in height are not permitted**;
- Minimum width of treads for stairs shall not be less than 300 mm. The treads shall be constructed and maintained properly so as to avoid slipping during use;
- Maximum height of riser shall not be more than 150 mm and number shall be limited to 15 per flight;
- No living space, store or other fire risk shall open directly into the staircases;
- The main staircase and external staircase shall be continuous from ground floor to the terrace level;
- No combustible material (interior finish) shall be used for decoration/wall panelling in the staircase;

- Floor indication boards shall be prominently indicated on the wall facing the staircases near to the landing. It shall be of size not less than 0.5 x 0.5 m;
- All exit marking signs shall be prominently indicated showing the way to the escape route, and the same shall be illuminated by electric light connected to corridor/staircase circuits along with emergency lighting, which should be designed to come on within one second of the failure of the normal lighting supply, and to remain on continuous operation for a minimum duration of 1 hour and 30 minutes;
- If external stairs are provided, care has to be taken to ensure that no wall opening or window opens on to or close to an external staircase;
- No combustible material of any kind shall be stored or used in any building or section thereof;
- Bare minimum quantities of flammable materials such as chloroform, ethyl alcohol, spirit, etc shall be allowed to be handled or stored;
- Doors in fire resistant walls shall be so installed that these may normally be kept in open position, but will close automatically when required;
- Corridor door openings in smoke barriers shall be not less than 1500 mm in width. Provision shall also be made for double swing single/double leaf type doors;
- Any room in which volatile flammable substances are used or stored, shall be provided with a suitably designed exhaust ventilation system. Proper care shall be taken in providing electrical installations in such rooms, which should conform to approved standards;
- Ventilators should be provided near cieling level for lighter than air vapours, and near the floor for heavier than air vapours like LPG;
- Fire Protection and Life Safety requirements as stipulated in National Building Code Part 4, latest version, as well as IS 14435 1997, 'Fire Safety in Educational Institutions-Code of Practice' should be complied with for all Educational Buildings;

- Portable fire extinguishers as per scales recommended in IS 2190-1992, 'Code of Practice for Selection, Installation and Maintenance of First Aid Fire Extinguishers' should be installed in all Educational Buildings;

- Teachers and other staff of the Educational Institutions should be sensitised to their responsibilities for the safety and well being of the students. They and selected Senior Students should also be trained in the use of first aid fire fighting equipment in case of fire emergency;

- Cooking of food, where carried out in Schools, should be done at a safe place, in a detached building, away from the main building where class rooms are located;

- If gas or electricity is used for the kitchen, proper safety measures have to be exercised in the handling of the connected equipment, and the ovens/burners should be kept at an elevated surface compared to the cylinders;

- Educational Institutions having auditorium should have fire protection and means of exit arrangements as required for similar capacity Assembly occupancies;

- Laboratories in the Educational Institutions shall comply with all the fire safety measures as stipulated in relevant standards, like IS 4209-1987, 'Code of Safety for Chemical Laboratories';

- Computer Rooms, where provided in Educational Buildings should have the fire protection arrangements as prescribed in IS-12456-1988, 'Code of Practice for fire protection of electronic data processing installations';

- Educational Buildings having height 15m or more should comply with fire protection and life safety norms for high rise buildings as prescribed in NBC Part 4;

- Emergency Plan should be made by all Educational Institutions, and evacuation drills should be organised at regular intervals, which should be not less than once a quarter;

- Along with the evacuation drills, it will be desirable to organise short duration special training programmes on any safety subject, so that the students from their very young age will be suitably trained in inculcating safety habits;

14.3. Institutional Buildings (Group-C)

14.3.1. General

- Fires in this type of occupancy had shown a rising trend in the last two decades, presumably because there had been an increasing number of such wide ranging occupancies also;
- As compared to normal Residential occupancies, Institutional occupancies, by and large, provide personal care services of occupants;
- As against Health Care Facilities, which fall under the Group, other categories of building covered by this Group such as Jails, Prisons, Orphanages, Old-age Homes, Day Care facilities etc., fall in the ordinary hazard classification with hardly any fire load density. However, life hazard potential is quite substantial, especially since freedom of movement of the inmates is generally restricted with limited or ordinarily blocked exits, and in several cases evacuation of occupants, particularly those with impaired physical and mental capacities, needs assitance;
- The staff employed in these occupancies have a major role to play in the life safety of occupants, and hence need special aptitude and training for effecting timely and orderly evacuation of occupants. These evacuation drills/training have to be practised periodically, atleast once in every three months;
- Since the ultimate responsibility for the life safety of the inmates of the Detention, Correctional, Asylums and such other Institutional occupancies rests with the Management of such occupancies, they have to ensure that all basic standard requirements of fire and life safety in the design and construction of the buildings, including the fire protection facilities, are adequately provided and properly maintained;
- A Systems Approach is necessary so that the fire safety as well as security requirements for such occupancies are controlled harmoniously without adopting contradictory concepts;

14.3.2. Fire Prevention/Fire Safety Measures in Health Care Facilities

- Potential fire and explosion hazards associated with medical gas piping systems shall be taken into account in the design, installation, testing, operation and maintenance of these systems;
- All stipulated safety precautions should be observed in the storage and handling of various types of gas cylinders which are usually found in such occupancies;
- Similarly, all necessary precautions should be observed in the storage and handling of bulk cryogenic liquid systems (generally liquid oxygen);
- Specific precautions are to be taken to protect oxygen cylinders, containers and associated equipment from abnormal mechanical shock and heat;
- Full cylinders shall be stored/kept segregated from empty cylinders;
- The floors of operation rooms, anaesthetezing locations and such other rooms/locations and contiguous areas where hazardous gases/vapours are likely to be present should have conductive floors to equalise/dissipate possible static charges. A resistance not exceeding 50 mega ohms is generally sufficient to prevent accumulation of dangerous electrical charges. Personnel entering such hazardous areas shall wear shoes having soles and heels of conductive rubber;
- As a general guidance, the undermentioned anaesthetic agents are considered flammable during conditions of clinical use: Cyclopropane, Ethylene, Ethyl Ether, Divinyl Ether, Ethyl Chloride etc;
- The following anaesthetic agents are considered non-flammable during conditions of clinical use: Chloroform, Nitrous Oxide, Halothane, Trichloroethylene, Methoxyfluorane, Enfluorane;
- Wherever clinical procedures are performed like operation rooms, delivery rooms etc., special mechanical ventilation arrangements are required. It will be desirable to maintain slight positive pressure in such areas to prevent infiltration of contaminated air into such sensitive areas;

- While plastic containers are preferred to glass containers to avoid breakage problems, care has to be exercised in the choice of plastic containers in their compatibility with the liquid to be contained;
- The relevant pollution control rules regarding the safe disposal of hospital wastes, which may contain various hazardous materials, have to be scrupulously complied with(Bio-medical Waste (Management and Handling) Rules, 1998 refers);
- It is essential that core personnel employed in hospital facilities like doctors, nurses, aides, wards, attendants, etc, shall be indoctrinated in all aspects of fire prevention, fire safety, evacuation procedures, etc. in case of emergencies. To ensure this, regular instructional programmes and fire drills should be conducted and records maintained;
- However, it has to be remembered that life safety of all the patient occupants in health care facilities cannot be adequately assured by evacuation procedures alone. It is, therefore, necessary that the fire protection measures incorporated and maintained for such occupancies should be of the highest standards so as to ensure maximum life safety opportunities for the occupants.

14.4. Assembly Buildings (Group-D)

- Mixed Occupancies are predominantly life hazard occupancies;
- Places of assembly in buildings of other occupancy, shall be so located, separated or protected as to avoid any undue danger to the occupants of the place of assembly from a fire originating in the other occupancy or smoke therefrom;
- Canteens in auditoriums pose substantial fire and life safety hazards, and are not recommended to be located in the basements. In any case, they must be sprinklered;
- All rooms or areas used for storage of any combustible materials or equipment, or for painting, refurbishing, repair or similar purposes shall be effectively cut off from assembly areas. Thy shall be located away from staircases. Besides installation of sprinklers, it will be necessary for provision of fire barriers (fire resistant seperating walls) also to segregate the fire hazardous areas from Assembly areas;

- Rooms containing equipments subject to possible explosion shall be effectively cut off from other parts of the building, and provided with adequate vents to the outside air;
- The proscenium wall of every theatre using movable scenery or decorations shall have exclusive of the proscenium opening, not more than two openings entering the stage, each not to exceed $2m^2$ and fitted with self-closing fire resistant doors;
- The decoration of places of assembly shall be of non-flammable materials. Fabrics and papers used for such purposes shall be treated with an effective flame retardant material. Stage settings made of combustible materials shall likewise be treated with fire retardant materials of Class 1 flame spread;
- Decoration materials and stage settings of combustible nature have been the cause of several theatre fires, which have resulted in total losses;
- The curtain shall have an emergency closing device capable of causing the the curtain to close without the use of power, and when so closed, it shall be reasonably tight against the passage of smoke;
- The stage roof of every theatre shall have a ventilator or ventilators in or above it, operable from the stage floor by hand, and also opening by fusible links or some other approved automatic heat/smoke actuated device, to give a free opening equal to at least one-eighth the area of the floor of the stage;
- The handling and use of gasoline, fuel oil and other flammable liquids shall not be permitted.

14.5.Business Buildings (Group E)

14.5.1. Business buildings shall be further sub-classified as follows:

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

Subdivision E-2: Laboratories, research establishments, libraries and test houses.

Subdivision E-3: Computer installations.

Subdivision E-4: Telephone exchanges.

Subdivision E-5: Broadcasting stations and T.V. Stations.

14.5.2. The fire protection and the means of escape requirements for business buildings are as given below:

- Business Buildings have no restrictions in height;
- They should be of fire resistant construction;
- Materials used for interior finish, furnishings etc. should be of Class-1 flame spread;
- The ocupant load for business building should be $10m^2$/person;
- The ocupants per unit exit width should be 50 for stairways, 60 for ramps and 75 for doors;
- Exits shall be so located that the travel distance on the floor shall not exceed 30m;
- No exit doorway shall be less than 1m in width;
- Exit doors shall not open immediately upon a flight of stairs;
- All means of exit including staircases, lifts, lobbies and corridors shall be adequately ventilated and lighted;
- Internal staircases shall be constructed of non-combustible material and should be protected staircases;
- No gas piping shall be laid in the stairway;
- No part of the building should be utilised for storage of flammable liquids or hazardous materials;
- Individual floors shall be prominently indicated on the wall facing the staircases as well as lift landings;
- Incase of high rise buildings, all necessary fire protection as well as means of exit requirements as per NBC Part IV should be incorporated;
- In case of high rise buildings, fire lifts should be provided as per Code;
- All requirements of Emergency and Escape Lighting as per Code should be implemened.

14.5.3. Due to the under mentioned reasons, the life safety requirements in business buildings amount to early alerting the occupants in case of fire or any other emergency, and providing adequate facilities for escape / evacuation so as to ensure life safety of the occupants considering the type and nature of the building:

- Building remains occupied generally only during day time;
- Occupants are generally expected to be alert;
- Occupants are expected to be familiar with the lay out and exits of the building;
- Generally, majority of the occupants are expected to be physically capable of self-evacuation in case of fire or other emergency. Assistance or special evacuation help will have to be rendered to physically challenged (disabled) people;
- Total evacuation may be difficult in case of a high rise building fire, in which case, phased evacuation may have to be adopted.

14.5.4. Other factors:

- The fire load in Business buildings is defenitely lower than Storage, or Hazardous occupancies. But, the occupant load, and thus the life hazard potential in these buildings, is quite high and, therefore, it is necessary that the Business buildings, especially those with larger areas and more floors, must have the stipulated scales of fire protection requirements as per Codes;
- The designer and the Code oficials will have to undertake a pre-evaluation of life safety as well as fire protection systems required for Business buildings taking into consideration factors like the need for support services for such premises like cafetarias, kitchens, auditoriums, storage areas, car parking facilities, small retail outlets etc. Similarly, the Code as well as mandatory special design and construction requirements for the access, movement, accommodation as well as for the means of exit requirements for physically challenged people, also have to be adequately incorporated in the buildings.

14.6. Mercantile Buildings(Group F)

14.6.1. As per NBC Part 4, Mercantile buildings form 3 sub-divisions:

Sub division F-1: Shops, Stores, Departmental Stores, Markets, with area up to 500 m^2;

Sub division F-2: --do-- with area exceeding 500m^2;

Sub division F-3: Underground Shopping centres, and larger Shopping Malls/Centres.

- Department Stores and Super-markets contain different kinds of merchandise, which together can constitute high fire load.

Generally, these buildings may be multi-storeyed ones, with customer movement patterns permitting both vertical and horizontal movements. Storeyed buildings have open stairs and sometimes escalators also. Their peculiar design, layout and high fire density, along with a large number of floating customer population as well as staff, all in combination virtually make these premises highly vulnerable from fire and life safety point of view;

- It follows from the above, as well as from the world-wide experience gained in the past through major fires in Department stores, that a lot of careful thought and planning have to be addressed in the design and construction of the buildings, and the fire protection and means of exit arrangements required to be incorporated in such buildings must also be of the highest standards. Stringent Code implementation is a must in such occupancies;
- Mixed Occupancies of this nature are quite hazardous and quite a few fire incidents had occurred in different cities / towns in India and abroad in such premises causing fatalities, especially in big Departmental Stores. Hazardous areas shall be segregated.

14.6.2 In some of the cities in India (like Surat for instance) there are huge multi-storey (high-rise) complexes such as Textile Market, where bulk quantities of textile materials are stored, along with retail outlets also. The high fire hazard potential in such complexes necessarly call for high standards of fire protection also.

14.6.3. In the case of Underground Shopping Complexes, the hazards are much more multifarious with more serious evacuation problems. Therefore, such complexes also shall scrupulously comply with all the fire and life safety protection requirements as stipulated in the Codes.

14.6.4. Apart from 'over-roof' mercantile operations, mercantile units o function in basements and sub basements levels also in our cities. These below grade shop complexes are quite fire hazardous and warrant due fire protection messures, like mandatory sprinkler protection.

14.6.5. Apart from what has already been stated, all Building Codes should address the problems relating to covered mall shopping centres also, particularly the life safety concerns.

14.6.6. Occupancies where goods of a highly hazardous nature are predominant, shall be considered under Hazardous buildings.

14.7. Industrial Buildings (Group G)

14.7.1. Subdivisions: Buildings under this Group are subdivided according to hazard categories:

Subdivision G-1: Buildings used for **low hazard** industries in which the contents are of low combustibility;

Subdivision G-2: Buildings used for **moderate hazard** industries in which there are possibilities of fires which may burn with moderate rapidity, and may give off large volumes of smoke;

Subdivision G-3: Buildings used for housing **high hazard** industries, which are liable to give rise to fires which will burn with extreme rapidity, and from which pistonous fumes or explosions are also likely.

- Guidance with regard to the classification of Industrial Buildings into low, moderate and high hazard classes and the types of industrial buildings coming under this subdivisions can be obtained from Annex-B to Part 4, NBC;
- In case of mixed occupancies of G-1, G-2, and G-3 classes of industries in one building, where no partition walls are provided between the various classes of occupancies, the entire building will have to be considered as a G-3 premises, and the fire protection requirements which are commensurate with high hazard class industry will have to be provided.

14.7.2.General

- Global statistics bear out the fact that fires and explosions in industrial and manufacturing facilities, which come under this Group of Occupancies, account for the major portion of direct material losses as well as indirect losses (such as production losses) in a country. In the matter of loss of lives also this Occupancy Group is one among the front ranking Groups like Assembly. The large number of such occupancies which abound in urban and rural areas in the country, as well as the innumerable types of hazardous materials handled and processed in these promises, and human factors are generally responsible for such heavy losses;
- The hazards involved in industrial occupancies vary greatly and, therefore, an integrated approach has to be followed in the matter of provision of adequate fire and life safety requirements for such premises;

- Factors to be considered for evaluation of life safety risks are materials used for interior finish, rate of fire spread, burn rate, evaluation of toxic fumes, potential ignition sources, fire load and smoke generation. Property protection follows employees evacuation;
- Industrial occupancies which come under the purview of Industrial legislation of the Central / State Government, for starting, siting, operating etc. of the industry, have to comply with the relevant provisions of the same, apart from complying with the requirements specified in relevant Parts of NBC as well as local Codes/Bye-laws/Regulations regarding design, and construction of the buildings and for incorporation of the fire and life safety requirements in the buildings;
- Hazardous, pollution-prone etc. industries, as designated by the authorised legislation, are required to formulate and submit their On-site and Off-site Emergency Plans to the concerned authorities on specified time schedules. The details of these requirements, including the details of information to be furnished on various documents/forms (to be submitted to appropriate authorities) like Safety Report, Safety Data Sheet, On-site Emergency Plan, Off-site Emergency Plan etc., are given in various Schedules under the Manufacture, Storage and Import of Hazardous Chemicals Rules 1989, issued by Govt. of India.

14.7.3. Whenever flammable vapours/ gases are present within their flammable limits, the slightest spark created by the operation of electrical equipment like switches or spark producing tools(friction sparks) can give rise to fire or explosion. While safety from electrical sparks can be achieved by safe electrical equipment/apparatus as already mentioned, spark from tools can be avoided by use of non-sparking tools.

- If Petroleum liquids are stored or handled at temperatures at or above their flash point, they should be treated with extreme caution (as for class-1 flammable liquids). Hazardous area normally covers an area extending upto 15m from equipment handling flammable/combustible liquids, or 30m from equipment handling flammable gases;
- In appropriate cases, clearance from the Chief Controllor of Explosives (Explosives Dept.) will also be necessary;

- Electricity generation can be done from conventional sources using coal, oil, gas turbines or diesel generating sets. Apart from above, Hydro-power and Nuclear power generation also are employed. Each one of the types have their own fire hazards which call for appropriate fire protection measures as stipulated in relevant Codes;
- In case of any fire outbreak in electricity generating and distribution stations, such occuapncies may not only completely disrupt the life of the community as a whole, but several other industries and enterprises depending upon them for power will also face shut down;
- **Industrial buildings of low and moderate hazard are permitted only up to 18 m height;**
- **Industrial buildings of high hazard are permitted only upto 15 min height;**
- The primary factors to be considered are building design, construction, nature, fire load potential and quantity of raw materials, fire and explosion hazards potential of processes involved, and the fire hazard potential of products (storage, handling and transportation risks of different chemicals);
- It is important that building design, process lay out and the fire protection systems allow for safe and prompt occupant egress in the event of fire or explosion;
- Since explosions are probably the cause for most destructive industrial accidents in terms of life and property loss, they require special attention. Flammable dust, vapours, mist or gas presents an explosion hazard. A carefully designed system is needed to ensure life safety from explosive forces. Specialised equipments designed to detect, suppress and control damage from explosions are available and must be utilized judiiciously;
- All high hazard industrial occupancies shall have explosion venting for any area subject to explosion hazard;
- The choice of the fire protection system shall depend onthe nature of the risk to be covered at the planning and design stages. Every detail with regard to maintenance of adequate safeguards against likely fire and explosion hazards in the entire premises will have to be taken care of.

14.8. Storage buildings (Grouip H)

14.8.1. General

- Storage occupancies can also be classified as low, ordinary or high hazard depending on the fire load of the materials stored. In many cases, it can be a combination of these also;
- Modern development in material handling techniques have led to adoption of high-stack storage areas, going up to 30 m height also;
- Materials in storage may also contain highly flammable liquids and gases. Special storage arrangements are adopted for flammable liquids like storage tanks(large cylindrical/horizontal storage tanks in Tank Farms as found in Oil Installations), and large cylindrical /horizontal/Spherical tanks/ containers etc for gases. The fire protection requirements for such storage occupancies are given in relevant Standards and Codes. They are not covered under Building Codes;

  Properly installed and maintained automatic sprinkler systems provide a highly effective protection against life and property losses in Storage occupancies;
- However, care has to be taken to ensure that sprinkler system design is compatible with the materials stored and with high-stack storages;
- Also, it will be necessary to supplement the sprinkler system with other measures like hydrant system, hose-reels, fire extingishers etc;
- Cold Storage warehouses, which are primarily used for extended storage of perishables like food products, have also their peculiar fire hazards even though the inside temperatures may be as low as-40^o C. The fire hazards primarily arise form the use of combustible materials like cork or expanded foam used for insulation, dunnage, packing materials etc. Polyurethane foams or polystyrene foams, which are commonly used as insulation materials, are not only highly combustible but also generate thick highly toxic smoke and gases which can prove a life hazard also. Besides, the refrigerant gases can also pose toxic and flammable hazards. A well designed automatic sprinkler system, with anti-freeze additives, is the ideal primary fire protection measure for such premises;

- All Storage occupancies should formulate an appropriate and efficient Emergency Plan, which should be regularly practised.

14.8.2. Large number of fires occur in storage occupancy group mainly becaue of the following reasons:

- They have the highest values of fire load density (up to 500 kg/m^2);
- The premises remain unoccupied most of the time, and if a fire breaks out, it remains undetected for some time, and by then it assumes serious proportions;
- By the time fire brigade is sommoned and arrives at the scene, the fire would have become a major one making fire fighting operations prolonged and difficult. The godwowns are invariably packed up to cieling /roof level, with few and inadequate aisles between stacks, rendering the fire fighting operations difficult;
- Level of even essential fire protection arrangements remain far below the stipulated minimum standards, or the existing fire protection systems fail to operate due to bad maintenance;
- Careless smoking;
- Electrical faults (bad maintenance);
- Bad house keeping;
- Spontaneous ignition (of oil/paint smeared cotton waste thrown underneath the stacks after cleaning/maintenance work);
- External sparks (from moving locos etc.);
- Welding /cutting, spray painting etc. within the building;
- Use of naked lights/ heaters/signs inside the building;
- Use of highly combustible materials like cork, expanded foam insulations etc. in cold storages;
- Large amounts of packing materials (including plastic expanded foam), paper, straw etc. which are invariably present in warehouses;
- Storage of hazardous cargo also along with other stores without proper segregation;
- Storage of flammable stores in 'bonded goods' area;

- Badly maintained or over - taxed sprinkler systems;
- Careless handling of mechanical handling equipment like EOT cranes, Forklift trucks etc;
- Failure to carry out regular closing hour checks;
- Arson/Sabotage.

14.9. Hazardous Buildings (Group J)

14.9.1. General

- NBC Part 4 explains in detail the purposes for which this group of buildings are utilised. Hazardous buildings are used for storage, handling, manufacturing and processing of a wide range of hazardous materials, generally in substantial quantities;
- Hazardous materials are materials which may be explosive, flammable, poisonous/toxic, corrosive or otherwise harmful, and likely to cause death or injury to persons / living beings.

14.9.2. The various central legislation governing the manufacture, storage, handling etc. of the hazardous materials are as given below:

Environment (Protection) Act, 1986;

Environment (Protection) Rules, 1986;

Hazardous Wastes (Management and Handling) Rules, 1989;

Manufacture, Storage and Import of Hazardous Chemicals Rules,1989.

- Fire and life safety deals with protection of both lives and property, and hence buildings storing, handling, manufacturing or processing hazardous materials are placed in this group of buildings posing the highest hazard.

14.9.3. Other Points:

- All openings in exterior walls made for utility services shall be protected by fire stop assemblies;
- Each building shall be provided with a power driven fan exhaust system of ventilation which shall be arranged and operated so as to produce a complete change of air in each room every 3 minutes;

- Breakage of gas line due to heat of fire can be disastrous. Approaching gas control valves in a room on fire becomes dangerous;
- Control Valve should be located outside the building. Such valve location should also be conspicuously marked on external walls for locating them readily in case of emergency;
- Use of explosion suppression system helps tackling explosion at early stage;
- Each building where gas is employed for any purpose shall be provided with an approved outside gas shut-off valve conspicuously marked;
- Any room in which volatile flammable substances are used or stored should be enclosed in a flameproof enclosure;
- Equipment or machinery which generates or emits combustible or explosive dust or fibers shall be provided with an adequate exhaust system;
- Certain dusts, besides being environmental hazard, can cause dangerous explosions if they are allowed to mix with air so as to reach their explosive limit.

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SECTION 9 - BUILDING CODES AND REGULATIONS - AN OVERVIEW

15.1. Early Building Codes

All through the history of mankind, there have been Building Regulations for safeguarding against fires and fire spread. Over the years, these regulations evolved into Codes and Standards developed by assigned Committees / Bodies responsible for community safety.

King Hammurabi, who ruled over Babylonea some 3500 years ago, will ever be remembered for his 'oft-quoted' stringent decree from his Code which ran as follows:

"In the case of collapse of a defective building, the architect is to be put to death, if the owner is killed by accident; and the architect's son, if the son of the owner loses his life".

The present day society can never even imagine of enforcing such barbaric laws of retaliation. Nevertheless, this historic anecdote gives an insight into the extreme importance and value the old civilisations used to bestow on human as well as building safety, in addition to the high levels of accountability and penalty which was being atached to Code violations.

Safety is often reckoned as the opposite of risk. Greater safety means less risk (elimination, or at least minimisation of risk) to people or property. Risk can never be eliminated, and hence safety can never be absolute.

15.2. Role of Codes in Community

A Building Code is a law that sets forth minimum requirements for design and construction of buildings and structures. These minimum requirements are established to protect the health and safety of society, and generally represent a compromise between optimum safety and economic feasibilty. Although builders and owners often established their own requirements, the minimum Code requiements must be met. Features covered include structural design, fire protection, means of egress, light, sanitation, and interior finish.

There are two types of Building Codes. **(i) Specification Codes** which spell out in detail what materials can be used, how large(or small)the building can be, and how components should be assembled.**(ii)Performance Codes,** which detailed the objective to be met, and establish criteria for determining if the objective has been achieved. The designer and builder are, thus, allowed freedom in selecting constructional methods and materials as long as the performance criteria can be met. Performance oriented Building Codes still embody a fair amount of specification - type requirements, but the provision exists for substitution of alternate methods and maerials, if they can be proved as adequate. The promulgation of modern Building Codes began with disastrous fire incidents which had taken place at the turn of the century. Thus, it is understandable that Building Codes and Fire Protection are partners in alleviating the loss of life and property.

The impact of Building Codes on Fire Protection and Prevention resulted in the establishmen of height and area criteria.

15.3.Role of Standards in Building Codes

Several of the provisions found in Building Codes are based on the standards published by nationally recognised organisations. The most extensive use of the standards is their adoption into the Building Code by reference, thus keeping the Building Codes to a workable size, and eliminating dupication of effort.

Building Codes and Fire Protection are two sides of the same coin, which serve to alleviate the loss of life and property. The architectural design of a building has a significant effect on its fire safety characteristics. Similarly, the fire protection measures incorporated for the buildng, both active and passive, also provide reasonable safety from the effects of fire.

15.4.National Building Code

It was as a sequel to the recommendations of a Panel ofExperts contituted by the Planning Commission in 1965 that Bureau of Indian Standards(the Indian Sandards Institution)was entrusted with the task of preparation of a National Building Code to bring in uniformity in the builing regulaions throughout the country for adoption by Govt. departments, local authorities and other construction agencies. The first version of NBC was published in 1970.

15.5. A vigorous implementation drive was taken up by the BIS(ISI) as well as the Fire Advisor's Office in the Ministry of Home Affairs to disseminate and propagate the contents for adoption by all concerned. Action Committees were set up by various state and local bodies not only for implementation of the Code, but for periodical review of the existing regulatory provisions at various levels also. Consequent to receipt of several comments and useful suggestions for modifications and additions to the various clauses in the Code, a revised version of the entire NBC was pulished in 1983 which is currently in vogue now.

15.6. The NBC has ten Parts, of which Part IV deals with Fire Protection. The provisions of the Code are formulated on the information contained in various Indian Standards woven into a continuous and cogent pattern relevant to each Part, and so framed to make the adoption process easy. Instructions from the Central Govt. do exist to the effect that the provisions of the NBC serve as a model for adoption by governmental departments local authority and other implementing organisations.

15.7. Part IV Fire and life safety consists of 17 Sections and 7 Appendices. Consequent to receipt of several comments and observations from various agencies, the BIS had instituted a Panel of Experts in 1995 (with Shri G.B. Menon, ex-Fire Advisor, Govt . of India as Convener of the Panel, who is also one of the two fire experts co-opted as a Consultant for this Project under GSDMA) for revision of Part IV. The panel worked under the jurisdiction of Fire Safety Sectional Committee CED-36, of which Shri J.N. Vakil, ex-Asst. General Manager, Tariff Advisory committee, Govt. of India, the other fire expert co-opted as a Consultant for this Project, was the Chairman.

15.8. Part IV prescribes only the basic minimum requirements for achieving fire and life safety in buildngs, and nothing in the Code prohibits better type of building construction, more exits, or other conditions that are prescribed in the Code. A point worth mentioning here is that while assessing the extent of fire hazards in a building, the nature of occupancy and the activities pursued by the occupants of the building must also be taken into consideration.

15.9. As per a dicision taken by the BIS last year the ten Parts of the NBC Part-IV are undergoing revision at present. The Convenor for the Panel for revision of Part IV is Shri.S.K. Dheri, ex-Chief Fire Officer Delhi Fire Service, who is a well-known expert in fire protection field.

15.10. In this context, it is mentioned that the Commentary and Handbook have been prepared on the basis of the last Draft Revision of NBC Part-IV which was circulated as well as the decisions taken in the relevant Committee Meeting. Part IV is still under revision.

15.11. International trends in Building Codes

In the west, initially reactive legislation followed particularly devastating fires like the Great Fire of London in 1666. Dedicated fire safety regulations and controls got formalised only since the last century. However, in the advanced countries like U.K., U.S.A., Europe etc., there has been an increasing trend for addressing the fire safety of buildings and structures through the recently developed discipline of Fire Safety Engineering. It can be defined as the application of scientific and engineering principles based on an understadning of fire, and of the behaviour of people in fire, in order to protect people, property and the environment from the destructive effects of fire. These objectives are achieved for building fire safety by a range of processes including:

- Assesement of the fire hazards and its effects;
- Reduction of potential damage by proper design, construction, arrangement and use of buildings, materials, structures, indus trial processes, transportation and storage systems etc;
- Fixing the parameters for appropriate level of evaluation for provision of optimum fire prevention and protection measures;
- Design, installation, maintenance etc, of fire detection, suppression, control, fire-related communications and equipment;
- Direction and Control of appropriate equipment and manpower in fire-fighting and rescue operations.

For major building projects and for specialised developments or where there are very unusual or multiple fire hazards, a fire safety engineering approach (or fire engineering approach) is necessary. It is not only beneficial from fire safety point of view, but is also the most cost effective approach.

15.12. Fire Safety Engineering and Indian Scenario

In a country like India, where enforcement of legislative controls are lacking, and where Code violations are more common than compliance, due care has to be taken to ensure that the new approach does not reduce the level of fire and life safety standards. Regulations should firmly place the responsibility for provision and maintenance of fire protection facilities in buildings on owners and occupants.

The different parties involved in the construction of a building like architects, structural engineers construction engineers, promoters, contractors, owners and statutory authorities have to be made accountable for inadequate provision or untimely failure of the fire protection measures in buildings. In this context, it will be desirable to amend the existing Building Codes / Bye-laws Development Control Rules to include the relevant provisions from a Govt Notification dated 21st March 2001 issued by Ministry of Urban Development, Govt. of India, which makes the players in the building industry accountable and liable for any negligence on their part for non - compliance with relevant Codes.

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Annex - A

PROPOSED CONTENTS OF REVISED NBC

Annex - B

LEGISLATION RELATING TO FIRE SAFETY / FIRE PROTECTION IN INDIA

1. Factories Act 1948 (as amended in 1987)
2. State Factories Rules (in various States)
3. Petroleum Act, 1934
4. Petroleum Rules, 1976
5. Indian Explosives Act, 1884
6. Explosive Substances Act, 1908
7. Explosive Rules, 1983
8. Gas Cylinder Rules, 1981
9. Carbide of Calcium Rules, 1937
10. Indian Mines Act, 1952
11. Oil Mines Regulations, 1984
12. Environment (Protection) Act, 1986
13. Environment (Protection) Rules, 1986
14. Air (Prevention and Control of Pollution) Act, 1981
15. Merchant Shipping Act, 1958
16. Merchant Shipping (Fire Fighting Appliances) Rules, 1990
17. Merchant Shipping (Fire Fighting Appliances) Rules, 1969
18. Hazardous Wastes (Management and Handling) Rules\, 1989
19. Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996
20. Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989
21. Cinematograph Act, 1952 (With State Acts and Rules)
22. Public Liability Insurance Act, 1991
23. Motor Vehicles Act, 1988 (As amended in 1994)
24. Central Motor Vehicles Rules, 1989
25. Model Fire Service Bill (As circulated to State Governments in 1958)
26. State Fire Service Acts and Rules (In various States)
27. Delhi Fire Prevention & Fire Safety Act, 1986
28. Delhi Fire Prevention & Fire Safety Rules,1987

Annex - C

LIST OF INDIAN STANDARDS RELATING TO FIRE SAFETY / FIRE PROTECTION (As given in NBC Part-4)

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 standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

(1)	IS 3808:1979	Method of test for non-combustibility of building materials (*first revision*)
(2)	IS 8757:1999	Glossary of terms associated with fire safety (*first revision*)
	IS 7673:1975	Glossary of terms for fire fighting equipment
(3)	IS 8758:1993	Recommendations for fire precautionary measures in the construction of temporary structures and pandals (*first revision*)
(4)	IS 3809:1979	Fire resistance test of structure (*first revision*)
	IS 1641:1988	Code of practice for fire safety of buildings (general) : General principles of fire grading and classification (*first revision*)
(5)	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*)
(6)	IS 3614(Part 1):1966	Specification for fire check doors : Part 1 Plate, metal covered and rolling type
(7)	IS 12458:1988	Method of test for fire resistance test for fire stops
(8)	IS 1646:1997	Code of practice for fire safety of buildings (general) : Electrical Installations (*second revision*)
	IS 2309:1989	Code of practice for protection of building and allied structures against lighting (*second revision*)
(9)	IS XXXXX:	Specification for fire dampers for air conditioning ducts
(10)	IS 11360:1985	Specification for smoke detectors for use in automatic electrical fire alarm system
(11)	IS 659:1964	Safety code for air conditioning
(12)	IS 1649:1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances (*first revision*)
	IS 1642:1989	Code of practice for safety of buildings (general): Details of construction (*first revision*)
(13)	IS 12777:1989	~~Fire safety flame spread of products~~ – Method for classification
(14)	IS 1642:1989	Code of practice for fire safety of buildings (general) : Details of construction (*first revision*)

	IS 1643:1988	Code of practice for fire safety of buildings (general) : Exposure hazard (*first revision*)
	IS 1644:1988	Code of practice for fire safety of buildings (general): Exit requirements and personal hazard (*first revision*)
(15)	IS 9457:1980	Safety colours and safety signs
	IS 12349:1988	Fire protection – Safety sign
	IS 12407:1988	Graphic symbols for fire protection plan
	IS XXXXX:	Fire fighting equipment – Symbols for operator control and other displays
(16)	IS 2175:1988	Specification for heat sensitive fire detectors for use in automatic fire alarm system (*second revision*)
	IS 11360:1985	Specification for smoke detectors for use in automatic electrical fire alarm system
	IS XXXXX:	Specification for fire detection and alarm systems – point heat detectors
	IS XXXXX:	Specification for multisensor fire detectors (under preparation)
	IS XXXXX:	Fire detection and alarm systems – Smoke point detectors using scattered light, transmitted light or ionization
	IS XXXXX:	Fire safety engineering subsystems – Detection, activation and suppression
(17)	IS 2189:1999	Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (*second revision*)
(18)	IS 636:1988	Non-percolating flexible fire fighting delivery hose (*third revision*)
	IS 884:1985	Specification for first-aid hose reel for fire fighting (*first revision*)
	IS 901:1988	Specification for couplings, double male and double female instantaneous pattern for fire fighting (*third revision*)
	IS 902:1992	Specification for suction hose couplings for fire fighting 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 fire fighting purposes (*second revision*)
	IS 905:1980	Specification for delivery breechings, dividing and collecting, instantaneous pattern for fire fighting purposes (*second revision*)
	IS 906:1988	Specification for revolving branch pipe for fire fighting (*third revision*)

	IS 907:1984	Specification for suction strainers, cylindrical type for fire fighting 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 fire fighting purposes (*second revision*)
	IS 939:1977	Specification for snatch block for use with fibre rope for fire brigade use (*first revision*)
	IS 940:1989	Specification for portable fire extinguisher, water type (gas cartridge) (*third revision*)
	IS 941:1985	Specification for blowers and exhauster for fire fighting (*second revision*)
	IS 942:1982	Functional requirements for 275-l/min portable pump set for fire fighting (*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 949:1985	Functional requirement for emergency (rescue) tender for fire brigade use (*second revision*)
	IS 950:1980	Functional requirements for water tender, Type B for fire brigade use (*second revision*)
	IS 952:1986	Specification for foghnozzle for fire brigade use (*first 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 AC3 phasse 50Hz.415 Volts type (*second revision*)
	IS 2097:1983	Specification for foam making branch pipe (*first revision*)
	IS 2171:1999	Specification for portable fire extinguishers, dry powder (cartridge type) (*third 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 2298:1977	Specification for single-barrel stirrup pump for fire fighting purposes (*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 defence personnel (*second revision*)
IS 2871:1983	Specification for branch pipe, universal for fire fighting purposes (*first revision*)
IS 2878:1986	Specification for fire extinguisher, carbon-dioxide type (portable and trolley mounted) (*second revision*)
IS 2930:1980	Functional requirements for hose laying tender for fire brigade use (*first revision*)
IS 3582:1984	Specification for basket strainers for fire fighting purposes (cylindrical type) (*first revision*)
IS 4308:1982	Specification for dry powder for fire fighting (*first revision*)
IS 4571:1977	Specification for aluminium 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 fire fighting (*first revision*)
IS 4928:1986	Specification for delivery valve for centrifugal pump outlets (*first revision*)
IS 4947:1985	Specification for gas cartridges for use in fire extinguishers (*second revision*)
IS 4989	Specification for foam concentrate (compound) for producing mechanical foam for fire fighting (Parts 1 to 3)
(Part 1):1985	Part 1 Protein foam (*second revision*)
(Part 2):1984	Part 2 Aqueous film forming foam (AFFF)
(Part 3):1987	Part 3 Fluoro protein foam
IS 5131:1986	Specification for dividing breeching with control, for fire brigade use (*first 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	Part 1 Hose clamps (*first revision*)
	(Part 2):1977	Part 2 Hose bandages (*first revision*)
	IS 5714:1981	Specification for hydrant, stand-pipe for fire fighting (*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 6234:1986	Specification for portable fire extinguishers, water type (stored pressure) (*first revision*)
	IS 8090:1992	Specification for couplings, branch pipe, nozzle, used in hose reel tubing for fire fighting (*first revision*)
	IS 8096:1992	Specification for fire beaters (*first revision*)
	IS 8149:1994	Functional requirements for twin CO_2 fire extinguishers (trolley mounted) (*first revision*)
	IS 8423:1994	Specification for controlled percolating hose for fire fighting (*first revision*)
	IS 8442:1977	Specification for stand post type water monitor for fire fighting
	IS 9972:1981	Specification for automatic sprinkler heads
	IS 10204:1982	Specification for portable fire extinguisher mechanical foam type
	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)
	IS 10993:1984	Functional requirements for 2000 kg dry powder tender for fire brigade us
	IS 11070:1984	Specification for bromochlorodifluoromethane (Halon-1211) for fire fighting
	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 fire fighting equipment – High capacity portable pumpset (1100-1600 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 l capacity fire extinguisher, mechanical foam type

IS 13849:1993	Specification for portable fire extinguisher dry powder type (constant pressure)
IS 14609:1999	Specification for ABC dry powder for fire fighting
IS 14933:2001	Specification for high pressure fire fighting hose
IS 14951:2001	Specification for fire extinguisher, 135 l capacity mechanical foam type
IS 15051:2002	Specification for high pressure fire hose delivery couplings
IS 15105:2002	Design and installation of fixed automatic sprinkler fire extinguishing system
IS 15220:2002	Specification for halon 1211 and halon 1301 – fire extinguishing media for fire protection
IS XXXXX:	Specifications for multipurpose aqueous film forming foam liquid concentrate for extinguishing hydrocarbon and polar solvent fires (under print)
IS XXXXX:	Specification for portable fire extinguisher mechanical foam type (store pressure) (under print)
IS XXXXX:	Specification for smoke detectors for use in automatic electrical fire alarm systems
IS XXXXX:	Specification for multisensor fire detectors
IS XXXXX:	Fire fighting – Portable fire extinguishers – Performance and construction
IS XXXXX:	Fire detection and alarm systems – Point heat detectors
IS XXXXX:	Fire detection and alarm systems – Smoke point detectors using scattered light, transmitted light or ionization
IS XXXXX:	Fire safety engineering subsystems – Detection, activation and suppression
IS XXXXX:	Gaseous fire – extinguishing systems : General requirements for design, installation and commissioning
IS XXXXX:	Gaseous fire – extinguishing systems: HCFC Blend A extinguishing systems
IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Argonite, IG 55 extinguishing system (under preparation)
IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Inergen, IG 541 extinguishing system (under preparation)
IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Nitrogen, IG 100 extinguishing system (under preparation)
IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Argon, IG 01 Extinguishing system (under preparation)

	IS XXXXX:	Specification for oscillating monitor for fire fighting
	IS XXXXX:	Trailor mounted high volume long range monitor with self-inducting non-aspirating aqua foam power nozzle for fire fighting
	IS XXXXX:	Stand-post and trailor mounted- Type high volume long range water-foam monitor with self-inducting non-aspirating aqua foam nozzle for fire fighting
	IS XXXXX:	Code of practice for water mist fire protection systems – System design, installation and commissioning
	IS XXXXX:	Fire extinguishers for seamless aluminium alloy gas containers above 0.5 litre water capacity and up to 300 bar charged pressure at 15 °C
	IS XXXXX:	Gaseous fire extinguishing systems – Carbon dioxide, total flooding and local application including in cabinet subfloors systems
	IS XXXXX:	Gaseous fire extinguishing systems – HFC 227ea extinguishing system
(19)	IS 2190:1992	Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (*third revision*)
(20)	IS 884:1985	Specification for first aid hose reel for fire fighting (*first revision*)
	IS XXXXX:	Code of practice for inspection and maintenance of gaseous fire extinguishing systems
(21)	IS 3034:1993	Code of practice for fire safety of industrial buildings : Electrical generating and distributing stations (*second revision*)
(22)	IS 6382:1984	Code of practice for design and installation of fixed carbon dioxide fire extinguishing system (*first revision*)
(23)	IS 14609:2001	Specification for dry powder for fire fighting – Class ABC fires
	IS XXXXX:	General requirement for design, installation and commissioning of gaseous fire extinguishing systems (under preparation)
	IS XXXXX:	Specification for HFC - 227 ea/FM-200 total flooding system including the quality tests of heptafluoro propane (FM-200) (under preparation)
	IS XXXXX:	Specification for NAF S-III (HCFC blend A) total flooding system including quality test of the blend (under preparation)
	IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Argon, IG 01 Extinguishing system (under preparation)

	IS XXXXX:	Specification for inert gaseous total fire protection total flooding system - Nitrogen, IG 100 extinguishing system (under preparation)
	IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Argonite, IG 55 extinguishing system (under preparation)
	IS XXXXX:	Specification for inert gaseous total fire protection total flooding system – Inergen, IG 541 extinguishing system (under preparation)
	IS XXXXX:	Specification for carbon dioxide systems – including high & low pressure and incabinet subfloor system (under preparation)
	IS XXXXX:	Specification for water mist fire protection systems – System design, installation & commissioning (under preparation)
(24)	IS 13716:1993	Code of practice for fire safety in hotels
(25)	IS 4963:1987	Recommendations for buildings and facilities for the physically handicapped (*first revision*)
(26)	IS 4878:1986	Byelaws for construction of cinema buildings (*first revision*)
(27)	IS 12456:1988	Code of practice for fire protection of electronic data processing installations
(28)	IS 1646:1997	Code of practice for fire safety of buildings (general): Electrical installations (*second 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 4209:1987	Code of safety in chemical laboratories (*first 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 11460:1985	Code of practice for fire safety of libraries and archives buildings
	IS 12349:1988	Fire protection-safety signs
	IS 12407:1988	Graphic symbols for fire protection plans
	IS 12456:1988	Code of practice for fire protection of electronic data processing installation
	IS 12458:1988	Method of test for fire resistance test of fire stops
	IS 12459:1988	Code of practice for fire-protection of cable runs
	IS 12777:1989	Fire safety - Flame spread of products - Method for classification
	IS 13045:1991	Code of practice for fire safety in industrial buildings: Floor mills
	IS 13694:1993	Code of practice for fire safety in iron and steel industries
	IS 13716:1993	Code of practice for fire safety of hotels
	IS 14435:1997	Code of practice for fire safety in educational institutions
	IS 14689:1999	Code of practice for fire safety in printing and publishing industry
	IS 14850:2000	Code of practice for fire safety of museums
(29)	IS 655:1963	Specification for metal air ducts (revised)

Annex - D

CALORIFIC VALUES OF COMMON MATERIALS AND TYPICAL VALUES OF FIRE LOAD DENSITY (As given in NBC Part-4)

CALORIFIC VALUES OF COMMON MATERIALS AND TYPICAL VALUES OF FIRE LOAD DENSITY

A-1 The calorific values of some common materials are given below:

Calorific Values of Common Materials

Material	Calorific Value (10^3 kJ/kg^{-1}) [1)]	Wood Equivalent (kg/kg)
Solid Fuels		
Anthracite	28.6	1.66
Bituminous Coal	30.8	1.75
Charcoal	28.4	1.61
Coke (average)	27.5	1.56
Peats	20.9	1.19
Sub-bituminous Coal	22.0	1.25
Woods (hard or softwood)	17.6	1.00
Hydrocarbons		
Benzene	39.6	2.25
Butane	47.1	2.68
Ethane	49.1	2.79
Ethylene	47.7	2.71
Fuel Oil	41.6	2.36
Gas Oil	42.9	2.44
Hexane	44.9	2.55
Methane (natural gas)	52.8	3.00
Octane	45.3	2.58
Paraffin	39.6 – 44.0	2.3 – 2.5
Pentane	46.0	2.61
Propane	47.3	2.69
Propylene	46.2	2.63
Alcohols		
Ethyl Alcohol	28.4	1.61
Methyl Alcohol	21.1	1.20
Propyl Alcohol	31.9	1.81

Polymers		
Casein	23.1	1.31
Cellulose	16.5	0.94
Cellulose Acetate	17.8	1.01
Polyethylene	48.4	2.75
Polypropylene	48.4	2.75
Polystyrene	41.8	2.38
Polyvinylchloride	20.9	1.19
Polymethylmethacrylate	24.6	1.40
Polyurethane	35.2	2.00
Polyamide (nylon)	22.0	1.25
Polyester	22.0	1.25
Common Solids		
Asphalt	38.3	2.13
Bitumen	33.4	1.90
Carbon	32.1	1.83
Cotton (Dry)	15.8	0.90
Flax	14.3	0.81
Furs & skins	18.7	1.06
Hair (animal)	20.9	1.19
Leather	17.6	1.00
Ozokerite (wax)	43.3	2.46
Paper (average)	15.4	0.88
Paraffin wax	40.9	2.33
Pitch	33.0	1.88
Rubber	37.4	2.13
Straw	13.2	0.75
Tallows	37.6	2.14
Tan bark	20.9	1.19
Tar (bituminous)	35.2	2.00
Wool (raw)	21.6	1.23
Wool (scoured)	19.6	1.11
Foodstuffs		
Barely	14.1	0.80
Bran	11.0	0.63
Bread	9.9	0.56
Butter	29.5	1.68
Cheese (Cheddar)	18.1	1.03
Corn meal	14.1	0.80
Flour	14.1	0.80
Margarine	29.5	1.68

Oatmeal	15.8	0.90
Rice	13.9	0.79
Soya been flour	16.1	0.91
Sugar	15.4	0.88
Whole Wheat	14.3	0.81
Miscellaneous		
Acetone	29.7	1.69
Acetaldehyde	25.1	1.43
Formaldehyde	17.6	1.00
Hydrogen	134.2	7.63
Magnesium	24.0	1.36

[1)] 1 kJ is approximately equal to 1 Btu so the figures in the tables are also equivalent to Btu/kg.

A-2 The typical values for Fire Load Density for arriving at the Classification of Occupancy Hazard is given below for guidance.

Typical Values of Fire Load Density

Building Type		Fire Load Density (expressed as Wood Equivalent Kilograms Per Square Meter
1.	Residential (A-1 & A-2)	25
2.	Residential (A-3 to A-5)	25
3.	Institutional and Educational (B & C)	25
4.	Assembly (D)	25-50
5.	Business (E)	25-50
6.	Mercantile (F)	up to 250
7.	Industrial (G)	up to 150
8.	Storage and Hazardous (H & J)	up to 500

Annex - E

BROAD CLASSIFICATION OF INDUSTRIAL AND NON-INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF HAZARD
(As given in NBC Part-4)

B-1 LOW HAZARD OCCUPANCIES

Abrasive manufacturing premises
Aerated water factories
Agarbatti manufacturing premises
Analytical and/or Q.C. Laboratories
Arecanut slicing and/or Betelnut factories
Asbestos steam packing and lagging manufacturers
Assembly buildings small (D-4 & D-5)
Battery charging and service stations
Battery manufacturing
Breweries
Brickworks
Canning factories
Cardamom factories
Cement factories and/or asbestos or concrete products manufacturing premises
Ceramic factories, crockery, stoneware pipe manufacturing
Clay works
Clock and watch manufacturing
Clubs
Coffee curing, roasting and grinding factories
Condensed milk factories, milk pasturising plants and dairies
Confectionary manufacturing
Dwellings, lodges, dormitories, etc
Educational and research institutions
Electric lamps (incandescent and fluorescent) and T.V. tube manufacturing
Electroplating works
Engineering workshops
Fruits and vegetables dehydrating and drying factories
Fruits products and condiment factories
Glass and glass fibre manufacturing
Godowns and warehouses (non-combustible goods)
Gold thread/gilding factories
Gum and/or glue and gelatine manufacturing
Ice candy and ice-cream and ice factories
Ink (excluding printing ink) factories
Mica products manufacturing
Office premises
Places of worship
Pottery works
Poultry farms
Residential buildings (A-1 to A-4) (except hotels A-5)

Salt crushing factories/refineries stables
Sugar candy manufacturing
Sugar factories and refineries
Tanneries
Umbrella assembling factories
Vermicelli factories
Water treatment/filtration plants and water pump houses
Zinc/copper factories

B-2 MODERATE HAZARD OCCUPANCIES

Airport and other transportation terminal buildings
Aluminium factories
Assembly buildings (D-1, D-2 and D-3)
Atta and cereal grinding
Bakeries and biscuit factories
Beedi factories
Bobbin factories
Book-binders, envelopes and paper bag manufacturing
Camphor boiling
Candle works
Carbon paper/typewriter ribbon makers
Card board box manufacturing
Carpenters, wood wool and furniture makers
Carpet and durries factories
Cashewnut factories
Chemical manufactures (using raw materials having F.P > 23°C)
Cigar and cigarette factories
Coir factories
Cold storage premises
Computer installations
Cork products manufacturing (coir, carpets, rugs and tobacco) (hides and skin presses)
Dry cleaning, dyeing and laundries, cable manufacturing
Electric substations/distribution stations
Electrical generating stations except u/g powerhouses
Enamelware factories
Filler and wax paper manufacturing
Flour mills
Garment makers
Ghee factories (other than vegetable)
Godowns and warehouses (other than non-combustible goods)
Grains and seed disintegrating or crushing
Grease manufacturing
Hosiery, lace, embroidery and thread
Hospitals including 'X' ray and other diagonastic clinics (institutional buildings)
Incandescent Gas Mantle manufacturers
Industrial gas manufacturing (onloy halogenated hydrocarbons/inert gases)
Man made yarn/fibre (except acrylic fibre/yarn)

Manure and fertilizer works (blending, mixing and granulating only)
Mercantile occupancies (departmental stores, shopping complex, etc)
Mineral oil blending and processing
Museums, archieves, record rooms
Oil and leather cloth factories
Open storage of flammable liquids (in drums, cans, etc)
Oxygen plants
Paper and cardboard mills (except raw material yard0
Piers, wharves, dockyards
Plastic goods manufacturing
Plywood/wood veneering factories
Printing press premises
Pulverizing and crushing mills
Residential apartments, hotels, cafes, restaurants
Rice mills
Rope works
Rubber goods manufacturing
Rubber tyres and tubes manufacturing
Shellac factories
Silk filiatures
Soaps and glycerine factories
Spray painting
Starch factories
Tea factories (including blending packing of tea)
Telephone exchanges, garages
Textile mills
Tobacco chewing and pan masala making
Tobacco redrying factories
Woolen mills

B-3 HIGH HAZARD OCCUPANCIES

A)

Aircraft hangers
Aluminium/magnesium powder plants
Bitumanised paper/hessian cloth/tar felt manufacturing
Bulk storage of flammable liquids (tank farm, etc)
Celluloid goods making
Chemical manufacturers (where raw materials have a F.P. <23°C)
Cigarette filter manufacturing
Cinema films and T.V. production studios
Coal, coke and charcoal ball and briquettes making
Collieries, steel plants
Cotton seeds cleaning and delinting factories
Cotton waste factories
Distilleries
Duplicating/stencil paper making
Fire works manufacture

Foamed plastic and/or converting plants
Godowns of warehouses (combustible/hazardous goods) (H)
Grass, hay, fodder and bhoosa (chaff)
Hazardous occupancy buildings (J)
Industrial gas manufacturing (except halogenated hydrocarbon gases/inert gases)
Industrial units (G_3 occupancies)
Jute mills and jute presses
Linoleum factories
Man made fibres (only acrylic fibre/yarn making)
Match factories
Mattress and pillow makings (foam plastics)
Metal or tin printers (if more than 50% is engineering, shift to ordinary hazard)
Oil mills
Oil extraction plants
Oil terminals/depots
Paints/varnish factories
Paper and cardboard mills (only raw material yard)
Pressing factories
Printing ink making
Resin, lamp black and turpentine manufacture
Saw mills
Surgical cotton manufacturing
Tarpaulin and canvas proofing factories
Turpentine and resin distilleries
Type retreading and resoling factories
Underground shopping complexes (F-3)

B)

Ammonia and urea synthesis plants
Explosive factories
LPG bottling plants
Petrochemical plants
Petroleum refineries

NOTE – In case of complexes having segregated plants with varying degrees of hazards, the competent authority having jurisdictions shall be consulted to decide the level of protections to be provided.

Annex - F

QUALIFICATIONS AND EXPERIENCE PROPOSED FOR FIRE PROTECTION ENGINEER / CONSULTANT FOR REGISTRATION / ACCREDITATION (Proposed by the Authors for inclusion in the documents revised as per GSDMA Project)

D1. QUALIFICATIONS AND EXPERIENCE

Any of the following sets of qualifications and experience may be considered:

1. A Degree in Fire Engineering, like B.E (Fire), from a recognized Institution, approved by the Government/All India Council of Technical Education like National Fire Service College, Govt. of India, Nagpur.
2. A pass in the Membership Examination of the Institution of Fire Engineers, England (M. I. Fire E of IFE, UK)

   Experience: Persons with any of above qualification should have a minimum of 15 years' professional experience in any Government/ Local Body/Major Public Sector Fire Service, with special experience in Design/Inspection/ Survey/Installation/ Consultancy/Maintenance pertaining to various types of fire protection systems and fire fighting equipment normally provided in various classes of occupancies.
3. A pass in the Graduate ship Examination of the Institution of Fire Engineers, England (Grad I Fire E, of IFE, UK).
4. A pass in the Graduateship Examination of the Institution of Fire Engineers India (G.I.F.E., of IFE, India)
5. A pass in the Divisional Officers' Course/Advanced Diploma of the National Fire Service College, Govt. of India, Nagpur.

   Experience: Persons with any of the qualifications mentioned at (3), (4) or (5) above, should have a minimum of 20 years' professional experience in any Governmental/Local Body/major Public Sector Fire Service, with special experience in Design/ Inspection/ Survey/ Installation/ Consultancy/ Maintenance pertaining to various types of fire protection systems and fire fighting equipment normally provided in various classes of occupancies
6. A Degree in Engineering, or its equivalent qualifications recognized by the All India Council of Technical Education or Associate Member of the Institute of Engineers.

   Experience: Persons with any of the qualifications mentioned at (6) above should have minimum of 20 years' professional experience in any Governmental/major Public Sector/well established Organization like Tariff Advisory Committee, Tata Consultancy Services, Engineers India Limited, etc., with special experience in Design/Inspection/Survey/ Installation/ Consultancy/ Maintenance of various types of fire protection systems and fire fighting equipment normally provided in various classes of occupancies.
7. Retired persons with the qualifications and experience prescribed above will also be eligible for consideration.

D2. APPOINTMENT AND SERVICE CONDITIONS

1. Selection to the Panel of Fire Protection Consultants (Panel of 4 to 5 Consultants), as well as the letter of appointment, shall be issued by the Competent Authority, in consultation with the Chief Fire Officer.
2. Conditions of Service shall also be notified by the Competent Authority
3. On acceptance of the appointment, the Fire Protection Consultant shall give an undertaking in writing that he will abide by the instructions issued by the Competent Authority/Chief Fire Officer in respect of his conditions of service and duties and responsibilities.

D3. SCOPE OF WORK & COMPETENCE

1. Scrutiny of all Plans and Specifications received along with the Application for Development Permission or subsequent Application for Modifications /Alterations, as passed on to him by the Chief Fire Officer, in respect of means of exit and fire protection requirements for high rise and special types of buildings/occupancies, so as to ensure conformity with the relevant Standards & Regulations.
2. Inspection of the construction work at various stages of progress of the work as well as on completion, as directed by the CFO and rendering reports to him
3. Conduct periodical/random surveys of the adequacy as well as serviceability of the fire protection systems and equipment and means of exit requirements provided in the existing high rise and special buildings or any other hazardous premises, as directed by CFO and render report to him (Not more than four such surveys to be entrusted to one Fire Protection Consultant in a month).

D4. DUTIES & RESPONSIBILITIES

1. He shall be responsible for satisfactory execution of his work to the Competent Authority through the Chief Fire Officer, who will be allotting various items of work shown in (D3) above.
2. After completion of the allotted work, he shall render a report (in writing, as required) to the Chief Fire Officer
3. In case he comes across any violation/non-compliance/discrepancy in the execution of the developmental work in respect of fire and life safety requirements, he shall immediately bring the same to the notice of the CFO.
4. Whatever work is allotted to him by the Chief Fire Officer as a member of the Panel of Fire Consultants, he shall carry out the same promptly and diligently, and shall render a report to the CFO. He shall seek from the CFO, any clarifications required with regard to the execution of his work
5. He shall be well conversant with all the relevant Regulations, Codes and Standards pertaining to his work, including NBC Part 4 and all relevant Indian Standards, and also shall keep abreast of all modern trends in his

field.

6. While carrying out his inspections of the developmental work and also while assessing the fire and life safety requirements of buildings, he shall be quite impartial, objective and shall display high standard of technical skill and competence commensurate with his position.
7. During construction stage of the building / development work, he shall carry-out occasional inspections, as directed by the CFO, for ensuring that all fire safety measures are being observed by the contractors' employees and all others at site.
8. After carrying out the scheduled inspections, he shall affix his signature at the appropriate places in the concerned documents.
9. In case of any difference of opinion between him and the CFO on any technical or other issues, the matter shall be referred to the Competent Authority for a decision.

Annex - G

ROLE OF INSURANCE INDUSTRY VIS-A-VIS RISK MANAGEMENT MEASURES - AN UPDATE

Insurance industry in India has taken a full turn, from days of open competition, then to purely a nationalized industry and now to an environment trying to catch up with truly competitive era, prevalent in most global markets to- day.

Fire insurance policy in India is governed by by Indian Fire Tariff, which prohibits insurers from deviating from rates terms and conditions indicated therein.

More than a century ago Fire insurers in India, some 106 in nos, from all over the globe, competing with each other, decided to form an Insurance Association of India to safeguard their common interests. There were four tariffs operating in the country for its four geographical regions viz east west north and south.

Then came the nationalization of Insurance Industry in 1970, when all foreign and private players were asked to wind up their shops and merge into 4 government companies. Meanwhile in the year 1987, it was decided to do away with 4 regional tariffs and follow only one All India Fire Tariff.

Then came the privatisation of Indian insurance industry in the year 1999, when 8 private insurance companies were allowed to do business side by side, with the four giant nationalized companies.

Tariffs are still being retained but in a much simpler form. Current Fire Tariff which has come into effect from 31.3.2001, is perhaps in its simplest form. It is only a miniature version of what it was all along during its existence for more that! a hundred years in the past. f

In times to come, when tariffs are removed to facilitate open competition, readers would find it convenient to refer the old tariff, to distinguish between a good risk from a bad one.

Keeping in view of the above, main provisions of the new tariff and those of the old tariff are reproduced below for ready reference.

Present fire tariff which has come into effect with effect from 31.3.2001 provides for the following:

Entire insured property in the same industrial compound carry the same rate.(In the earlier tariff each individual block was rated on its own merits- **Differential rates were considered for blocks segregated by perfect party walls and double fire proof doors.)**

If two or more independent products are manufactured in the same compound, such manufacturing blocks are however still rated 'per se" in the new tariff if they are located detached.

Providing different rates for different constructions has been done away with However, additional rate of Rs 4.00%0 for buildings (and their contents)having walls and /or roofs of wooden planks/thatched leaves and/or grass/hayof any kind/bamboo/plastic cloth/asphalt cloth/canvas/tarpaulin and the like which are treated as of kutcha construction for rating.

Discounts granted for fire protection systems are as follows:

- **Hand Appliances and hydrant System-5%**
- **Hand appliances and independent sprinkler/fixed water spray system-**7.5%+5%
- **Hand appliances, Hydrant system and independent sprinkler/fixed water spray system-10%+5%**

Risks having sum insured (in one compound of one complex in one location) of Rs 50 crores and above attract claim experience discounts/ loadings based on claims experience of preceeding three years (excluding the expiring policy period). Maximum discount granted is 15%, for up-to 5% claims experience and the maximum loading charged is 100%, for risks producing claims experience above 500%.

Insurers are also allowed to grant discounts for voluntary deductibles opted by insureds. These vary from 2%, for opting deductible of 5% OF CLAIM AMOUNT SUBJECT TO MINIMUM OF Rs 10 lacs for ACT Of GOD perils (and Rs 5 Lacs for other perils), to 25% for opting deductible of 5% OF CLAIM AMOUNT SUBJECT TO MINIMUM OF Rs 20 crores for ACT Of GOD perils (and Rs 10 crores for other perils).

Now compare this with the provisions of earlier All India fire tariff given below.

RCC framed structures, with brick/ RCC walls all- around, RCC roofs, RCC floors and RCC staircases, were considered as of superior construction. Buildings of superior constructions were granted a discount of 10% .

Buildings having walls of other than brick work were considered as class II buildings and were charged rates higher than those applicable to class I buildings which were necessarily required to have brick walls all around. The difference in rates between a class I building and a class II building used to be varying from Rs 0.25%0 to 1.80%0.

Buildings with wooden floors were charged a loading of Rs 0.40%0 for each upper floor in respect of flour mills, paper mills, woolen mills, jute mills and textile mills. Loading per floor was 0.25%0 in case of tea factories.

A discount of 10% on tariff rates was permitted, if electrical installations complied with the requirements of IS: 1646.

Discounts granted for fire protection systems were as follows:

- **Hand appliances- 2.5%**
- **Hand appliances and trailer pumps/ fire engine-7.5%**
- **Hand Appliances and hydrant System-22.5%**
- **Hand appliances and independent sprinkler/fixed water spray system-35%**
- **Hand appliances, Hydrant system and independent sprinkler fixed water spray system-50%/45%**
- **Hand appliances, Hydrant system and fixed Co2/DCP/FOAM HALON/HALON alternatives systems -45%**
- **Automatic fire alarm systems- 5%**
- **Mutual Aid schemes-5%**
- **Co2 flooding system in textile blow rooms-20%**
- **Diversion system in textile blow rooms-10%**

There was no scheme for voluntary deductible, neither there were loadings for bad claims experience.

Discount of up-to 10% was available on risks having sum insured above Rs 25 crores for good claims experience for the past 5 years (excluding the expiring policy period), which had to be below 10% (for claims experience of below 5% for last 10 years this could be increased to 15%

On top of this a maximum discount of up-to 25% could be allowed for good physical features, which mainly included following.

- **Proximity of public fire brigades**
- **Compound wall/fencing all around with gates wide enough for entry of fire brigade vehicles**
- **Provision of fire hydrant system**
- **Additional water supplies and pumping capacities than what are normally required under rules**
- **Provision of fire engines**
- **Full time works brigade for fire fighting**
- **Fulltime fire/safety officer**
- **Safety committees**
- **Workers training in plant operation /safety**
- **Hot/cold work- permit systems**
- **No smoking signs**

- **Good housekeeping**
- **Provision of an incinerator, at a safe location for burning of wastes.**
- **Physical separation between blocks for exposure protection**
- **Blocks located at safe distance from boundary walls**
- **Fireproofing of structural steelwork supports of building**
- **RCC roofs**
- **Vertical Separations**
- **Non combustible false ceilings/wall linings/ductings**
- **Explosion venting**
- **Compartmentation**
- **Provision of fire dampers**
- **Doors/windows in external walls to facilitate fire fighting**
- **Absence of Continuous working**
- **Segregation of boiler rooms/Thermic fluid heaters**
- **Electrical interlocks for thermic fluid heaters/ovens/vessels/driers**
- **Use of LPG gas/ Liquid fuel**
- **Elevated floor surfaces for Godowns**
- **Storage on pallets/racks in warehouses**
- **Only manual or battery type goods handling vehicles.**
- **Adequate aisle space and clearances from walls and ceilings in Godowns**
- **Compliance with Explosive Regulations**
- **Fire proofing of steel supports of spheres**
- **Segregation/separation of plant control rooms.**
- **Explosion suppression systems**
- **Continuous electrical bonding and grounding of chemical process equipments**
- **Adequate relief systems on pressure vessels**
- **Proven processes**
- **Suitable drainage system for safe handling of liquid effluents**
- **Provision of refuge areas in high rise buildings**
- **Segregation of lift wells and staircases in high rise buildings with provision of a one hour fire resistance fire door at every landing**
- **Incombustible baffles at every alternate floor in service shafts/cable ducts with one hour fire resistance shutters at every floor**
- **A permanent vent at top of every shaft**
- **Staggering windows with projecting ledges in external walls**
- **Drencher sprinklers every three floors**
- **Segregation of fuel storages, fire pump rooms and transformer rooms**
- **Independent air conditioning systems for every floor.**

Annex - H

LIST OF FIGURES

Acknowledgement: The figures mentioned above have been adopted courtesy foreign Manuals / Books as indicated below:

HMSO Manual of Firemanship Book 1: Figures 1, 2, 3, 4, 5, 8, 11.

HMSO Manual of Firemanship Book 3: Figures 40, 41, 42, 46, 47, 57, 58, 59(a), 59-B, 60, 61-A, 61-B, 62.

HMSO Manual of Firemanship Book 7: Figure 29

HMSO Manual of Firemanship Book 9: Figures 14, 15, 16, 17, 18, 19(a), 19(b), 20(a), 20(b), 21(a), 21(b), 22, 23, 24, 25, 26, 30, to 39, 53.

IFE Fire Technology: Figures 29, 30

NFPA Fire Protection Handbook: Figure 51

BS: Figures 48, 49, 50, 52, 54, 55, 56.

Annex - I

UDC 614·84 : 003·62

IS : 12407 - 1988

Indian Standard

GRAPHIC SYMBOLS FOR FIRE PROTECTION PLANS

1. Scope — Covers symbols to be used on fire protection plans in architectural, engineering, building and allied design fields for the various types of fire fighting equipments.

2. Symbols

2.1 The basic geometrical shape to distinguish each of the following categories have been given in Table 1. A set of supplimentary symbol elements has also been specified in Table 2 which when enclosed within the basic shape give its meaning. These supplementary symbols define, for example, where systems or devices are normally dry or contain water, foam, powder or gas or are activated manually or automatically by heat, smoke or flame:

a) Portable fire extinguishing equipment,
b) Fixed fire extinguishing system,
c) Fire mains
d) Miscellaneous fire fighting equipment,
e) Control and indicating equipment,
f) Alarm initiating devices,
g) Fire warning devices,
h) Fire venting,
j) Escape routes, and
k) Fire and explosions risk zones.

2.2 The devices which do not fall into any of the above categories have been allocated unique symbols in Table 3.

2.3 The examples are given in Table 4.

2.4 The symbols are intended for reproduction on drawings by hand or machine drafting including template or dry transfer methods.

2.5 The meaning of all symbols used shall be defined in a legend in a clear directly understandable form.

2.6 The sizes of the symbols should all be to the same relative scale on any one drawing and relative to the scale of the drawing itself.

Fire Safety Sectional Committee, BDC 36 [Ref : Doc : BDC 36 (4272)]

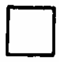
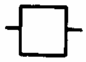
Adopted 30 May 1988	© May 1989, BIS	Gr 3

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110 002

IS : 12407 - 1988

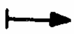
TABLE 1 BASIC GEOMETRICAL SHAPES

(*Clause* 2.1)

Sl No. (1)	Epuipment (2)	Symbol (3)	Sl No. (1)	Equipment (2)	Symbol (3)
1.	Portable fire extinguisher		8.	Alarm - initiating device (point type, manual or autcmatic)	
2.	Wheeled fire extinguisher		9.	Linear detector	
3.	Fixed fire extinguishing system — Total protection of a room		10.	Fire warning device	
4.	Fixed fire extinguishing system— Local application		11.	Natural venting	
5.	Fire main		12.	Pressurization (smoke control)	
6.	Miscellaneous fire-fighting equipment		13.	Special risk area or room	
7.	Control and indicating equipment				

IS : 12407 - 1988

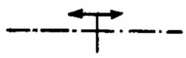
TABLE 2 SUPPLEMENTARY SYMBOL ELEMENTS
(*Clause* 2.1)

Sl No. (1)	Equipment (2)	Symbol (3)
1.	Water	
2.	Foam or foam solution	
3.	Powder ordinary	
4.	Metal powder	
5.	Halon	
6.	Carbon dioxide (CO_2)	
7.	Extinguishing gas other than halon or CO_2*	
8.	Valve	
9.	Outlet	
10.	Inlet	
11.	Heat	
12.	Smoke	
13.	Flame	
14.	Explosive gas (*see* 23)	
15.	Manual actuation	
16.	Bell	
17.	Sounder	
18.	Loudspeaker	
19.	Telephone	
20.	Illuminated signal	
21.	Combustible materials	
22.	Oxidizing agents	
23.	Explosive materials	

*To be defined within the plan legend.

IS : 12407 - 1988

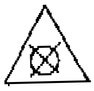
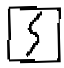
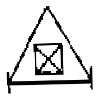
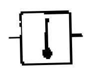
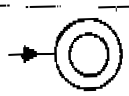
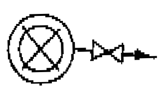
TABLE 3 SYMBOLS USED ALONE
(*Clause* 2.2)

Sl No. (1)	Equipment (2)	Symbol (3)
1.	Water bucket	
2.	Sand bucket	
3.	Pillar hydrant*	
4.	Ground hydrant*	
5.	Escape route, direction to follow	
6.	Escape route, final exit	

*The number of bars corresponds to the number of outlets; in the examples the pillar hydrant has two outlets and ground hydrant has one.

IS : 12407 - 1988

TABLE 4 EXAMPLES OF SYMBOLS
(*Clause* 2.3)

Sl No. (1)	Equipment (2)	Symbol (3)	Sl No. (1)	Equipment (2)	Symbol (3)
1.	Water portable extinguisher		10.	Hose station, wet standpipe	
2.	Metal powder portable extinguisher		11.	Smoke detector (point type)	
3.	Carbon dioxide portable extinguisher		12.	Gas detector (point type)	
4.	Wheeled BC powder extinguisher		13.	Telephone	
5.	Foam extinguishing system (total protection of the room)		14.	Heat detector (linear type)	
6.	Ordinary powder extinguishing system (total application)		15.	Alarm sounder	
7.	Manual control of a water extinguishing system (total protection of a control)		16.	Manual control of a natural venting device	
8.	Dry riser, inlet without valve		17.	Control and indicating equipment with audible and illuminated signals	
9.	Wet riser, outlet with valve		18.	Room containing explosive materials	

Annex - J

4·84 : 614·8·013 : 003-62

IS : 12349 - 1988

Indian Standard

FIRE PROTECTION — SAFETY SIGNS

1. Scope — This standard covers the safety signs for use in the field of fire protection and fire fighting.

2. Safety Signs

2.1 The safety signs are presented in the tabular form based on:

a) Means of giving warning of fire and manual controls (*see* Table 1),

b) Means of escape from fire (*see* Table 2),

c) Means of fire fighting (*see* Table 3),

d) Areas or materials of special fire risk (*see* Table 4), and

e) Supplementary signs (*see* Table 5).

2.2 The colour red, green and yellow, shall conform to Shade No. 536, 221 and 309 of IS : 5-1978 'Colours for ready mixed paints and enamels (*third revision*)' respectively. The paint shall conform to IS : 2932-1974 'Specification for enamel, synthetic, exterior (a) undercoating, (b) finishing (*first revision*)'. The outermost dimensions of square (side), triangle (altitute), circle (diameter) shall be 125 mm and size of rectangle shall be 125 × 250 mm.

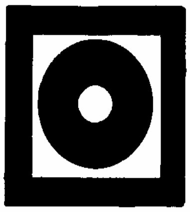
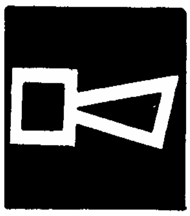
Fire Safety Sectional Committee, BDC 36 [Ref : Doc : BDC 36 (4271)]

Adopted 7 June 1988 | © April 1989, BIS | Gr 4

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG

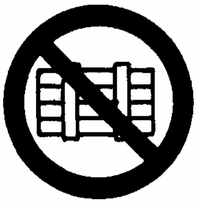
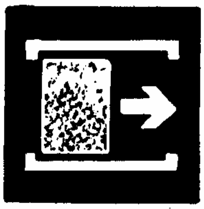
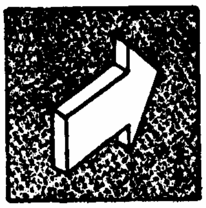
IS : 12349 - 1988

TABLE 1 MEANS OF GIVING WARNING AND MANUAL CONTROLS

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
1		Manual activating device	Square sign Background: red Symbol: white	To be used to indicate either a fire alarm call point or the manual control of a fire protection system (e.g. fixed fire extinguishing system)
2		Alarm sounder	Square Background: red Symbol: white	May be used alone or in conjunction with sign No. 1 above if the fire alarm call point actuates an audible alarm immediately perceptible to the occupants
3		Telephone to be used in emergency	Square Background: red Symbol: white	Sign to indicate, or to show the position of a telephone available for giving warning in case of emergency

IS : 12349 - 1988

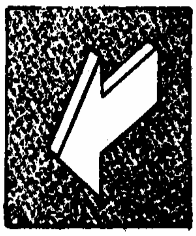
TABLE 2 MEANS OF ESCAPE

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
1	 	Emergency exit	Square Background: green Symbol: white	This sign may be used to indicate all exits which can be used in the event of an emergency. It shall be accompanied by an arrow (Sign No. 1 of Table 5) unless the door is immediately apparent. It may indicate to right or to left.
2		Do not obstruct	Round sign Background: white Symbol: black Circular band and cross bar: red	Sign to be used in situations where obstruction would present a particular danger (escape routes, emergency exits, access to fire-fighting equipment, etc)
3		Slide to open	Square Background: green Symbol: white	To be used in conjunction with sign No. 4 of this table on sliding emergency exit doors, where they are permitted. May be used in the inverse direction
4		Push to open	Square Background: green Symbol: white	This sign is to be placed on a door to indicate the direction of opening

(Continued)

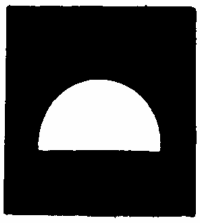
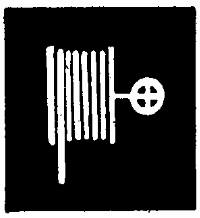
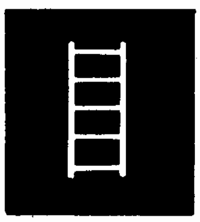
IS : 12349 - 1988

TABLE 2 MEANS OF ESCAPE — *Contd*

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
5		Pull to open	Square Background: green Symbol: white	This sign is to be placed on a door to indicate the direction of opening
6		Break to obtain access	Square Background: green Symbol: white	The sign may be used: a) where it is necessary to break a glass panel to obtain access to a key or to a means of opening b) where it is necessary to break open a panel to create an exit.

IS : 12349 - 1988

TABLE 3 FIRE-FIGHTING EQUIPMENT

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
1		Collection of fire-fighting equipment	Square Background: red Symbol: white	This sign is used to avoid proliferation of signs
2		Fire extinguisher	Square Background: red Symbol: white	
3		Fire hose reel	Square Background: red Symbol: white	
4		Fire ladder	Square Background: red Symbol: white	

IS: 12349 - 1988

TABLE 4 AREAS OR MATERIALS OF SPECIAL FIRE RISK

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
1		Danger of fire — Highly flammable materials	Triangular Background: yellow Symbol: black Triangle: black	To indicate the presence of highly flammable materials
2		Danger of fire — Oxidizing materials	Triangular Background: yellow Symbol: black Triangle: black	
3		Danger of explosion Explosive materials	Triangular Backgroud: yellow Symbol: black Triangle: black	To be used to indicate the possible existence of an explosive atmosphere, flammable gas or explosives
4		Water as extinguishing agent prohibited	Round Background: white Symbol: black Circular band and cross-bar: red	To be used in all cases when the use of water on a fire is inappropriate
5		Smoking prohibited	Round Background: white Symbol: black Circular band and cross-bar: red	To be used in cases where smoking can cause danger of fire

(Continued)

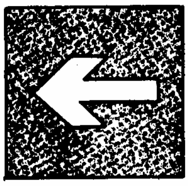
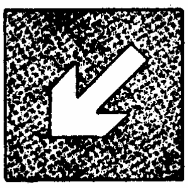
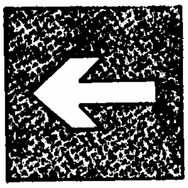
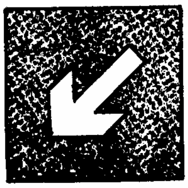
IS : 12349 - 1988

TABLE 4 AREAS OR MATERIALS OF SPECIAL FIRE RISK — *Contd*

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
6		No open flame — Smoking prohibited	Round Background: white Symbol: black Circular band and cross-bar: red	To be used in cases where smoking or open flame can cause danger of fire or explosion

IS : 12349 - 1988

TABLE 5 SUPPLEMENTARY SIGNS

Sl No.	Sign	Meaning	Shape and Colours	Comments on Use
1	 	Directional arrow for escape route	Square or rectangular sign Background: green Symbol: white	To be used only together with sign No. 1 of Table 2 to indicate the direction to an emergency exit
2	 	Direction of location of fire-fighting equipment or warning device	Square or rectangular sign Background: red Symbol: white	To be used only together with one of signs No. 1 to 3 of Table 1 and 1 to 4 of Table 3 to indicate the direction of location of fire fighting equipment or a warning device