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Government of India - Ministry of Railways

FIRE PROTECTION IN BUILDINGS



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Centre
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Excellence in Maintenance

Maharajpur, GWALIOR - 474 020

FIRE PROTECTION

IN

BUILDINGS

Foreword

Indian Railways, which hold the major chunk of Civil Engineering assets in country, is looked upon as a premier organisation in respect of quality, workmanship & safety assurance. To safeguard the travelling public as well as railway employees against sudden disasters like fire, adequate safety measures shall have to be adopted.

It has been observed that even after ensuring strict quality control, workmanship and using fire-resisting material, fires do occurs in buildings. Hence buildings are required to be provided with adequate means of fire minimisation, containment & extinguishment with properly designed exit means.

Through this handbook CAMTECH has made nice attempt to provide the knowledge about basics of fire, its effects on human lives & destructive nature, and its preventive/protective measures. Efforts have been made to cover various requirements like fire minimisation, its containment and fire-fighting with exit requirements etc. as specified by the code of practice.

I hope, this handbook will certainly prove to be a valuable source of technical knowledge and will be quite helpful to civil engineering personnel in Railways.

CAMTECH/Gwalior ***R.N.Misra***
Date : 30.11 .2005 ***Executive Director***

Preface

The nature of fire is destructive as well as productive. When the fire occurs, nothing is left in its original form as it destroys each and every living/non-living identity. On the other side, fire is a nature's gift to mankind if used productively for various purposes like for cooking, warming, and manufacturing of various products, etc. Living in an environment where safety of every human being is the highest priority of every nation, it is important to envisage the safety measures against the fire also.

Indian Railway is a big organisation having large assets of civil engineering structures and buildings, where large varieties of products are used, most of them are combustible and flammable in nature and thus, require special attention to keep them away from fire. Therefore, keeping in mind the destructive nature of fire, almost all buildings whether residential, institutional, educational, assembly etc. are required to be planned, designed, constructed and maintained by adopting the latest fire protection measures so that the losses due to fire, to human lives and properties can be minimised.

This handbook is prepared with the objective to provide informative technical details on *'Fire Protection in Buildings'* for the guidance of civil engineering personnel involved in planning, designing, construction and maintenance of buildings. It covers the basic nature of fire, behaviour of various combustible materials, effects of fire on occupants, building & surroundings, preventive as well as protective measures with brief description of codal provisions.

This handbook does not supersede any existing instructions from Railway Board, RDSO & Zonal Railways and the provisions of IRWM, BIS codes & reports on the subject. *This handbook is not statutory and contents are only for the purpose of guidance.* Most of the data & information mentioned herein are available in some form or the other in various books and other printed matter.

I am grateful for the assistance given by Shri K.C.Shakya, CTA/Civil, who went through the complete text, collected information, data etc. and did text-editing work. Nice data entry has been done by Shri Ramesh Bhojwani, Console Operator, CAMTECH.

We welcome any suggestions from our readers for further improvement.

CAMTECH/Gwalior ***Manoj K. Agarwal***
Date : 29.11 .2005 ***Director/Civil***

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ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/2005/C/FIRE/1.0/CS. # XX date ...…….....

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

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Chapter – 1

Introduction

Since ancient time, fire is used to provide light, heat for cooking the food, to make better tools, and as a weapon in times of war. As early civilizations developed, people discovered more uses of fire. Early religions included fire as a part of their rituals, reflecting its importance to society. Keeping a controlled fire burning played a central part in ancient communal life. At the same time, fire remains a potentially destructive force in people's lives. Natural fires started by lightning and volcanoes destroy wildlife and landscapes. Carelessness with campfires leads to many wildfires. If not controlled, unwanted fire may result in serious hazards and may spread to other areas causing great losses to property as well as human lives.

Buildings are also a potential fire hazard, as every building contains something, which easily catches fire, and it is impossible to eliminate completely the chances of fire in building. No building material is fully fire-resistant because most non-combustible materials employed in construction suffer some damage under the action of heat and flame. The by-product of the fire, the smoke and the hot gases, causes damage to the human life by reducing visibility and producing suffocating effect resulting in mass panic, which in turn causes maximum danger to life. This problem gets further aggravated in high-rise buildings, as safe evacuation of occupants and extinguishment of fire in such buildings poses serious problems.

However, by adopting the appropriate safety measures during planning, designing, construction and maintenance of the building, the safety of the occupants can be assured to the maximum possible extent in the event of fire breaks out. Absolute safety from fire is not attainable in practice but by adopting certain measures it is definitely possible to provide reasonable degree of safety of human lives as well as of the building. The development of new engineering approaches and latest building codes and standards has led to safer buildings without dramatically increasing the cost of construction.

First step in fire safety planning of the building is obviously a prevention of fire. The measures that centre on prevention and/or spread of fire are called *preventive measures*, which include, selection of non-combustible material, limiting contact between combustible and possible ignition source, keeping combustibles within suitable enclosures and following correct operational and maintenance procedures.

However, prevention of all fires is not possible. Therefore, fire safety planning of buildings, mainly focuses on the measures oriented towards protection against unwanted fire i.e. adopting *protective measures*, which include, planning, designing and constructing the building so as to ensure containment of fire, adequate structural stability, provisions of clear exit routes for safe escape of occupants and installation of appliances for detecting, controlling and extinguishing the fire.

In the subsequent chapters, the basic technical information on the subject has been covered in details, covering (i) '*fire basics'* i.e. combustion process, factors affecting it and its extinguishment (ii) '*effects of fire in building'* i.e. effects of fire on occupants, property and surroundings, the fire-resisting properties of construction materials, and fire retardant materials (iii) '*Philosophy of Fire Protection'* i.e. basic conceptual details of the various fire protection measures required in the buildings covering both fire safety and fire fighting aspects.

Brief description of the codal provisions for fire protection in buildings, with fire detection and extinguishment arrangements has also been covered.

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Chapter – 2

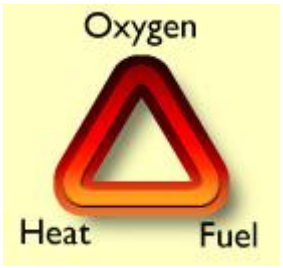
Fire Basics

2.0 What is Fire?

Fire is a chemical reaction involving rapid oxidation or burning of flammable material i.e. **fuel**. Oxidation reaction that produces fire is also called **combustion,** and it generates light, heat, gases and soot.

Fire needs presence of three elements i.e. oxygen, heat and fuel, so it can happen. Fire can occur only, when all these three elements are present in the proper condition and proportions. If any one of these elements is taken away, fire can not begin or in case of an already burning fire, extinguishment will occur.

These three elements represented on a triangle are commonly known as **fire triangle**.



OXYGEN + HEAT + FUEL = **FIRE**

2.1 How Combustion Occurs?

Several important elements are required to be present for combustion to occur. The first requirement is **fuel** and **oxygen**. Fuel for a fire may range from trees in a forest to furniture in a home to gasoline in an automobile. The oxygen in the reaction usually comes from the surrounding air. The next requirement for combustion is **heat** or source of ignition. Ignition sources may be in the form of a spark, a flame, or even a very hot object. The ignition source must provide enough heat to produce vapours/gases and heat the fuel to flammable temperature to start the chemical reaction. Finally, a chemical **chain reaction** (reaction that continuously fuels itself) must occur between the fuel and oxygen for combustion to continue.

(i) Fuel

Any combustible/flammable material, which gives off sufficient vapours or gas on heating for combustion to occur, is called fuel. Fuel must be in a gaseous state (so that it can react with oxygen) before a fire can occur. Heat from the fire's ignition source, and later from the fire itself, decomposes solid and liquid fuels, releasing flammable gases called volatiles. Some solids, e.g. wax, melt into a liquid first. The liquid then evaporates, giving off volatiles that may then burn.

(a) Fuels are broadly grouped as, **(i) Solids** like wood, fabric, rubber and plastic. **(ii) Liquids** such as petrol, oil, cooking oil or even nail varnish remover and **(iii) Gases** like propane, butane and 'natural' gas.

- **Solids** give off flammable vapours on heating. Certain solids such as paper or flour appear to ignite almost instantly. This is because they give off vapours and reach a flammable temperature almost immediately. In fact, fine dusts dispersed in the air can **explode.**

  Other solids like timber take longer to ignite because they are more dense and so don't give off flammable vapours so easily.

- **Liquids** are a bit different to solids. They are a lot more runny for a start. Though, solids need to be heated to give off flammable vapours, some liquids give off vapours even in cold weather.

- **Gases** are already vapours and will ignite in a single stage.

(b) **Chemically,** fuels mainly comprises of compounds containing the elements carbon and hydrogen. Fuels often also contain oxygen, nitrogen, chlorine, and sulphur. *Cellulose* is the principle combustible compound in wood, paper, and cotton. It contains carbon, hydrogen, and oxygen. *Plastics* that burn, such as polyvinyl chloride (PVC), polystyrene, polymethyl methacrylate (PMMA), nylon, and polyurethane, are composed mostly of carbon and hydrogen. Liquid fuels i.e. oil and gasoline etc., and gaseous fuels i.e. methane, propane etc. contain both carbon and hydrogen.

(ii) Oxygen

When Oxygen in the air combines with flammable vapours given off by **Fuels** in the required proportion, they create a form of heat at a *molecular level*. Then, a source of *ignition* (a match or spark etc.) can cause it to combust.

Without enough Oxygen, ignition cannot happen. However, if there is too much Oxygen then the vapours won't be concentrated enough to ignite. A flammable gas or vapour will only burn in air if the composition lies between certain limits. These limits are referred to as the *lower and upper limits of flammability, i.e* lowest & highest concentration of fuel in air that will just support a self-propagating flame.

(iii) Heat

A fire can start when a fuel becomes so hot that it releases sufficient flammable gases for combustion to occur. At this temperature, known as fuel's *ignition temperature*, a spark or flame will start the combustion reaction. Ignition/heat source can be open flame, such as that from a match or lighter, sparks, such as those generated by electricity or any very hot object. The term ignition temperature is normally used with reference to solid fuels. Liquid fuels have, instead, a *flash point temperature*. At a liquid's flash point, an ignition source will cause a flame to flash across the surface of the liquid.

Ignition/flash point temperature is the temperature to which fuel is to be heated to produce enough vapours to enable a *momentarily flash* to take place. However for the fuel to continue

burning independently of the ignition source it is required to be heated to a *fire point temperature* i.e. lowest temperature at which the heat from the combustion of burning vapours is capable of producing sufficient vapours to enable combustion to continue.

On heating solid and liquid fuel, to its *spontaneous ignition temperature*, it ignites on its own. This temperature is higher than the ignition temperature, because a flame or spark is not present to provide the extra heat needed to kick-start the chemical reaction. Heat within the fuel provides this energy. Some fuels do not have a spontaneous ignition temperature because they break down into other substances before they can ignite on their own. Flammable gases have just one ignition temperature. They will ignite at this temperature if they are present in the right concentrations.

(iv) Chain Reaction

Once kicked off, to continue fire requires a chemical chain reaction. The heat of the ignition source starts the reaction, and heat from the fire's flame continues the reaction. The flame needs to heat the fuel and makes it to release enough flammable gases to continuously support the chemical reaction.

2.2 Products of Combustion

The products that a fire releases, and the rate at which it releases them, depend on the fuel and on the fire's burning rate. Some fuels will produce more heat than others as they burn, and some will produce different kinds of gases. A fire that burns slowly may produce different products than one that burns quickly. The burning rate also affects the rate at which a fire releases products. During combustion normally light and heat, gases and soot are released.

(i) Light and Heat

Once a material ignites, a flame forms. The flame consists of volatile gases moving upward, and it is the region in which the combustion reaction occurs. The gases in the flame move upward because they are hotter, and therefore lighter than the surrounding air. Unburned carbon particles that glow and travel upward as the flame heats them, imparts colour to the flame.

Different fuels produce varying amounts of heat. The rate at which a fire generates heat is equal to the burning rate of the fuel multiplied by the amount of heat produced by the combustion reaction. This second factor is called the effective heat of combustion. When a gram of wood burns, for example, it produces 8 kJ of heat energy. Wood's effective heat of combustion is therefore 8 kJ/g. Polyurethane's effective heat of combustion is about 18 kJ/g. Polyurethane's burning rate is also about twice that of wood under similar conditions, i.e. polyurethane fires produce heat at about 4.5 times the rate of wood fires.

(ii) Gases

Fires can produce a number of different gases, including some that are harmless and some that are toxic. Carbon dioxide (CO_2) and water vapours (H_2O) are two relatively harmless gases produced by fires. Toxic gases from fires include carbon monoxide (CO), hydrogen cyanide (HCN), sulphur dioxide (SO_2), and hydrogen chloride (HCl).

The specific gases and their amounts a fire produces, depend on the type of fuel involved and the environment surrounding the fire. Different fuels will react differently in the combustion reaction, producing gases and amounts of gas specific to that type of fuel. For example, in well-ventilated conditions, polyurethane produces ten times more carbon monoxide for each gram burned than does wood. Fires that burn in an oxygen-rich environment will also produce less carbon monoxide than fires that burn where little oxygen is present. A well-ventilated fire has plenty of oxygen, so nearly all of the fuel's volatile gases can take part in the combustion reaction, combining with oxygen in the air to produce carbon dioxide and water vapour. These fires produce less carbon monoxide because there is less carbon and oxygen left over from the initial combustion reaction to form carbon monoxide.

Fires that occur in an environment lacking sufficient oxygen will burn incompletely and smolder, producing more amounts of carbon monoxide. For example, in an enclosed room, a fire will use up oxygen from the air as it progresses, decreasing the amount of oxygen in the room over time. Without sufficient oxygen, the volatile gases from the fire cannot fully take part in the combustion reaction. Some of the gases instead react to form carbon monoxide, which requires less oxygen than complete combustion. Eventually, the amount of oxygen decreases below the level necessary for continued combustion, causing the fire to self-extinguish. Depending on the type of fuel, most fires self-extinguish at an oxygen concentration between 12 and 14 percent (by volume). Normal atmospheric air has an oxygen concentration of 21 percent.

(iii) Soot

As fires produce light, heat, and gases, they also produce soot, consisting of mostly carbon particles. *Smoke* may be defined either as just the soot particles given off by a fire, or as both the soot and the gaseous products of combustion.

The amount of soot produced by a fire depends on the type of fuel, the fuel's burning rate, and environmental conditions. Most plastic fuels produce more soot than wood and other cellulose fuels. Plastics also usually burn more quickly than wood. The composition of plastic and plastic's more rapid burning rate, cause it to produce about 2.7 times as much soot as does wood. Fires also tend to produce more soot when they smolder and less soot when they burn freely in a well-ventilated area, with plenty of oxygen available.

2.3 Rate of Combustion

Different kinds of fires burn at different rates, one fire may slowly smolder, while another may quickly use up its fuel. The rate at which a fire burns depends on the composition of the fuel, the surface area of the fuel, the amount of oxygen that is available and on the way the fuel absorbs heat. This absorption determines how heat will affect the fuel's temperature. A fuel's capacity to absorb heat depends on the type of fuel involved and its arrangement.

Most plastics burn at twice the rate of cellulose fuels, such as wood and leaves, because of the different chemical reactions involved. The burning rate of the same fuel, however, can also vary depending on how much of the fuel's surface is exposed to the air. As the exposed surface of a fuel increases in comparison to its volume, the burning rate of the fuel increases as well. When the fuel's gases have more surface area from which to escape, they can come into contact with more air. The increased exposure to air increases the amount of oxygen available for combustion. For example, people often use small twigs and pieces of wood

called kindling to start a campfire. Kindling has a large amount of surface area compared to its volume. Its relatively large surface area to volume ratio also means that kindling heats and ignites more easily than thicker pieces of wood. Once ignited, kindling burns very quickly.

Similarly, a fine suspension of dust particles in air or inflammable gases or vapours in air will burn with explosive violence with disastrous consequences, because they have the greatest surface area, exposed to air, as compared to the same substance when in solid or liquid state.

Broadly, rate of combustion depends on the following factors :

- The area of solid or liquid in contact with air or any oxygen.
- The amount of heat generated to raise the temperature of un-burnt portion to its ignition temperature.
- The ability of the material to carry away the emitted heat rapidly from the burning portion i.e. heat absorption capacity of fuel.
- Wind velocity.
- Amount of humidity present in the atmosphere.

2.4 Type of Combustion

Based on rate of combustion, amount of heat and light generated, combustion is broadly classified as under:

- *Slow or incipient combustion* : is one in which the amount of heat and light emitted is feeble.
- *Rapid or active combustion* : is one in which a considerable amount of heat and light is emitted within a short time.
- *Deflagration* : is a case of combustion, which takes place with a considerable rapidity, evolving heat and light.
- *Explosion* : is a very rapid combustion with generation of intense pressure and high temperature with more or less noise.
- *Spontaneous* : is a case of combustion which occurs without the application of external flame or spark.

2.5 General Classes of Fuels

Based on physical state fuels are classified as;

2.5.1 Combustible Solids

These are divided into three classes according to their specific surface :

- *Tinder:* Solid with a specific surface of more than 20 sq. cm. per gm.
- *Kindling :* Solid with a specific surface of 2 to 20 sq. cm. per gm.
- *Bulk-fuel:* Solid with a specific surface of .04 to 2 sq. cm. per gm.

Tinder can be ignited by an ordinary / matchstick but kindling requires burning tinder for igniting it. Bulk-fuel cannot be ignited by match or tinder, but requires burning kindling for ignition.

(a) Combustion of Wood

When wood catches fire, there is distillation of moisture contained in it at 100^0C. The temperature does not initially exceed above 100^0C,until all the water particles are evaporated. At 170^0C, wood decomposes and CO_2 gas is given off with rise in temperature. After this, there is a steep rise in temperature from 200^0C above; there is a distillation of inflammable substances like Acetone, Acetic Acid, Methyl, Alcohol, etc. contained in it.

The distillation starts vigoursly at above 275^0C, when the combustion is automatic and no external source of heat is required. Within a range of temperature of 270^0C to 300^0C, there will be an automatic spread of fire and the combustion becomes very vigorous. It is, therefore, important that the temperature of the un-burnt stack of wood in timber-fires is never allowed to exceed this limit and they are to be kept cool by spray of water in the vicinity of fire burning to avoid the spread of fire.

2.5.2 Flammable Liquids

Flammable liquids are those, which evaporate at all temperature and pressure. These liquids are generally of organic origin and have their flash points below the ordinary temperature. They are potential fire hazards and need to be stored and handled carefully in well-ventilated rooms. The flammable liquids are categorised in three groups as per their miscibility with water and specific gravity as under.

Group 'A'	Those liquids which mix with water e.g. Acetone, Alcohol, Glycerine, Methylated Spirit etc.
Group 'B'	Those liquids which do not mix with water and are lighter than water and float on it e.g. Petrol, Fuel oil, Lubricating oils, Paraffin oil etc.
Group 'C'	These liquids which do not mix with water and are heavier than water e.g. Carbon-di-sulphate, Tetra Ethylene lead and Tetra Methyl Lead (used for treating petrol).

(a) Special Feature of Oil Fire

When heavy fuel oils or crude's burn, a layer of hot oil is formed below the surface extending towards the bottom of the tank at a rate depending on the type of oil involved. This propagation of hot oil zone is also known as **heat wave**.

With distilled oils (petrol, kerosene and diesel) no expanding hot layer is formed. Thus, refined oil and products with their narrow boiling range do not establish heat wave. Due to formation of heat wave in oil fires, in presence of water, following phenomenon may occurs:

- **Boil Over :** In case, water is present at the bottom of a tank containing crude or heavy fuel oils, the contact between water and the heat wave i.e. hot layer of oil, will immediately cause a flash of the upper layer of water into steam, expanding the volume by many times and a wave of burning oil may be suddenly expelled out of the tank with a great force. This phenomenon is known as *boil over*.

- **Slop Over :** The slop over or spill over is a minor boil over which takes place with wet oil, containing a percentage of water. For example, the sudden application of foam or spray upon the hot oil surface burning in a tank that is full or nearly full. It is for this reason that when the oil level is within 3 m of the top of the tank, great care should be taken, when applying foam specially when the oil is boiling.

2.5.3 Inflammable Gases

From fire hazard point of view, gases may be divided as under -

- Gases which are *combustible or inflammable* viz. acetylene, coal gas, hydrogen sulphite, methane, hydrogen, propane etc. and inflammable and poisonous gas like carbon mono oxide.
- Gases which *support combustion* viz. Oxygen, nitrous oxide etc.
- Gases which are '*inert*' viz. nitrogen, helium, carbon-di-oxide, etc.
- Gases which are *toxic and / or suffocating and very irritating*, making fire fighting very difficult viz. chlorine, ammonia, hydro-choric acid, gas, sulphur di-oxide etc.

All combustion gases form ignitable mixers, when they are mixed with air at definite minimum and maximum concentration of their volume in air. For example, acetylene gas forms ignitable mixer between 2.5% to 31% in volume with air, Petrol vapour forms ignitable mixer between approximately 1.3 % to 6.0 % in volume with air etc. This is known as the range of inflammability of the gas or vapour, and the wider is the range, the more hazardous is the gas or vapour.

Each gas or vapour possesses a definite weight in relation to air. This is termed as the density of the gas or vapour as compared to air. Some are heavier than air e.g. sulphurated hydrogen, chlorine, nitrous oxide (nitrous fumes), petrol vapour etc. while some are lighter than air e.g. hydrogen, coal gas, acetylene, ammonia, carbon mono-oxide etc.

To avoid gas fire it is important to avoid formation of required concentration of gas and air in the area, by ventilating the gas away. If a gas is heavier than air, it should be ventilated at floor level, while it is lighter than air, ventilation near about ceiling level is necessary. In both cases, however, openings have to be provided at opposite levels to allow air to enter to enable the gas or vapour to flow out quickly.

Gases or vapours having approximately equal density to that of air provide some difficulty in removing them by mere ventilation method, as these gases and vapour merely hung about where they leak. In such cases, it is necessary to employ a powerful fan or blower or exhauster to throw them out in to the atmosphere through some opening.

2.6 Extinguishment of Fire

From the triangle of combustion it is evident that a fire can be extinguished either by *starvation* i.e stopping the supply of fuel, or by *smothering* i.e. stopping the supply of oxygen, or by *cooling* i.e. stopping the supply of heat. This can be achieved by using:

- **Water**
- **Foam**
- **CO_2 gas, or**
- **Dry chemical powder**

Water extinguishes fire by taking away the "*heat"* element of the fire triangle. Water is very effective for extinguishing fire involving solid fuels, however it is not that effective for fire involving flammable liquids, certain chemicals and combustible metals. Being a good conductor of electricity it may cause electrocution if used to extinguish electrical fire. Electrical equipment must be unplugged and/or de-energized before using a water extinguisher on it.

Foam forms a blanket or a film on a surface of burning liquid/solid and extinguishes the fire by stopping the supply of "*oxygen"* and as well as taking away the "*heat"* of the burning material.

CO_2 gas is a non-flammable gas that extinguishes fire by displacing oxygen, or taking away the "*oxygen"* element of the fire triangle. The carbon di-oxide is also very cold as it comes out of the extinguisher, so it cools the fuel as well. CO_2 gas is not as effective for extinguishing fire involving solid fuels, because it may not be able to displace enough oxygen to successfully put the fire out.

Dry chemical powder extinguishes the fire by coating the fuel with a thin layer of dust separating the fuel from the oxygen/air i.e. by stopping supply of "*oxygen"*. The powder also interrupts the "*chemical reaction"* of the fire. Dry chemical extinguishers come in a variety of types suitable for extinguishing different classes of fires. The powder used is mainly of two types consisting of either (i) sodium or potassium bi-carbonate, urea potassium bi-carbonate and potassium chloride base *or* (ii) monoammonium phosphate base.

2.6.1 Extinguishment of Solids Fire

Fire involving *combustible solids* can be extinguished by cooling the fuel and / or by stopping the supply of oxygen through application of water, foam or by covering it with dry chemical powder. Sand/earth covering can also be used for controlling the wood/metal fire.

2.6.2 Extinguishment of Flammable Liquids Fire

Fire involving *flammable liquids* can be extinguished as under:

(a) Liquids under Group 'A'

- Dilution with water (depending on quantity)
- Covering the container (depending on quantity)
- Application of foam.- It should be noted that these liquids mixed freely with water, tend to break down the foam by absorbing its water content, as such the rate should be at least 5 times the normal rate, or special Alcohol resisting foam compound shall be used.
- Dry chemical extinguisher.

(b) Liquids under Group 'B'

- Water in the form of fire spray or Fog forming emulsion.
- Covering the container (depending on quantity).
- Application of foam at normal rate.
- CO_2, Dry Chemical extinguishers.

(c) Liquids under Group 'C'

- Application of water (covering, with water above the liquids since it is heavier than water).
- Application of foam (where sealing effect can not be obtained by water).

2.6.3 Extinguishment of Inflammable Gases Fire

Fires involving *flammable gases and vapours* can be extinguished by using either CO_2 or dry powder extinguisher. For certain gas fires and particularly flammable vapour fires, water can be used successfully in a form of fine spray, only to cool down the container and to reduce the rate of vapourisation. Flammable vapour fires e.g. petrol can also be put out by use of foam.

Gas fires, however, differ from other vapour fires in one important respect. In the case of flammable vapour fires, extinction of the fire is the main concern of the fire fighter but in case of gas fires, stoppage of flow of gas is more important. If the fire involving gas is extinguished, but the flow is not stopped then the escaping gas will accumulate in greater volume and will result in a more serious fire and explosion.

Therefore, in case of a gas fire, the procedure should be as follows:

- Stop the flow of gas at the earliest and cool the gasholder by water spray. This is most important.

- CO_2 or dry powder extinguisher may be used to put out the fire so as to gain access to the valves for closing the same. After the fire is out, the valve must not be left open even for a short time.

- In case of cylinder fires, water spray may be used to cool down the cylinders so as to obviate the danger of cylinder explosion.

- If the leakage of gas from cylinder/vessel can not be remedied or stopped, the vessel should be taken out in an open space and the gas shall be allowed to burn in a controlled state, water being all the time sprayed to cool down the cylinder. Alternatively, if there is adequate opening on all sides, so that there is no risk of gas migrating to near by buildings, then the gas may be allowed to escape into atmosphere, by completely opening the valve.

- Where it is suspected that gas has been leaking for some time, it must be ensured that all the neighbouring buildings are completely evacuated until the defects have been remedied and the condition is safe enough. Also electric switches must not be operated inside a closed room suspected of full of inflammable gas.

2.7 Classification of Fires

Depending upon the type of fuel involved in the fire and its method of Extinguishment fires are classified in four classes. For each class of fire, fuel type, preventive means and general method of Extinguishment is as under:

Class	Fuel	Prevention	Extinguishment
A	**Ordinary combustibles or fibrous material** such as wood, paper, cloth, rubber and some plastics (anything that will leave an ash)	Keep storage and work areas free of trash. Avoid placing materials next to possible heat sources.	By cooling the material below its ignition temperature and soaking the fibres to prevent re-ignition. Use pressurized water, foam, or multipurpose dry chemical Extinguishers. ***Don't use carbon di-oxide or BC rated dry chemical Extinguishers.***
B	**Flammable or combustible liquids** such as gasoline, kerosene, oil-base paint, paint thinners and grease.	Don't refuel equipment while the engine is hot or in a confined space. Keep all flammable liquids in tightly sealed, spill-proof containers. Use flammable liquids only in well ventilated areas.	By removing oxygen, preventing the vapours from reaching the ignition source or inhibiting the chemical chain reaction. Use multi-purpose or ordinary dry chemical and carbon di-oxide Extinguishers.
C	**Energized electrical equipment** such as appliances, switches, panel boxes and circuits.	Replace electrical items with worn insulation or broken fittings. Don't misuse fuses – never replace a fuse with a higher rated unit. Don't overload wall outlets.	By using an agent, which is not capable of conducing electricity. Use multi purpose or ordinary dry chemical and carbon di-oxide extinguishers. ***Don't use water extinguishers, as water is a conductor of electricity.***
D	**Combustible metals** such a magnesium, titanium potassium and sodium. These metals burn at high temperatures and give off sufficient oxygen to support combustion.	Pure metals such as potassium react violently or even explosively with water all reactive metals should be stored in sealed containers in a non-reactive liquid to prevent decay (surface oxidation) from contact with moisture in the air.	By using heat absorbing medium i.e. covering it with a dry powder or sand. ***Don't use water or other moist agent to extinguish fire as it will cause further reactions.***

Multipurpose (ABC rated) chemical extinguishers leave a residue that can seriously harm sensitive equipment such as computers. Because of this, CO_2 extinguishers are preferred in these instances because they leave very little residue.

2.8 Foam as Extinguisher

From the triangle of combustion it is evident that a fire can be extinguished either by *starvation* or by *smothering* or by *cooling* it. Water extinguishes fire by lowering the temperature below the ignition point. In case of fire of inflammable liquids use of plain water is restricted as most of inflammable liquids have lower specific gravity as a result water has a tendency to sink down. Therefore, if the characteristic of water is modified by reducing its specific gravity then it can float over the surface and can be employed as an extinguishing agent for the fire of inflammable liquids.

This modified form of water known as **foam,** is an aggregate of tiny gas filled or air filled bubbles, lighter than the lightest oils. When applied correctly and in sufficient quantity it forms a blanket capable of covering the surface of burning liquid and also absorbs the heat and cools the burning liquid, thus, resulting in extinguishment of fire by cooling and blanketing.

2.8.1 Types of Foam

Depending on the materials used and the methods of preparation, foam for fire extinguishment is of two types;

(a) Chemical Foam

When a solution of aluminium sulphate reacts with solution of sodium bi-carbonate in the presence of small quantity of stabiliser, a frothy product is obtained, which retains its texture for comparatively long time. This froth is known as **chemical foam**, with bubbles filled with carbon-di-oxide gas. The foam is relatively insoluble in most of the inflammable liquids and owing to its lightweight, floats on the surface of the liquid. It puts out fire by blanketing action, with little role by carbon-di-oxide.

(b) Mechanical Foam

The mechanical foam is produced by adding suitable compounds to water and then violently aerating it by employing suitable type of foam making equipment. The general properties of **mechanical foam** are similar to that of chemical foam except that the bubbles are filled with air. Foam produced in this manner is also called **air-foam**.

2.8.2 Production of Chemical Foam

When foam is required in smaller quantities, chemical hand extinguishers are employed where in two separate solutions are mixed when the extinguisher is operated. Bubbles of gas are formed throughout the liquid and the whole container is filled with foam, which is ejected by gas pressure set-up by the CO_2 generated.

When larger quantities of chemical foam are required, then it is produced either by employing chemical engine or some form of continuous foam generator. The principle of working of the chemical engine is precisely the same as that of hand extinguisher but on a larger scale.

Large quantities of chemical foam can be produced either (a) By brining together solutions of the two ingredients in required proportion, which on mixing produces foam, or (b) By introducing into a hose line, the main ingredients in powder form. In the presence of water, the powder dissolves and the resultant chemical action generates the foam.

2.8.3 Production of Mechanical Foam

It has already been explained that by introducing a suitable compound into the water stream and then aerating the resulting mixer stable foam can be produced. This basic principle applies irrespective of the size of equipment. The compound used is generally known as *foam compound,* although also referred as foam liquid or foam concentrate. The equipment used for induction and aeration is called foam equipment and the resulting foam is called mechanical foam.

Foam compounds commonly used are hydrolised protein type, soap based and similar type. However, protein type compounds have proved more satisfactory, and are generally used for effectively dealing with fires involving hydrocarbons such as petrol, oils, paints, fats, neptha, etc. The various foam compounds used are:

- Liquid soap;
- Hydrolised protein compound;
- Sulphonated compound and
- C.R.D. compound

Protein based compounds are not used on alcohol or spirit fires, due to risks owing to the reaction between the spirit and the foam.

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Chapter – 3

Effects of Fire in Building

3.0 General

The fire in building feeds on combustible contents of a building. The possible intensity and development of fire depend on many parameters such as nature and quantity of combustible materials, their distribution and availability of oxygen (air supply) for their combustion. Once the fire starts, it tends to ignite all the combustible materials in the surrounding areas and in case it is not checked it may spread to other parts of the building. If not controlled within a reasonable period it may lead to collapse of the structure.

3.1 Effects of Fire

The study of fire accidents in the past has indicated that the fire causes damage to the building and its contents, where as the by-product of the fire i.e. smoke and hot toxic gases causes damage to the human lives. Smoke reduces visibility and the hot toxic gases produce suffocating effect and the combined effect of the two is to bring about mass panic which in turn causes maximum danger to life. The damages caused by the fire can be broadly grouped as under:

- Danger to life of occupants.
- Danger of spread of fire to other areas.
- Danger of damage to property (building and its contents).

3.1.1 Danger to Life of Occupants

As fire breaks out in building and intensifies, the occupants try to escape to the safe area. The requirement to evacuate the affected area of building and resultant panic, besides other factors, depends on extent of combustible content in the building i.e. *fire load* or *fire severity* of the building. The **fire load** of a building is duration of time (in hours), the fire would last in terms of standard fire test. Experience indicates that panic seldom develops even in the presence of potential danger, so long as occupants of buildings are moving towards exists which they can see within a reasonable distance and with no obstructions or undue congestion in the path of travel. However, the panic starts due to

- 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, and
- persons stumbling and falling on stairs.

Danger from panic is greater when a large number of people are trapped in a confined area.

Under panic condition/situation physical capabilities of the persons also get restricted/limited as enumerated under:

Sr. No.	Physical capabilities under normal conditions	Physical capabilities under panic situation
1	Climbing stairs at a stretch – upto three floors	Climbing stairs at a stretch 1 ½ to 2 floors maximum.
2	Walking at a brisk pace – 1.5 metres per second for 10-15 minutes.	The speed becomes 0.75 to 1 metres per second and time gets reduced to three minutes to five minutes maximum.
3	Carbon-di-oxide discomfort level ranges between 3 to 10 percent	The discomfort level comes down to 2 percent.
4	Sense of direction remains normal.	The sense of direction becomes hazy – a person forgets and gets confused much quicker.
5	Normal analytical capability/decision taking capability exists.	The person is more liable to just accept what the other person says – is more prone to simple suggestions.

Therefore, for safety of occupants, the adequate means of escape should be provided in a building so that they can reach the place of safety in the shortest possible time in the event of a fire. The safe exit of occupants from the building should be ensured by way of providing definite escape-ways, passages, corridors and stairs etc. leading to a street or to an open space. *Lifts and escalators, which are generally provided in the multi-storied buildings, are not considered as exits,* even though they are well designed but from the experience in the past, they failed to operate successfully in the event of fire. In case there is a fire in a particular storey, the exit provisions in the building should be such that the occupants of the floor immediately above and below that floor should be able to have safe exit in reasonable short time.

3.1.2 Danger of Spread of Fire to Other Areas

On outbreak of fire in a building there is always a potential danger of it spreading to other areas through a combustible material present in the building, transmission of heat and smoke. Therefore, buildings should be so designed that, if fire or smoke should occur, it would be extinguished almost immediately. In any event, it could not spread much beyond the place of occurrence or could be contained in a limited area for sufficient time to enable the occupants in the danger zone to escape to place of safety.

Experience has shown that concealed spaces within a building such as space between ceiling and false ceiling, horizontal and vertical ducts (service and electrical shafts), etc. tend to act as flues/tunnels during a fire. Therefore, the design aspect of the building should be such, that each compartment should be capable of restraining the fire within the compartment for appropriate duration of time. Spread of fire or smoke can be prevented by compartmentalization of building, venting of heat and gases, and provision of dampers etc.

3.1.3 Danger of Damage to Property (Building and its contents)

It has been observed in past, that on outbreak of fire, buildings too had gutted in fire. Fire causes damage to the structural components of the building and in case of excessive damage

it may cause collapse of the building. Damage to the building components depends on the fire load/severity and the *fire resistance* property of the material used in construction. During fire the probable symptoms of building collapse are -

- Failing or spalling of pieces of mortar, stone, etc. from the wall;
- Horizontal cracks, more indicative of danger than vertical cracks;
- Sagging floors or beams or gaps appearing between the edges of floors and walls;
- Displacement of steel or cast iron pillars supporting joints or beams;
- Bulging of walls.

Therefore, proper selection of material and the method of construction may be the guiding factors in minimizing the danger to the occupants and property from fire. The use of fire resisting materials and construction of the structural elements like columns, beams, floors, load bearing walls, lintels, arches etc. in such a manner that at the time of fire they should continue to function as structural elements till such time as would enable the occupants to escape to safe places, the danger to the human life can be reduced to large extent.

Further, structural elements of the building must be designed *for strength and fire-resistance* consistent with the fire-load (i.e. combustible content) of the building. For this, it is necessary to assess the fire-resistance of locally available building materials under varying fire and structural loads.

3.2 Problem of High-rise Buildings

The problems of fire in high-rise buildings are many and they are tremendously complex, unique and special, not generally encountered in traditional low-risk and low-rise buildings. The rise of smoke and hot gases, their possible consequences become more significant with the increase of building height. Most floors are beyond the reach of fire department aerial ladders therefore, gaining access to the fire from the outside becomes extremely difficult. The fire fighting activities such as locating the fire, conducting fire fighting and rescue operations are comparative difficult.

The important aspects, which make multi-storied buildings more vulnerable to fire hazards are :

a) High-rise buildings contain a larger number of ignition sources as well as flammable and combustible substances.

b) Most high-rise buildings have high occupancy. Evacuation of occupants, especially invalids, old persons and children, in most cases poses enormous practical difficulties. The problem is aggravated by the fact that staircases are the only safe means of escape. Electrically operated passenger lifts and elevators behave erratically during fires; quite often, they get stuck at the floor where the fire is raging.

c) Vertical spread of fire in high-rise buildings is fast due to '**chimney/funnel effect'**. Hot air and combustion products during a fire tend to go up, creating a drought and accelerating flow of cool air from down below, which sustains and spreads combustion. Convected and radiated heat from floors below can ignite carpets, curtains and furniture in upper floors.

d) High-rise buildings are often so high that quite a few upper storeys are beyond the reach of aerial fire fighting equipment available with the fire brigades. In such cases, fire needs to be fought from within the building. Fire fighting personnel encounters lot of practical difficulties, such as logging, poor visibility and use of cumbersome and heavy self-contained breathing apparatus.

All these make fire fighting, rescue and salvage operations in such buildings a frighteningly difficult task.

3.3 Fire Resistance of Structural Elements

In simple terms, the fire resistance of an element is its stability, integrity and insulation for a specified duration of fire. Stability means its capacity to withstand collapse. Integrity is related to withstanding against cracking/opening of the material so that flames do not penetrate through. Insulation is the ability of its unexposed face to remain cool. On satisfaction of all these criteria, a particular element can be termed as fire resistant for a specific duration. The fire performance of the element depends on properties such as modulus of elasticity, strength, thermal expansion and creep etc. of the material used in its construction at the elevated temperature.

The basic approach for determining the fire resistance rating of the material is to assess the duration of time, a building element carries a load to which it is subjected, when exposed to a standard fire. For the material normally used in buildings, fire resistance ranges from 30 minutes to 4 hours.

3.4 Fire Behaviour of Various Building Materials

When different materials are exposed to or come in contact with fire, there load carrying capacity and stability changes depending on its properties such as modulus of elasticity, strength, thermal expansion, creep etc at the elevated temperature. Some material may even contribute in combustion thus causing spreading of fire. Time taken for complete collapse or disintegration and the rate of spread of flame through the material varies in each case. The factors, which affect these variations, are:

- Nature of materials, that is whether it is combustible or not;
- Ignition temperature of the material if it is combustible;
- Intensity of fire to which the material is exposed;
- Size, particularly the thickness, of the element/component;
- Physical load or stresses on the structural components.

Material used in construction of building can be grouped in two categories based on their location /structural function i.e. structural components and surface finishes.

3.4.1 Structural Components

Behaviour of materials generally used in structural elements of the buildings, under fire is as under:

a) **Timber:** Timber has a low thermal conductivity and it produces a protective skin of charcoal in a fire, which reduces the rate of combustion. When subjected to fire, timber first gets charred to certain depth and thereafter, this charred layer serves as insulation to check the spread of fire to the inner portion. Much, however, depends on whether it is hard or soft wood, its cross sectional area and its chemical treatment, if any. Teak, Sal, Shisham, Babul are generally considered as hardwoods and Chir, Deodar, Kail, Walnut, Spruce as softwoods.

A dense wood offers greater resistance to fire than a lighter one. Presence of resins and oils in wood increases combustibility. No woodwork of any kind should be laid within 60 cm of a fireplace or a flue.

b) **Stone:** Stone in general is a good heat insulator but inferior to brick when subjected to heat owing to its tendency to spall and split into pieces and specially when a jet of water is applied suddenly.

The usage of stone in a fire resistive construction should be strictly restricted to the minimum. Hot stone when subjected to sudden cooling develops cracks and can lead to failure of structure. Granite, when exposed to serve fire, explodes and disintegrates. Limestone is least recommended as it crumbles and gets ruined by an ordinary fire. Only compact sandstone having fine grains may be used as it can stand the exposure to moderate fire without serious cracks.

c) **Bricks:** Bricks generally have a very low thermal conductivity and nearly approach fire proof stage if all stones and foreign materials are removed from them. First class bricks moulded from good clay can stand exposure to fire for a considerable length of time. The properties of bricks, which render them fire resistant, are the size of bricks, the method of construction and the component of fire-resistive material in bricks i.e. clay, etc. It has been well established that brick masonry construction is most suitable for safeguarding the structure against fire hazards.

d) **Concrete:** It consists of three constituents viz; coarse aggregates (gravel, broken-stone, brick or clinker or hard materials), fine aggregate and matrix. Where it is reinforced with steel member, it is called reinforced concrete. In a fire, effect of temperature upto 250°C on the strength of concrete is small, however, concrete rapidly dries and contracts between 400°C and 500°C with the result that it cracks. At about 800°C the cement begins to decompose. If a jet of water is applied on to heated concrete, it may slake the lime causing rapid expansion.

It has been noticed that in an average fire, the concrete surface gets disintegrated for a depth of about 25 mm. This is due to the dehydration of mortar in concrete by the fire. Hence in a reinforced concrete fire resistant construction, the thickness of clear cover should be more.

e) **Glass:** Glass conducts heat faster than metal and when heated, tends to crack easily because of its low thermal conductivity and uneven expansion. By the use of glass reinforced with steel wire netting, such cracks can be minimised. Even when the cracks are formed, the fractured glass remains in its original position, as the embedded wire holds the cracked portion and does not allow it to fall. The reinforced glass has a higher melting point than the ordinary glass, and as such it is commonly used for fire resisting doors, windows, sky-lights etc.

f) **Metals**

- **Steel:** Steel although incombustible has a very low fire resistance value and looses two-thirds of its strength when heated to over 600°C. With the increase in temperature, the co-efficient of elasticity of the metal falls appreciably rendering the structural members soft and free to expand. When the members in this state come in contact with water used for extinguishing the fire, they tend to contract, twist or distort and thus the stability of the entire structure is endangered. It has been noticed that unprotected steel when subjected to fire causes the collapse of the structure. Hence in a fire resistant construction, structural steel members must be suitably protected by covering them with materials like brick, terra cotta, concrete etc.

- **Cast Iron:** While fighting a fire in a building having cast iron structural members, it is wise to avoid playing a jet of water directly on them because the rapid cooling may cause these members to suddenly contract and thus cause cracks.

- **Wrought Iron:** When exposed to heat, wrought iron members normally loose shape and get distorted.

- **Lead and Zinc:** These metals melt easily and allow the fire to spread quickly. These may, therefore, cause serious burns to the fire fighters while working under panels or fittings of these metals.

g) **Asbestos:** Asbestos, the fibrous form of several minerals and hydrous silicates of magnesium, can be moulded or woven into various fabrics and when combined with Portland cement to form a material having great fire resistive value, are largely used in the construction of fire resistive partitions, roof etc. It is non-flammable and a poor heat conductor; asbestos has been widely used to make fire-resisting products such as safety clothing for fire fighters and insulation products such as hot-water piping.

h) **Plaster or Mortar:** Plaster or mortar is incombustible and as such, by suitable choice of the type of mortar, the walls or ceiling of a building can be made more fire resistant. Cement mortar preferred to lime mortar is liable to calcine. The resistance of the plaster to fire hazards can be increased by using it in thicker layers or reinforcing the plaster with metal laths. Gypsum plaster when applied over structural members like steel columns etc. makes a good fire resistive quality.

i) **Plastics:** Plastics are of two types viz; thermoplastics and thermosetting plastics. In general, all thermoplastics are inflammable whilst thermosetting plastics are fire resisting.

3.4.2 Surface Finishes

For surface finish of structural components various materials are used such as building boards for lining of walls partitions and ceilings, paints and varnishes etc. The types of building boards commonly used are, Fibre Board, Plaster Board, Plywood Board and Plastic Board. The fire resistance of building boards mainly depends on the material used, their thickness and finally, in their method of erection.

Surface finishes can also contribute to the spread of fire and combustibility. The use of flammable surface finishes, such as boards etc. may spread the fire, even though the structural elements may be adequately fire resistant.

Based on the rate of spread of fire surfacing material used in buildings have been grouped in various classes as under:

***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.

3.5 Fire Retardant Building Materials

Reducing the surface spread of fire through material helps in evacuation of the occupants of the building and give time for fire fighting personnel to reach the site before the fire goes out of control. This can be achieved by suitably treating the building material mainly wood, paper, plastic etc. by fire retardant and flame retardant compounds. These materials when added or applied increase the resistance of that product to fire. They are less flammable than the materials they protect, burn slowly, and do not propagate fire. Some flame-retardant materials prevent the spread of flame; others burn and thereby create a layer of char that inhibits further combustion.

These compounds can be incorporated into a material either as a reactive component or as an additive component.

- *Reactive-type flame retardant materials* are preferable because they produce stable and more uniform products. Such materials are incorporated into the polymer structure of some plastics.
- *Additive-type flame retardant materials* are more versatile and economical. They can be applied as a coating to wood, woven fabrics, and composites, or as dispersed additives in bulk materials such as plastics and fibres.

3.5.1 Fire Retardant Chemicals

The chemicals mainly used for fire retardance are either chemical compounds or mixer of compounds, containing phosphorus, nitrogen, sulphur, boron, halogen, antimony, aluminium, etc. The type of chemical used as fire/flame-retardant determines, how it works i.e.

- *Boron or aluminium* increases the amount of char, or burnt material, formed in the early stage of a fire. The char forms a protective layer that prevents oxygen from reaching the inner layers of the material and thus sustaining the fire. Chemicals commonly used are borax, boric acid, and hydrated aluminium oxide.

- *Phosphorus* containing compounds such as phosphoric acid work by forming a surface layer of protective char. Nitrogen used with phosphorus are effective in cellulose, polyester, and polyurethane products. *Antimony* by itself is ineffective as a flame retardant and is used only in combination with halogens, especially bromine and chlorine.

- *Bromine* works as a flame retardant in its gaseous phase. When bromine compounds are exposed to flame, the bromine dissociates from the material and forms a heavy gas. This dissociation disperses heat, and the bromine gas forms an insulating layer around the material. The layer prevents flames from spreading by inhibiting access to oxygen and by slowing the transfer of heat. *Chlorine* works in a similar manner in both its liquid and gaseous phases. The most important fluorine-containing flame retardant materials are the chloro-fluoro-carbons, which are used as blowing agents in polyurethane and polystyrene foams.

3.5.2 Treatment of Timber

It is not possible to make timber fully fire-resistant, chemicals and paints only retard the action of fire. Timber can be rendered non-inflammable, which will not flame or glow but merely char, and will not, therefore, assist in the propagation of fire.

This is done by pressure impregnation of the timber with large quantities of chemicals. The most common of which are aluminium di-phosphate and sulphate, borax and boric acid, zinc chloride and sodium tetra-borate. This treatment retards increase in temperature during fire. Paints of asbestos, magnesium sulphate, ferrous oxide etc. also have been found to be very much effective. White washing is effective to some extent in retarding the action of fire.

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Chapter – 4

Philosophy of Fire Protection in Building

4.0 General

In planning, designing and construction of any building, particularly high-rise buildings, provisions are required to be made to ensure safety against fire. An indefinite combination of variables are involved in the phenomenon of fire, all of which cannot be quantified. Therefore, provisions are based on the fire behaviour characteristics of different materials and structural elements of buildings. The activities pursued by the occupants of buildings are also taken in to consideration for assessing the extent of hazards and devising the methods by which the hazards could be minimized.

Absolute safety from fire is not attainable in practice. Therefore, approach is to specify measures, which will provide that degree of safety from fire, which can be reasonably achieved. These include certain essential features for early detection of fire so as to minimise its impact on both life and property, compartmentation for containment of fire, ventilators to prevent the dispersion of smoke, means of early extinguishments, and communication system for instructions to occupants and also to the people responsible for fire fighting to communicate. It also includes provision of fire resistant walls, floors, stairs, shafts and other elements, and to control fuel contents for minimizing combustibility and potential smoke generation. Fire safety organization and fire response plan of the important building shall also be prepared/set-up for proper response from occupants in the event of fire.

4.1 Fire Protection in Building

The important aspects of the fire protection in buildings is to ensure:

- Safe means of egress and evacuation in the event of fire.
- Structural stability under fire conditions and protection against fire spread.
- Effective means to contain and fight the fire, with fire fighting installations of the fire brigade and by in-built protection systems.

➢ i.e. to specify measures to cater two basic requirements - **Fire safety** and **Fire fighting**.

- **Fire safety** aspects are in-built requirements to be taken care of in the architectural & structural design and construction of building i.e. before the incidence of fire. These measures are also termed as **passive measures**.

  It includes, subdividing the building both horizontally and vertically in to fire tight cells called compartmentation, provision of separating walls, which are common to adjoining buildings, and provisions of space separation etc. Smoke and other products of combustion are controlled by properly controlled ventilation. Exit ways and refuge platforms are provided and planned so that the occupant has early and unobstructed

access to these areas at the time of emergency evacuation of the building. In addition, provisions are made for various elements by assigning requisite fire rating to them.

- **Fire fighting** aspects deal with the installation and maintenance of the fire fighting equipment and installation, within and outside the building premises, which would come into operation after the incidence of the fire. These measures are also termed as **active measures**.

  It includes, installation of fire alarms and detectors to give early warning of the outbreak of a fire, installation of equipment for automatic fire extinction such as hand extinguishers, sprinklers, CO_2 safety systems and provision of facilities to assist the fire service personnel etc. Since local fire brigades are not in a position to combat fire above certain height, with the facilities available with them, therefore, additional in-built fire fighting facilities in buildings above certain heights or horizontal areas are also required to be provided.

4.2 Approach Towards Fire Protection

Stipulation of the various fire protection measures for building, to minimise the loss of life & property and effects of fire on surrounding area, are broadly based on following aspects/ philosophy.

4.2.1 Classification of Buildings

The extent of danger or hazard and related risk within the building, in case of fire, depends on the nature of use or the operations carried out in the building reflecting the extent of combustible contents in the building i.e. 'fire load' or 'fire severity'.

In terms of occupancies, buildings are classified as under :

Sr. No.	Building type	Fire load density*
1	Residential	25
2	Institutional and educational	25
3	Assembly	25-50
4	Business	25-50
5	Mercantile	Up to 250
6	Industrial	Up to 150
7	Storage and hazardous	Up to 500

***Expressed as wood equivalent kilograms per square metre.**

- Fire load of various occupancies reflects a fire severity of half an hour to 4 hours of standard test fire, and is inter-related with the laid down live loads for the structural design.

4.2.2 Type of Construction

Having identified the amount of heat generated in the event of fire within compartmentalized area in a building, the prime objective is to see that the various elements like floors, side

walls, columns, roof, fittings etc. are able to withstand or resist or endure ravages of fire for a duration more than the fire itself would have lasted.

Therefore, based on degree of fire resistance of various elements, buildings are classified in terms of **types of construction**. The approach is to spell out the actual fire resistance of structural and non-structural components made of various materials, taking into account their functional utility.

The buildings are classified in four categories i.e. **type I, type II, type III and type IV**. For a given type of construction, the fire rating of different elements of a building both structural and non-structural, may have different values.

⏩ Various structural design codes, spelt out the design parameters for various elements to take care of the fire resistance requirement.

4.2.3 Area & Height Limits

In case of fire, quick & safe evacuation of the premises by the occupants before the structure may collapse, is of vital importance. This aspect spells out the importance of limiting the horizontal and vertical extent of the building based on the fire load of the building and the type of construction, i.e:

i) If the type of construction of the building is equal to the fire severity due to the occupancy, the building is very safe for the occupants. This means, that in the event of fire, the occupants get sufficient time to evacuate the building; particularly if the type of construction is 4 hours grading as in type 1.

ii) Secondly, if the type of construction of the building is more than the fire severity due to occupancy, the building is more than safe for occupants.

iii) Thirdly, if the type of construction of the building is less than the fire severity due to occupancy then the building is less safe for the occupants.

Based on above considerations, the area limits are prescribed for the buildings. *For case (i)* the area of the building can be as much as possible in a given plot of land except for other open spaces required for light and ventilation. *For case (ii)* since fire grading is higher than the fire severity, therefore there is no limitation on the area of the building. This is precisely the approach followed in Chicago and New York building codes, hence the buildings in these cities are very high. *For case (iii)* since the fire grading is lower than the fire severity of the occupancy, the area of the building has to be controlled in addition to the open spaces for light and ventilation in a given plot.

⏩ All modern building codes co-relate the extent of horizontal areas and vertical limits of the buildings depending upon the occupancies and the type of construction. The approach in our country is to regulate the horizontal and vertical areas and height limits each with respect to **F**loor **A**rea **R**atio (**FAR**) and **F**loor **S**pace **I**ndex (**FSI**)**.**

4.2.4 Exit and Egress Requirements

The prime objective of fire safety requirements is to ensure safe and speedy evacuation of all the occupants in the building on different floors to an outside place of safety in the event of fire. For evacuation the mental and physical state of the occupants in various occupancies is an important aspect to arrive at the exit requirements as this reflects the capacity to escape.

- The population of the building is assessed in terms of **occupant load** i.e. area taken per person, from which the total population on all floors/spaces can be worked out.

- The capacity of the persons to evacuate through various exits (doors, corridors, staircases, ramps, galleries etc.) is spelt out in terms of the **capacity** (occupants) **per unit exit width** of 50 cm. This gives the number of people who can cross the exit within a specified time of evacuation. Depending on the nature of population of the space/room/hall, the capacity is smaller in residences (old/children) & hospitals, in comparison to offices where the occupants are healthy & active.

- The distance within which a staircase or a ramp shall be made available in a building is given in terms of the **travel distance** for various occupancies. In buildings with mixed age group, travel distance required is shorter than in case of active/agile people oriented occupancy.

⏩ Therefore, with the *occupant load*, *capacity per unit exit width* and the *travel distance*, it is possible to arrive at the number and widths of doors, corridors, staircases, ramps, etc. Individual construction requirements for different types of exits are laid down keeping in view, the safe evacuation of the occupants of the building.

- In *multi-storied buildings* minimum two staircases separated from each other shall be provided. In the event of one of them engulfed in fire, the alternate serves as a rescue option. Suitable smoke stop doors in between corridors connecting two staircases shall also be provided, in view of possible spread of smoke from one exit to the other.

In multi-storied building, following additional requirements are also needed:

- The staircase shafts should be pressurised so that smoke does not engulf the same.
- The staircases are also to be of the enclosed type.
- In case of basements, access to basement has to be cut off from the continuing staircase.
- Lifts are not expected to be used as exits during fire. A minimum of one **fire lift** shall be provided for the exclusive use of firemen in an emergency.
- Buildings more than 15 metre in height shall not have collapsible gates.

4.2.5 Refuge Area

Escape from high-rise building cannot be accomplished in few minutes. Therefore, the safety of occupants must be ensured in ways that do not depend upon immediate attempts or mass evacuations on sounding of an alarm. Occupants of each floor must have ample areas of refuge, which can, if necessary, be occupied by them with safety for the duration of a fire elsewhere in the building.

Refuge areas provided shall be safe from smoke and heat throughout the duration of fire or until rescue is possible.

4.2.6 Separation of Hazardous Area

To prevent spread of fire from hazardous area of the building to other locations, separating walls are provided. Walls used for this purpose are of two types e.g. one between adjoining properties and the other, which sub-divide the property. The former is a type of wall that is owned jointly by two parties. It must be a fire-resisting one so that fire from one side may not communicate to the other side. Naturally, it must have no openings in it, which can spread the fire. It is known as a *separating wall or party-wall*. The latter type of wall may have, on the other hand, doors and other openings in it to afford communication with other parts of the building, which it divides. It is known as *Division Wall*.

⏩ Where openings are provided, they shall not exceed certain area of the wall in the case of an external wall and they shall be protected with fire resisting assemblies or enclosures having adequate fire resistance.

4.2.7 Control of Fire Spread

It has been observed that concealed spaces within the building such as space between ceiling and false ceiling, horizontal and vertical ducts (service and electrical shafts), etc. acts as flues/tunnels during fire thus assisting spread of fire to other areas. Therefore to prevent spread of fire due to above, buildings are required to be compartmentalised with provision of dampers. The design aspects of the building should be such, that each compartment is capable of restraining the fire within the compartment for appropriate duration of time.

- **Compartmentalisation*:*** It includes partitioning large floor areas by firewalls into smaller areas. Fire doors protecting wall openings should be kept closed. Spaces between floor and ceiling or roof and ceiling, should be isolated at frequent intervals by fire stops. Spandrels should have a high fire rating and be sufficiently deep (minimum depth of 3 ft) at each floor level to prevent flames extending out the windows in one story from igniting materials in the story above.

- **Fire dampers*:*** The dampers should be provided to seal the control zones, thus preventing smoke from spreading to escape routes and refuge areas, and to guide ventilation area air to points where it is needed. These should be installed in ducts, along with fire or smoke detectors.

4.2.8 Control of Smoke Spread

Though, compartmentation limits spread of fire, still smoke can readily spread to adjacent spaces through the various leakage/openings in the enclosure, such as cracks, openings around pipe ducts, airflow grills and doors, as perfect sealing of all these openings is not possible. Smoke and toxic gases obstruct the free movement of occupants of the building through the means of escape (escape routes) and pose a greater difficulty to firemen in their activities of fire fighting and rescue operations.

Hence, minimization & exclusion of smoke and toxic gases is of great importance. This can be achieved by:

- Limiting the use of materials in internal finishes that may produce large quantities of smoke and toxic gases during burning.
- Providing means to avoid spread of smoke i.e. venting and pressurisation system.

a) Venting System

The smoke and hot combustion products from a fire, being lighter than the surrounding air, tend to rise and on reaching the roof or ceiling spread out (mushroom) on all sides and form a layer which floats on top of the cold air beneath. In the absence of vents, this layer becomes progressively deeper until the whole building is filled with hot smoky gases. The hot gases at the roof level moved by convection currents contribute to rapid lateral spread of fire.

The provision of properly designed and suitably located vents in adequate number helps the speedy removal of smoke and hot gases, thereby preventing spread of fire, besides reducing risks of explosion of unburnt gases and reducing damage to the contents and structure of the building by heat and smoke. It is easier to vent a building of smoke than clear it of smoke once it has been filled.

Venting can be achieved by:

- *Natural draft system*, which utilises roof vents or vents in walls at or near the ceiling level. Such vents are normally open or are designed for automatic opening in case of fire, by release of smoke sensitive devices.
- *Exhaust draft system,* which utilises smoke exhaust equipment of adequate capacity. Equipment shall be fire safe type.

⏩ Where smoke venting facilities are installed, they shall be adequate to prevent dangerous accumulation of smoke during the period of evacuation of the area served with a margin of safety to allow for unforeseen contingencies.

b) Pressurisation System

Another way for protecting escape routes against ingress of smoke, especially in high-rise buildings is pressurisation. ***In pressurisation system****,* air is injected in to the protected escape routes, i.e. into the staircases, lobbies or corridors, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the escape routes will be prevented. Pressurisation system is of two types:

- ***Single stage,*** which is designed for operation only in the event of an emergency, and

- ***Two stages,*** where normally a certain level of pressurisation is maintained in the protected escape routes, and an increased level of pressurisation brought into operation in an emergency. In air conditioned area, normal air conditioning system and the pressurisation system shall be treated as an integral one especially for a two-stage system with certain changes.

⏩ When provided, it will be desirable to have all the staircases in a building pressurised. Otherwise, the use of pressurised and naturally ventilated staircases in the same building may cause difficulties and hence shall be avoided. Under no circumstances pressurised staircase shall connect to an unpressurised staircase through a corridor or lobby. The pressurisation system can be interconnected with the automatic/manual fire alarm system for actuation.

4.2.9 Fire Protection in Services

To prevent outbreak of fire and its subsequent spread, following aspects shall be taken care of while providing various services in the buildings, particularly in high-rise building;

- Electrical distribution cables and wiring shall be laid in separate duct. Water mains, telephone line, inter communication lines, gas pipes or any other service line shall not be laid in the ducts used for electric cables.

- Service ducts to carry electrical and telephone lines and cables etc. shall be enclosed by walls having adequate fire resistance. Inspection doors shall also have similar fire resistance.

- Where refuse chutes are provided, they shall not be provided in staircase wells, air conditioning shafts.

- Air-conditioning installations are another important service, which requires special consideration. Air-conditioning installations with a continuous ducting passing through various floors are responsible for the spread of fire from one floor area to the other.

  Therefore, to contain fire on each floor, it is necessary to provide either appropriate air-conditioning dampers with thermal fuse, or to provide exclusive ducting for each floor separately and not on continuity with other floors linking various floors.

- Where gas pipes run in the building, the same shall run in separate shafts exclusively provided for purpose. There shall be no inter-connection of this shaft with the rest of the floors.

- Separate circuits for water pumps, lift, staircase lighting and for blowers for pressurising systems shall be provided directly from main switch gear panel and they shall be laid in separate conduit pipes so that fire in one circuit will not affect the other. Master switches controlling essential services circuits shall be clearly labeled. Medium and low voltage wiring running in shafts and within false ceiling shall run in metal conduit. PVC cables should have the additional sheating or protection provided by compounds sprayed after installation because of notorious secondary damages in case of fire. Meter rooms on upper floors shall not open in the staircase enclosure.

- In the case of lighting for staircases and corridors, there shall be separate circuits and they shall also be capable of connecting to alternative supply.

This requires a need for stand-by electric generator to be installed to supply power to staircase and corridor lighting circuits, fire lifts, stand-by fire pump, pressurisation fans and blowers, smoke extraction and damper systems in case of failure of normal electric supply.

- Transformers should be housed in a building in a separate room or enclosure and care should be taken so that the oil from ruptured transformer does not flow in to other parts of basement in case of installation in basement. There shall be direct access to the transformer from outside in the case of basement installation. Transformers shall not be housed on upper floors.

- Switchgears shall be housed in a separate room from the transformer bays by the fire-resisting wall. The transformer if housed in basement shall be protected by an automatic high-pressure water spray system. When housed on ground floor, it shall be cut off from the other portion by fire resisting walls of 4-hour fire resistance.

4.2.10 Detection and Alarm System

Detection of fire in its initial stage is of vital importance, as it helps to warn the occupants for safe and quick evacuation of the building as well as in prompt initiation of fire fighting measures. If the fire does not itself provide adequate warning, the fire detection and alarm facilities shall be provided in the buildings particularly important and high-rise buildings.

In buildings, above 24 metres in height, other than the residential buildings, in addition to the manually operated electrical fire alarm system, automatic fire detection & alarm system, shall also be provided. The system shall be installed based on its suitability, the type of risk and the structural feature of the building.

Manually operated electrical fire alarm system shall be readily accessible to all the occupants of the floor and shall be of break glass type, where the call is transmitted to the control room without any other action on the part of the person operating the call box.

Where combination system i.e. the detection, alarm and automatic fire extinguishing system are provided, like automatic sprinklers, there is no need to provide separate automatic detectors.

⏩ The requirement of fire detection depends on type of occupancy of the building and its horizontal and vertical extent. Details of various detection & alarm system have been covered in next chapter.

4.2.11 Fire Fighting Installations/Equipments

Having catered for the detection of the fire, the next requirement is to examine fire fighting equipment and installations to be provided in the building. Normally fire engines have a capacity to fight fires up to maximum 24 m, therefore, the in-built fire fighting equipment and installations plays a major role in fighting fire above 24 m.

a) At the lowest scale, to contain the fire immediately in the form of first-aid, fire-fighting appliances like extinguishers etc. shall be provided on all floors including basements.

b) The most important source for fighting fire in all buildings except hazardous uses is water. Therefore, for buildings above 15 metres in height, fixed fire-fighting installation like dry riser, wet riser, automatic sprinkler installation, high-pressure water spray systems etc. shall be provided.

- Accordingly, depending upon the height of the buildings, the need for providing underground static tanks and terrace tanks of certain capacity is recommended. The pump capacity depends upon the height and nature of use of the building. In multi-storeyed buildings, the provision of the static water storage tank is very important. This shall be exclusively provided for only fire fighting purposes and shall be accessible by the fire brigade.

- Having provided one of the important resources for fighting fire, this could be made use of by providing either dry or wet riser or down comer with hydrant outlets and hose reel on each floor landing. A fire service inlet at a ground level shall also be provided to rising main for charging it by fire service pump in case of failure of static fire pump.

The diameter of the hydrant for the riser installation shall depend on the heights of buildings and the occupancies.

c) Automatic sprinklers shall be installed in basement, used as car parks (area more than 200 sq. metre) any room or apartments or departmental stores or shops of area more than 750 sq. metre and all buildings more than 45 metre of height.

d) Automatic high-pressure water spray system emulsifier shall be installed for protection of indoor transformers or substation in basement area. For boiler room and ancillary storage or furnace oil in basement, the foam generating system should be provided.

e) However, in premises where the use of either water or foam cannot be used for fire extinguishment because of the special nature of the contents of the buildings or area to be protected, the CO_2 fire extinguishing installation should be provided.

⏩ The level of fire fighting equipment and installation in the building depend on the capacity of the local fire brigade to fight fires as well as the height & the nature of use of building. Fire-fighting provisions can be made with *portable appliances* or through *fixed fire fighting installations* or *both* (details of various fire-detection and extinguishing systems are covered in next chapter).

4.2.12 Access to Building

To enable the fire brigade personnel to reach the building premises and fight the fire from different positions, it is necessary to have the suitable access to reach the building with clear vehicular access around the building. For this, besides the normal marginal open space provided around buildings for lighting and ventilation, it is necessary to provide a clear space of 6 metres of permanent and strong pavement for carrying fire engine and other vehicles.

The location of this access depends on the height of the buildings to ensure the trajectory.

4.2.13 Fire Lifts

To enable fire services personnel to reach the upper floors in high-rise buildings (buildings 15 m in height or above) with the minimum delay fire lifts shall be provided for the exclusive use of the fireman in an emergency. Fire lifts shall be of certain minimum capacity, and fully automated with emergency switch on ground level. In case of fire, these lifts shall be operated by the firemen only, though in normal course, other persons may use it.

Each fire lift shall be equipped to operate automatically through alternate supply in case of failure of normal electric supply. It should have suitable inter-communication equipment for communicating with the control room on the ground floor of the building.

⏩ The number and location of fire lifts in a building shall be decided after taking into consideration various factors like building population, floor area, section of building (compartmentation), etc.

4.2.14 Emergency Lighting

In case of fire, for the proper guidance of occupants for evacuation, emergency lights shall be provided to ensure:

- Clear and unambiguously indication of the escape routes.
- Adequate illumination along such routes to allow safe movement of persons towards and through the exits,
- That fire alarm call points and fire-fighting equipments provided along the escape routes can be readily located.

⏩ Emergency lights shall be powered from a source independent of that supplying the normal lighting. Where provided the emergency lighting shall be put on within 5 seconds (preferably within 1 seconds) of the failure of the normal lighting supply.

4.2.15 Emergency Control Centre

In case of large buildings, especially those with many occupants, emergency control centre, or fire command station shall be provided, on the entrance floor with communication system and facilities for receiving the message from different floors. Details of all floor plans alongwith the details of fire fighting equipment and installations shall be maintained in the control room. The centre should have two-way communication with every floor and be able to direct rescuers and fire fighters and transmit instructions to occupants to guide them. The centre should also be able to control all electromechanical systems, such as elevators, air conditioning, and fans. To assist fire fighters, controls should be capable of venting, pressurising, or sealing any zone in a building.

4.3 General Fire Protection Requirements for High-rise Buildings

Based on the fire protection approach as discussed above, fire safety and fire fighting provisions to be provided in a high-rise building (i.e. more than 15 metres height in India) are summerised as under:

- Proper and easy approach from main road to building.
- Entrance gate sufficiently wide to enable easy entry of fire engine and equipment.
- Sufficient space around building for operation of fire tender.
- Adequate separation of individual buildings for preventing spread of fire from one building to another.
- Architectural and structural designed in a manner to limit the spread of fire both horizontally and vertically.
- Compartmentation to contain fire in the respective areas.
- Use of fire resistant materials for construction.
- Provision of well-located, well-ventilated staircase facilitating convenient exits in case of fire, with fire resistant doors at entrance.
- Proper escape route on the floor i.e. corridors & lobbies.
- Adequate provision of lifts and fire lift, terminating at ground floor level.
- Provision of standby generator for operation of lifts and lighting in staircase, corridor etc.
- Portable fire extinguishers at different floors.
- Automatic /manual fire alarm system.
- Floor-wise independent safety and fire fighting provisions including Hose Reel/ Hose Pipes and Exit signs.
- Provision of sprinkler system in basement. Further provision of mechanical ventilation in basement is considered desirable.
- Underground and overhead storage tank of adequate capacity for fire fighting purpose.
- Wet riser, down comer system.
- Control room with care taking organisational staff with communication system to all floors and facilities for receiving messages from different floors through suitable Public Address System.
- Maintaining fire-fighting equipment and installations in working conditions with proper testing at regular intervals.
- Training periodically the occupants of the building to ensure use of fire-fighting equipment efficiently at the time of need.

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Chapter – 5

Fire Detection and Extinguishing Systems

5.0 General

Early detection of fire is an important aspect of fire protection planning of the buildings, particularly high-rise buildings. Once a fire is detected in its incipient stage, it helps to warn the occupants so that they can escape/evacuate the building in time, and as well as help in prompt initiation of fire control measures i.e. fire extinguishment. If a fire does not itself provide adequate warning to occupants, the automatic fire detection and alarm facilities shall be provided in the building depending upon importance and the nature of use. Fire detection devices can also be combined with automatic fire-extinguishing equipment/installations.

5.1 Fire Detectors

The out -break of fire can be detected, either visually by the occupants of the building or through automatic detecting devices. Accordingly, the occupants of the building can be alarmed through manually operated alarms i.e *manual call boxes* or automatic audio-visual alarm devices such as gongs, horns, sirens etc., which are combined to operate with detectors.

Manual Call Boxes (MCBs)

Manual call boxes (MCBs) are used for raising alarm manually. These are of the break-glass type and can be installed at various locations in the building. The MCB has a micro-switch, which is normally kept pressed by a thin glass plate. The micro-switch has a set of contacts. As long as the glass keeps the micro-switch pressed, a green LED keeps glowing steady. When the glass is broken manually, in emergency, the micro-switch is released bringing a resistor into the circuit. The green LED goes off and a red LED starts glowing, giving audio-visual indication of fire.

5.1.1 Automatic Fire Detection

Fire produces a variety of changes, or releases a variety of by-products like heat, smoke, gases and radiations, in the surrounding environment. These by-products or stimuli are also referred as fire signatures. Any of these fire signatures can be exploited for automatic sensing of fire condition provided that it is of sufficient magnitude. Heat, radiation and smoke are produced copiously during a fire. However, generation of gases is fuel specific, accordingly, three basic types of automatic fire detectors are mainly used i.e. *heat*, *smoke* and *radiation detectors*.

(A) Heat Detectors

There are two main classes of heat-sensitive detectors. One is *point or spot type of detector*, which is affected by the limited area of hot gas layer immediately adjacent to it, and other is *line type of detector*, which is sensitive to the effect produced by heated gases along any portion of the detector line.

In each class, there are two types of heat detectors:

- ***Fixed temperature heat detectors***, which are designed to operate when the temperature of the heat sensitive element is raised to a predetermined level.

- ***Rate of rise heat detectors***, when a flaming fire takes place, temperature of air rises rapidly. When the rate of rise of temperature exceeds a predetermined value, these detectors get operated. These detectors are normally used as supplements to the fixed temperature heat detectors.

Heat sensing cables, it is a line type device whose sensing element comprises of two current carrying wires, separated by a heat sensitive insulation. At the *rated temperature*, this insulation gets softened & operates the detector by allowing the wires to make electrical contact.

B) Smoke Detectors

There are three distinct types of smoke detectors, which are used only at places where the ambient temperature varies within the limits of 0^0C to 38^0C. Beyond this temperature range, performance of smoke detectors is not satisfactory.

- ***Ionization type smoke detectors***, it works on the effects of the combustion products on ionization current. It responds quickly to invisible smoke from a clear burning fire, as compared to optically dense smoke. These detectors have an ionization chamber containing small amount of radioactive material that ionises the air in sensing chamber, thus, permitting flow of current through the air between two charged electrodes. When smoke particles enter the ionization area, they decrease the conductance of the air by attaching themselves to the ions. These detectors get operated when conductance reduces to less than the predetermined level.

- ***Photo electric smoke sensors***, in this type of sensor, a light source and a photo sensitive device are housed in such a way that light normally does not fall on photo sensitive surface. When smoke particles of fire enter the housing and come in the path of light rays, some light is scattered by reflection and refraction on the photosensitive device surface, causing the detector to respond.

  Obscuration type of smoke detectors, these devices also contain a light source and light sensitive element. Receiving element is placed directly in line with light source. Source light is usually collimated. When smoke particles come in the light path, light intensity reaching the photosensitive surface gets reduced, which in turn, initiates the alarm.

- ***Chemically sensitive smoke detectors***, they have a chemically coated sensitive element, which responds in the presence of carbon monoxide or other products of combustion present in smoke.

C) Radiation/Flame Detectors

These are designed to operate in dark or normally lit environments, where sunlight or other ambient lighting is expected. They are intended to detect the radiation emitted by flames travelling in straight lines, although reflected radiation may actuate a detector. They are normally of following types:

- ***Ultra violet flame detector***: These detectors work to detect the ultra violet radiations emitted by the flame. The sensing elements are generally solid-state (semiconductor) devices or gas filled tubes that are sensitive to UV radiations.

- ***Infra Red flame detector***: These detectors employ Infra Red (IR) sensing photocells and optical filter. Since IR radiation is present in ambient atmosphere in appreciable magnitude, therefore, optical filtering is required to filter out wavelengths outside the desired wave band. Flame being a copious source of IR radiation, can be detected from quite a long distance. Some IR detectors respond to total IR energy and some respond to flickering of flame associated with diffusion/open flame.

⏩ Each type of detector has its own characteristic and limitation. No single detector is suitable for universal application. The product of combustion and their growth differ from one type of fire to another in one respect or other. In each fire, response of different types of detectors would be different, therefore, selection & provision of fire detectors depend on the type of fire expected, ceiling height and type of construction, ambient conditions and other building features.

Once the correct type of detectors is selected for a particular application it is essential that they are spaced and mounted correctly as per the provisions of relevant code of practice, otherwise, they may be ineffective.

The details of various detectors, their application and mounting instructions are covered in detail in the relevant codes of practices.

5.2 Fire Extinguishing System

Extinguishing a fire involves removing one of the requirements for combustion. Fire fighters may physically remove the fuel from the fire by taking a burning item outside a structure. They can remove heat by cooling the fire with water or remove oxygen by smothering the fire with chemicals or a fire blanket.

In buildings, depending upon the importance, occupancy/use and height, suitable fire fighting arrangements shall be provided such as First-aid extinguishing equipment, wet riser, down comer, automatic sprinkler installation, high/medium velocity water spray, foam & gaseous or dry powder system. The details of such systems are as under:

- ***First-aid Extinguishing Equipment***

It includes, the use of portable fire extinguishers, which are handy and manually operated such as carbon-di-oxide, foam, dry chemical powder type etc. Depending upon the capacity, the discharge from a fire extinguisher may last from 20 to 120 seconds. Sometimes, buckets full of water and dry sand are also installed at convenient places for taking care of minor fires. This equipment is useful in extinguishing the fire as soon as it starts.

- ***Static Water Storage Tanks***

To ensure availability of satisfactory supply of water for the purpose of fire fighting, underground/terrace level static storage tank with required capacity are provided in the buildings. These tanks shall be fed through mains or alternate source of supply, and shall be so located/provided that static water storage should be entirely accessible to the fire engines of the local fire service.

- ***Fire Hydrants***

It consists of providing a water supply line/main around the periphery of the building with hydrant outlets, so that water can be easily made available for fire fighting. Hydrants are fed from an underground water tank at prescribed water pressure.

- ***Wet riser System***

This consists of providing 100 to 150 mm dia. vertical pipes at suitable locations within the building. These pipes are also known as wet risers and kept permanently charged with water through a pressurised supply. They are fed from an underground water storage tank through a fire pump, which ensures supply of water at 0.3 N/sq.mm at the topmost outlet. The wet risers are provided with suitable connections/landing valves at each floor, from where constant supply of water can be drawn in the event of fire.

- ***Down comer System***

In this arrangement of fire fighting, down comer pipe connected to terrace tank through terrace pump, gate valve and non-return valve are provided having mains not less than 100 mm internal diameter. Down comer pipes are provided with landing valves on each floor/landing, from where constant supply of water can be drawn in the event of fire. It is also fitted with inlet connections at ground level for charging with water by pumping from fire service appliances and air release valve at roof level to release trapped air inside.

- ***Dry riser***

It is an arrangement of fire fighting within the building, comprising of vertical rising mains not less than 100 mm internal diameter with landing valves on each floor/landing. Mains are normally dry but are capable of being charged with water usually by pumping from fire service appliances.

- ***Automatic Sprinkler System***

In this system, a network of water supply pipes (normally 20 mm dia.) is fixed to the ceiling of the floor or roof slab. The centre to centre spacing of the pipes is normally 3 m. The pipes receive supply of water through header pipes normally 40 mm in dia., which in turn, are connected and fed from water storage tank. An installation known as sprinkler head is fitted to the pipes in ceiling at regular intervals normally at 3 m c/c. Each sprinkler head is provided with a fusible plug. In the event of fire, the fusible plug in the sprinkler (nearest to fire) melts by virtue of rise in temperature and water gushes out of the sprinkler head. The water spray falls on the fire and helps in extinguishing the same.

- ***Automatic High Velocity Water Spray or Emulsifying System***

Automatic high velocity water spray or emulsifying system are provided for protection of indoor transformers etc.

- ***Foam Extinguishing System***

As explained in previous chapters, foam extinguishing systems are normally provided for protection of oil oriented fire hazardous e.g. oil storage areas. Fixed foam installations can be low, medium or high expansion types, which can cover fire risks in oil storage areas generally. High expansion foams are used for cable tunnels and other confined areas.

- ***Halon System***

A building with highly valuable and combustible material would normally provided with a halon fire protection system. However, these days due to its adverse effects on environment, the carbon dioxide system is provided instead of halon system. For some special fire risk, carbon dioxide may not be suitable and it may be necessary to provide

BCF (Bromochloro-difluoromethane) - Halon 1211 or
BTM (Bromochloro-trifluoromethane) - Halon 1301.

However, the use of halons shall be discouraged, as halons are ozone depleting substances (ODS) and their use is being phased out throughout the world.

- ***Carbon dioxide Fire Extinguishing System***

Fixed carbon dioxide fire extinguishing installation shall be provided on premises where water or foam cannot be used for fire extinguishing because of the special nature of the contents of the buildings/areas to be protected. Drawback of the system is that human beings cannot continue to work in the area, where carbon-di-oxide has been released, due to fear of asphyxiation.

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Chapter – 6

General Fire Protection Requirements

6.0 General

Building acts or codes, municipal and state laws regulate the construction of buildings and prescribe minimum requirements for fire protection, sanitation, and safety etc.. Such laws are intended primarily to set standards for new construction but also to prevent the continued use of buildings deficient in these respects. The municipal and state laws regulate the location, use, and size of various types of buildings located in that area. The codes serve as guides in the enactment of local building laws.

Based on general philosophy of fire protection, Bureau of Indian Standard (BIS) has stipulated the various fire protection measures/provisions for buildings vide NBC – SP-7: 1983 (Part IV- Fire protection). The codal provisions endeavour to avoid requirements, which might involve unreasonable hardships or unnecessary inconvenience or interference with normal use and occupancy of buildings, but insists upon compliance with minimum standards for fire safety necessary in public interest.

The fire protection requirements for the buildings vary from building to building based on its occupational use as well as on type of construction. Therefore, for prescribing the protection requirement first of all, buildings are categorised in different groups based on occupancy and type of construction. Brief description of codal classification of buildings and fire zone demarcation is as under.

(a) Classification of Buildings (based on occupancy)

All buildings, existing or new are classified according to the use or the nature of occupancy in various groups and sub-groups as per the detailed guidelines provided in the code. The brief description of various groups are as under:

Group A - Residential Buildings

These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities except any building classified under Group C. *These buildings are further sub divided in five groups i.e. A1 to A5.*

Group B - Educational Buildings

These shall include any building used for school, college or day care purposes involving assembly for instruction, education or recreation for not less than 20 students. *These buildings are further sub divided in two groups i.e. B1 & B2.*

Group C - Institutional Buildings

These shall include any building or part there of, which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants. *These buildings are further sub divided in three groups i.e. C1, C2 & C3.*

Group D - Assembly Buildings

These shall include any building or part of a building, where groups of people congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, theatres, motion picture houses, assembly halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants, places of worship, dance halls, club rooms, passenger stations and terminals of air, surface and marine public transportation services, recreation piers and stadia, etc. *These buildings are further sub divided in five groups i.e. D1 to D5.*

Group E - Business Buildings

These shall include any building or part of a building, which is used for transaction of business for keeping of accounts and records and similar purposes, professional establishments, service facilities etc. City halls, town halls, computer installations, telephone exchange, court houses and libraries shall be classified in this group so far as the principal function of these is transaction of public business and keeping of books and records. *These buildings are further sub divided in five groups i.e. E1 to E5.*

Group F - Mercantile Buildings

These shall include any building or part of a building, which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail. Storage and service facilities incidental to the sale of merchandise and located in the same building shall be included under this group. *These buildings are further sub divided in three groups i.e. F1, F2 & F3.*

Group G - Industrial Buildings

These shall include any building or part of a building or structure, in which products or materials of all kinds and properties are fabricated, assembled, manufactured or processed, e.g. assembly plants, industrial laboratories, dry cleaning plants, power plants, generating units, pumping stations, fumigation chambers, laundries, building/structures in gas plant, refineries, dairies and saw mills, etc. *These buildings are further sub divided in three groups i.e. G1, G2 & G3.*

Group H - Storage Buildings

These shall include any building or part of a building, used primarily for storage or sheltering (including servicing, processing or repairs incidental to storage) of goods, wares, or merchandise (except those that involve combustible or explosive products or materials)

vehicles or animals, e.g. ware houses, cold storage, fright depots, transit sheds, store houses, truck and marine terminals, garages, hangers, grain elevators, barns and stables.

Storage properties are characterized by the presence of relatively small number of persons in proportion to the area.

Group J - Hazardous Buildings

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

(b) Types of Construction

Based on the fire resistance rating of various structural and non-structural components of building, construction of the buildings is classified into four categories, namely *Type 1 - Construction, Type 2 -Construction, Type 3 -Construction, Type 4 -Construction.* The required fire resistance ratings (in hours) of structural and non-structural members for various type of construction are as under.

Sr. No.	Structural element		Type of construction			
			Type 1	**Type 2**	**Type 3**	**Type 4**
1	Exterior walls:					
	a) Fire separation less than 3.7 m	i) Bearing	4	2	2	1
		ii) Non bearing	2	1 ½	1	1
	b) Fire separation of 3.7 m for more but less than 9 m	i) Bearing	4	2	2	1
		ii) Non bearing	1 ½	1	1	1
	c) Fire separation of 9 m or more	i) Bearing	4	2	2	1
		ii) Non bearing	1	1	1	1
2	Fire resisting walls	-	4	2	2	2
3	Fire separation assemblies (like fire check doors)	-	4	2	2	2
4	Fire enclosures of exit ways, hallways and stairways.	-	2	2	2	2
5	Shaft other than exit ways, elevator and hoist ways	-	2	2	2	2
6	Exit way access corridors	-	1	1	1	1
7	Vertical separation of tenant spaces	-	1	1	1	1
8	Dwelling unit separation	-	1	1	1	1
	Non-load bearing partitions.	-	At least half an hour			

9	Interior bearing walls, bearing partitions, columns, girders, trusses (other than roof trusses) and framing.	i) Supporting more than one floor	4	2	2	2
		ii) Supporting one floor only	3	1 ½	1	1
		iii) Supporting a roof only.	3	1 ½	1	1
10	Structural members support walls.	-	3	1 ½	1	1
11	Floor construction including walls	-	3	1 ½	1	1
12	Roof construction	i) 5 m or less in height to lowest member	2	1 ½	1	1
		ii) More than 5 m but less than 6.7 m in height to lowest member.	1	1	1	1
		iii) 6.7 m or more in height to lowest member.	0	0	0	0

For building above 15 m in height non-combustible materials shall be used for construction and the internal walls of staircases should be of brickwork or reinforced concrete or any other material of construction with minimum of 2 hours rating. The walls for the chimney shall be of Type 1 and Type 2 construction depending on whether the gas temperature is above 200^0 C or less.

The fire resistance ratings of various building components shall conform to accepted standards. The fire resistance ratings of various building components such as walls, columns, beams and floors has been provided in the code for assessing & ensuring adequacy of fire resistance.

(c) Fire Zones

Based on fire hazard inherent in the buildings and structures according to occupancy, the city or area under the jurisdiction of the authority is demarcated into distinct zones, i.e fire zones.

The number of fire zones in a city or area under the jurisdiction of the authority, depends upon construction, classification of existing buildings based on occupancy and the expected future development of the city or area. In large cities or areas, three fire zones may be necessary, while in smaller ones one or two may be adequate.

Code provides detailed guidelines regarding number and designation of fire zones, change in fire zone boundaries and instruction for overlapping fire zones. It also covers guidelines for restriction on existing buildings, temporary buildings/structures and restriction on the type of construction for new buildings in different fire zones.

6.1 General Fire Protection Requirements

All buildings are required to satisfy certain requirements, which contribute, individually and collectively, to the safety of life from fire, smoke, fumes and panic arising from these or similar causes. These fire protection requirements depend mainly on the type of use, height and type of construction of building. Fire protection requirements for individual type of occupancy and high rise buildings (>15 metres) have been covered in detail in the code. There are, however, certain general principles and common requirements, which are applicable to all or most of the occupancies. Though, all these requirements are complementary to each other, they can be grouped in three categories:

Category – I – Requirements to prevent spread of fire and damage to property.

Category – II - Exit requirement for safe escape of occupants.

Category – III – Fire detection/alarm & extinguishment arrangements.

(A) Requirements to Prevent Spread of Fire and Damage to Property.

It covers following measures:

1. Occupation of Buildings under Construction

A building or portion of the building may be occupied during construction, repairs, alterations or additions only if all means of exit and fire protection measures are in place and continuously maintained for the occupied part of the building.

A *high rise building* during construction shall be provided with the following fire protection measures, which shall be maintained in good working condition at all the times:

- Dry riser of minimum 100 mm diameter pipe with hydrant outlets on the floors, shall be provided, with a fire service inlet to boost the water in the dry riser. Its provision and maintenance should be as per laid down Indian Standards.

- Drums filled with water of 2000 litres capacity with two fire buckets on each floor;

- A water storage tank of minimum 20000 litres capacity, which may be used for other construction purposes also.

2. Maximum Height

Height above the ground level and the number of storeys of the buildings is restricted, depending upon its occupancy and the type of construction. The maximum permissible height for any combination of occupancy and types of construction depends on the width of street fronting the building, or floor area ratios and the local fire fighting facilities available. Height restrictions based on above factors have been covered in detail in the code.

3. Floor Area Ratio (FAR)

Based on type of occupancy and construction of the building, the floor area ratios are also restricted. The comparative floor area ratios for occupancy facing one public street at least 9 m wide are as under:

Occupancy classification	Type of construction			
	Type 1	Type 2	Type 3	Type 4
Residential	UL	2.0	1.4	1.0
Educational	UL	2.0	1.4	1.0
Institutional	UL	1.5	1.0	0.8
Assembly	UL	1.0	0.7	0.5
Business	UL	2.9	2.3	1.6
Mercantile	8.0	1.8	1.4	1.0
Industrial	7.5	1.9	1.6	1.3
Storage	6.0	1.5	1.3	1.0
Hazardous	2.8	1.1	0.9	NP

UL – Unlimited; NP – Not permitted

Note : The above FAR values are subject to further restrictions as prescribed in the code. These values can also be modified by taking into account the other aspects as prescribed in the code.

Each portion of a building, which is separated by one or more continuous fire resisting walls, having a fire resistance of not less than 2 h, extending from the foundation to 1 m above the roof at all points, may be considered to be a separate building for the calculation of maximum permissible height and floor area, provided openings, if any, in the separating wall are also protected by fire assemblies of 4 h.

4. Open Spaces

The open spaces around or inside a building shall conform to laid down standard and development control rules & general building requirements.

For *high-rise buildings*, the following additional provisions for 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 in a dead end except in the case of residential building, up to a height of 30m.

- The compulsory open spaces around the building shall not be used for parking, and

- Passageway and clearance required for fire-fighting vehicles to enter the premises shall be adequate, and at the main entrance shall be not less than 4.5 m. If any arch or covered gate is constructed, it shall have a clear head -room of not less than 5 m.

5. Openings in Separating Walls and Floors

Openings in separating walls and floor shall be designed to limit fire spread through these openings.

- *For types 1 to 3 construction*, a doorway or opening in a separating wall on any floor shall be limited to 5.6 m^2 in area with a maximum height of 2.75 m and a maximum width of 2.1 m. Every wall opening shall be protected with fire resisting doors or steel rolling shutters having the fire rating of not less than 2 h, conforming to Indian standards. All openings in the floors shall be protected by vertical enclosures extending above and below such openings, the walls of such enclosures having a fire resistance of not less than 2 h and all openings therein being protected with a fire resisting assembly having a specified fire resistance rating.
- *For type 4 construction*, openings in the separating walls or floors shall be fitted with 2 h fire -resisting assemblies.
- Openings in walls or floors which are necessary to be provided to allow passages of all building services like cables, electrical wirings, telephone cables, plumbing and fixtures etc., shall be protected by enclosure in the form of ducts/shafts having a fire resistance not less than 2 h. The inspection door of all service shafts shall have fire resistance not less than 1 h. Medium and low voltage wiring running in shafts/ducts, shall either be armoured type or run through metal conduits. Further, the space between the conduits and the walls shall be filled in by a filler material, compressed asbestos, fibre glass wool, rock-wool, ceramic wool etc, mixed with cement or any other material having fire resistance rating of not less than one hour.

6. Fire Stop or Enclosure of All Openings

Where openings are permitted, they shall not exceed three-fourths the area of the wall in the case of an external wall and they shall be protected with fire resisting assemblies or enclosures having a fire resistance equal to that of the wall or floor in which these are situated. Such assemblies and enclosures shall also be capable of preventing the spread of smoke or fumes through the openings so as to facilitate the safe evacuation of building in case of fire.

7. Surface Interior Finishes

The use of flammable surface finishes on walls (including external façade of the building) and ceiling also affects the safety of the occupants of a building as they tend to spread the fire. Therefore, only appropriate class of surface finishes shall be used as under:

Class 1	Class 2	Class 3
May be used in any situation.	May be used in any situation, except on walls, façade of the building and ceiling of staircase and corridors.	Should 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 façade 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 which include untreated wood fibre-board may be used as ceiling lining, provided the ceiling is at least 2.4 m from the top surface of the floor below, and the wall surfaces conform to requirements of class. Class 4 materials shall not be used in kitchens, corridors and staircases. Some types 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 for return air in air-conditioned buildings.

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 because there is considerable danger from fire starting and rapidly spreading within the concealed cavity unknown to the occupants whose escape may be hampered there by. For detailed information on materials and details of construction with their fire resistance ratings, reference may be made to Indian Standards.

8. Glazing

Building of types 1 to 4 construction shall employ either wired glass or electro-copper glazing, except that type 4 construction may have the alternative of hardwood sashes or frames or both.

Wired glass shall comply with the following requirements:

a) Thickness of glass - The thickness of glass shall be not less than 6.0 mm.
b) Embedded wire netting - Embedded wire netting shall not larger than 10 mm mesh.
c) Size of squares of glass - The area shall not exceed 0.25 m^2.
d) Sashes and frames - The sashes or frames or both shall be entirely of iron or other suitable metal securely bolted or keyed into the wall, except in the case of panels in internal doors.
e) Setting of glass - The panels of glass shall be set in rebates or grooves not less than 0.6 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 lead, cement or putty used for weather proofing purposes.

Electro-copper glazing shall comply with the following requirements:

a) Thickness of glass shall be not less than 6.5 mm.
b) Size of squares of glass shall not exceed 100 cm^2.
c) Sectional lights - The square glasses to be formed by electro-copper glazing into sectional lights shall not be exceed 0.37 m^2 in area.
d) Sashes and frames - The sashes or frames or both shall be entirely of iron or other hard metal, securely bolted or keyed into the wall, except when in panels in internal doors.
e) Fixing of sectional lights - The sectional lights shall be set in rebate or grooves not less than 6.5 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 lead, cement or putty used for weather proofing purposes.

Maximum permissible area shall be 5 m^2 for protection by wired glass or electro-copper glazing.

Casement - Hard metal casements not exceeding 0.8 m^2 fitted with wired glass or electro-copper glazing, secured to the frames by hard metal hinges not more than 60 cm apart and by fastening at top, centre and bottom are permissible.

9. Skylights

Wired glass for skylights or monitor lights shall comply with the following requirements.

a) Thickness of glass shall be not less than 6.0 mm.
b) Embedded wire netting shall be not larger than 10 mm mesh;
c) Frames and glazing - The frame shall be continuous and divided by bars spaced at not more than 70 cm centres. The frame and bars shall be of iron or other hard metal, and supported on a curb either of metal or of wood covered with sheet metal. The 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.

Maximum permissible area shall be 5 m^2 for protection of wired glass.

10. Electrical Installations

For requirements regarding electrical installations from the point of view of fire safety, reference may be made to Indian Standards.

11. Heating

Installation of chimney and heating apparatus shall conform to laid down Indian Standards.

12. Air-conditioning and Ventilation

Air-conditioning and ventilation requirements of different rooms or areas in any occupancy shall be as per prescribed standards (given in Part VIII Building Services: Section 1 Lighting and ventilation and Section 3 Air-conditioning and heating).

Air-conditioning and ventilating systems shall be so installed and maintained as to minimize the danger of spread of fire, smoke or fumes thereby from one floor or fire area to another, or from outside into any occupied building or structure.

Air-conditioning and ventilating systems circulating air to more than one floor or fire area shall be provided with dampers designed to close automatically in case of fire and thereby preventing spread of fire or smoke. Such a system shall also be provided with automatic controls to stop fans in case of fire, unless arranged to remove smoke from a fire, in which case these shall be designed to remain in operation.

Air-conditioning system serving large places of assembly (over 1000 persons), large departmental stores or hotels with over 100 rooms in a single block shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system and shall have of approved smoke sensitive devices for actuation.

From fire safety point of view, it will be preferable to provide separate air handling units for the various floors so as to avoid the hazards arising from spread of fire and smoke through the A.C. ducts. The A.C. ducts should conform to prescribed IS standards.

13. Smoke Venting

Code prescribes that the smoke venting facilities, where required for safe use of exits in windowless buildings, underground structures, large area factories shall be automatic in action with manual controls in addition.

Where smoke venting facilities are installed for purpose of safe use of exits, these shall be adequate to prevent dangerous accumulation of smoke during the period of time necessary to evacuate the area served, using available exit facilities with a margin of safety to allow for unforeseen contingencies. It is recommended that smoke exhaust equipment should have a minimum capacity of approximately a 5 minutes air change. Where mechanical venting is employed, it shall be fire safe. Power operated smoke exhausting systems may be substituted for natural draft vents only by specific permission of the Authority concerned.

Natural draft smoke venting shall utilize roof vents or vents in walls at or near the ceiling level. Such vents shall be normally open, or, if closed, shall be designed for automatic opening in case of fire, by release of smoke sensitive devices. The discharge apertures of all natural draft smoke vents shall be so arranged as to be readily susceptible to opening by fire service personnel.

14. Fire Lifts

Fire lifts shall be provided with a minimum capacity for 8 passengers and fully automated with emergency switch on ground level. In general, buildings 15 m in height or above shall be provided with fire lifts. In case of fire, only fireman shall operate fire lifts. In normal course, it may be used by other persons.

Each fire lift shall be equipped with suitable inter-communication equipment for communicating with the control room on the ground floor of the building.

The number and location of fire lifts in a building shall be decided after taking into consideration various factors like building population, floor area, section of building (compartmentation), etc.

The floor area, speed, ceiling requirement, electric supply requirement of the fire lift shall conforms to Indian Standards.

(B) Exit Requirement for Safe Escape of Occupants

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 doorway; corridor; passageway(s) to an internal staircase, or external staircase, or to a veranda 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.

Lifts and escalators shall not be considered as exits.

In every building, *exists* shall comply with certain *minimum requirements*, except those not accessible for general public use.

- All exits shall be free of obstructions.
- **No building shall be so altered as to reduce the number, width or protection of exits to less than that required**.
- All means of exit including staircases, lift lobbies and corridors shall be adequately ventilated.
- Exits shall be clearly visible and the routes to reach the exit shall be clearly marked and sign posted to guide the population of the floor concerned. Signs shall be illuminated and wired to an independent electrical circuit on a alternative source of supply. The sizes and colours of the exit signs shall be in accordance with Indian Standard.
- The floors of areas covered for the means of exit shall be illuminated to values not less than 1 ft candle (10 lux) at floor level. In auditoriums, theatres, concert halls and such other places of assembly, the illumination of floor exit/access may be reduced during periods of performances to values not less than 1/5 ft candle (2 lux).
- Fire check doors for fire resistance of 1 h shall be provided at appropriate places along the escape routes to prevent spread of fire and smoke, and particularly at the entrance to lifts and stairs where a '*funnel or flue effect*' may be created, inducing an upward spread of fire.
- 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 so arranged that they may be reached without passing through another occupied unit.

1. Design Parameters

For planning and design of exit ways, codal design parameters are as under:

(a) Occupant Load

For determining the exits required, the number of persons within any floor area or the occupant load shall be based on the actual number of occupants, but in no case less than as under.

Sr. no.	Group of occupancy	Occupant load Floor area in Sq.m/person
1	Residential (A)	12.5
2	Educational (B)	04
3	Institutional (C)	15*
4	Assembly (D) a) with fixed or loose seats and dance floors b) without seating facilities i/c dining rooms	 0.6* 1.5#
5	Mercantile (F) a) street floor and sales basement b) upper sale floors	 3 6
6	Business and Industrial (E&G)	10

7	Storage (H)	30
8	Hazardous (J)	10

* Occupant load in dormitory portion of homes for the aged, orphanages, insane asylums, etc. where sleeping accommodation is provided, shall be calculated at not less than 7.5 sq.m gross floor area/person.

the gross floor area shall include, in addition to the main assembly room or space, any occupied connecting room or space in the same storey or in the storeys above or below, where entrance is common to such rooms and spaces and they are available for use by the occupants of the assembly place. No deductions shall be made in the gross area for corridors, closets or other subdivisions; the area shall include all space serving the particular assembly occupancy.

The occupant load of a **mezzanine floor** discharging to a floor below shall be added to that floor occupancy and the capacity of the exits shall be designed for the total occupancy load, thus, established.

(b) Capacity of Exits

The unit of exit width, used to measure the capacity of any exit, shall be 50 cm. A clear width of 25 cm shall be counted as an additional half unit. Clear width less than 25 cm shall not be counted for exit width.

Occupants per unit exit width shall be as under:

Sr. No.	Group of occupancy	Number of occupants		
		Stairways	Ramps	Doors
1	Residential (A)	25	50	75
2	Educational (B)	25	50	75
3	Institutional (C)	25	50	75
4	Assembly (D)	40	50	60
5	Business (E)	50	60	75
6	Mercantile (F)	50	60	75
7	Industrial (G)	50	60	75
8	Storage (H)	50	60	75
9	Hazardous (J)	25	30	40

Note - The total occupants from a particular floor must evacuate within 2½ minutes for Type 1 construction, 1½ minute for Type II construction and 1 minute for Type III construction. Size of the exit door/exit way shall be calculated accordingly keeping in view the travel distance.

When **horizontal exit** is provided in buildings of mercantile, storage, industrial, business and assembly occupancies, the capacity per storey per unit width of exit of stairways in table may be increased by 50%; and in buildings of institutional occupancy it may be increased by 100%.

(c) Travel Distance

Exits shall be so located that the travel distance on the floor shall not exceed the distance as given below:

Sr. No.	Group of occupancy	Maximum travel distance	
		Type of construction	
		Types 1 & 2	Types 3 & 4
1	Residential	22.5	22.5
2	Educational	22.5	22.5
3	Institutional	22.5	22.5
4	Assembly (D)	30.0	30.0
5	Business (E)	30.0	30.0
6	Mercantile (F)	30.0	30.0
7	Industrial (G)	45.0	*
8	Storage (H)	30.0	*
9	Hazardous (J)	22.5	*

*** Construction of Type-3 & 4 is not permitted.**

Note:

- For the sprinkler system, the travel distance may be increased by 50% of the values specified.
- In so far as basements are concerned, the travel distance will reckon half the value as prescribed in the table.
- Ramps are also counted as one of the means of escape.

The travel distance to an exit from the dead end of a corridor shall not exceed half the distance specified in table. Whenever more than one exit is required for any room space or floor of building, exits shall be placed as remote from each other as possible and shall be arranged to provide direct access in separate directions from any point in the area served.

(d) Number of Exits

The number of exits provided shall be as per the requirement prescribed for different occupancies in the code.

All buildings which are 15 m in height or above and all buildings used as educational, assembly, institutional, industrial, storage and hazardous occupancies, and mixed occupancies with any of the aforesaid occupancies having area more than 500 m^2 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 walls of buildings and shall open directly to exterior, interior open space or to an open place of safety. Further, the provision or otherwise of alternative staircase shall be subject to the requirements of travel distance being complied with.

(e) Refuge Area

Unless fully sprinkled, in case of buildings more than 24 m in height, refuge area of 15 m^2 or an area equivalent to 0.3 m^2 per person to accommodate the occupants of two consecutive floors, whichever is higher, shall be provided as under:

The refuge area shall be provided on the periphery of the floor and open to air atleast on one side protected with suitable railings.

- *For floors above 24 m and upto 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 provided in excess of the requirements shall be counted towards FAR.

Note : Hospitals shall follow the above norms, whether sprinkled or not.

2. Requirement of Various Exit ways

Codal requirements for various type of exit/escape ways and their parts are as under:

(a) Doorways

- Every exit doorway shall open into an enclosed stairway or a horizontal exit of a corridor or passageway providing continuous and protected means of egress.

- No exit doorway shall be less than 100 cm in width except assembly buildings where door width shall be not less than 200 cm. Doorways shall not be less than 200 cm in height.

- Exit doorways shall open outwards, that is, away from the room, but shall not obstruct the travel along any exit. No door, when opened, shall reduce the required width of stairway or landing to less than 90 cm; overhead or sliding doors shall not be installed.

  Note : In the case of buildings where there is a central corridor, the door of rooms shall open inwards to permit smooth flow of traffic in the corridor.

- Exit door shall not open immediately upon a flight of stairs; a landing equal to at least the width of the door shall be provided in the stairway at each doorway; the level of landing shall be the same as that of the floor, which it serves.

- Exit doorways shall be openable from the side which they serve without the use of a key.

- Mirrors shall not be placed in exit ways or exit doors to avoid confusion regarding the direction of exit.

(b) Corridors and Passageways

Exit corridors and passageways shall be of width not less than the aggregate required width of exit doorways leading from them in the direction of travel to the exterior.

Where stairways discharge through corridors and passageways, the height of corridors and passageways shall be not less than 2.4 m.

(c) Internal Staircases

Interior stairs shall be constructed of non-combustible materials throughout. Interior stairs shall be constructed as a self-contained unit with an external wall constituting at least one of

its sides and shall be completely enclosed. Hollow combustible construction shall not be permitted.

A staircase shall not be arranged round a lift shaft. No gas piping shall be laid in the stairway.

Notwithstanding the detailed provision of exits, following minimum width (in metres) shall be provided for staircases.

a)	Residential buildings (dwellings)	1.0
b)	Residential hotel buildings	1.5
c)	Assembly buildings like auditorium, theatres and cinemas	2.0
d)	Educational buildings up to 30 m in height	1.5
e)	Institutional buildings like hospitals- (i) Up to 10 beds (ii) More than 10 beds	 1.5 2.0
f)	All other buildings	1.5

The minimum width of tread without nosing shall be 250 mm for internal staircase of residential buildings. This shall be 30 cm for assembly, hotels, educational, institutional, business and other buildings. The treads shall be constructed and maintained in a manner to prevent slipping.

The maximum height of riser shall be 19 cm for residential buildings and 15 cm for other buildings and the number shall be limited to 15 per flight.

Handrails shall be provided at a height of 100 cm to be measured from the base of the middle of the treads to the top of the handrails. Further, the gap between the two verticals shall not exceed 30 cm. This gap shall be reduced to 15 cm, where children are likely to use the staircase.

The number of people in between floor landings in staircase shall not be less than the population on each floor for the purpose of design of staircase. The following aspects shall also be taken in to consideration while designing the staircases:

- The minimum headroom in a passage under the landing of a staircase and under the staircase shall be 2.2 m.
- For building 15 m in height or more, access to main staircase shall be through a fire/smoke check door of 1 hour fire resistance rating. Fire resistance rating may be reduced to half an hour for residential buildings.
- No living space, store or other fire risk shall open directly into the staircase or staircases.
- External exit door of staircase enclosure at ground level shall open directly to the open spaces or through a draught lobby, if necessary.
- The main staircase and external staircase shall be continuous from ground floor to the terrace level.
- No electrical shafts/AC ducts or gas pipe, etc, shall pass through the staircases. Lift shall not open in staircase.
- No combustible material shall be used for decoration/wall panelling in the staircase.

- Beams/columns and other building feature shall not reduce the head room/width of 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. All exit way marking signs should be flush with the wall and so designed that no mechanical damage shall occur to them due to moving of furniture or other heavy equipments. Further, all landings of floor shall have floor indicating boards prominently indicating the number of floor as per bye laws.
- The floor indicating board shall be placed on the wall immediately facing the flight of stairs and nearest to the landing. It shall be of size not less than 0.5x0.5 m.
- Individual floors shall be prominently indicated on the wall facing the staircases.
- In case of single staircase it shall terminate at the ground floor level and the access to the basement shall be by a separate staircase. However, the second staircase may lead to basement levels provided the same is separated at ground level by ventilated lobby with discharge points to two different ends through enclosures.

(d) External Stair

External stairs, when provided shall comply the following :

- External stairs shall always be kept in sound operable conditions.
- All external stairs shall be directly connected to the ground.
- Entrance to the external stairs shall be separate and remote from the internal staircase.
- Care shall be taken to ensure that no wall opening or window opens on to or close to a external stairs.
- The route to the external stairs shall be free of obstructions at all times.
- The external stairs shall be constructed of non-combustible materials, and any doorway leading to it shall have the required fire resistance.
- No external staircase, used as a fire escape, shall be inclined at an angle greater than 45^0 from the horizontal.

External stairs shall have straight flight not less than 100 cm wide with 20 cm treads and riser not more than 19 cm. The number of risers shall be limited to 15 per flight. Handrails shall be of height not less than 100 cm and not exceeding 120 cm.

(e) Spiral Fire Escape

The use of spiral staircase shall be limited to low occupant load and to a building not exceeding 9 m in height. A spiral fire escape shall be not less than 150 cm in diameter and shall be designed to give adequate headroom.

(f) Horizontal Exits

The width of horizontal exit shall be same as for the exit doorways. Where there is a difference in level between connected areas for horizontal exits, ramps, not more than 1 in 10 m slope shall be provided; steps shall not be used.

A horizontal exit shall be equipped with at least one fire door of self-closing type. Doors in horizontal exits shall be openable at all times from both sides.

(g) Ramps

Ramps shall comply with all the applicable requirements for stairways regarding enclosures, capacity and limiting dimensions. The slope of a ramp shall not exceed 1 in 10. In certain cases steeper slopes may be permitted but in no case steeper than 1 in 8.

For all slopes exceeding 1 in 10 and wherever the use is such as to involve danger of slipping, the ramp shall be surfaced with approved non-slipping material.

(h) Fire Tower

Fire towers are the preferred type of escape route for storeyed buildings and their application shall be considered as the safest route for escape. Their number, location and size shall depend on the building concerned, and its associated escape route.

In every mercantile, business or assembly buildings, theatres, and institutional buildings except residential buildings, over 8 storeys or 24 m in height, at least one required means of egress shall preferably be a fire tower.

The enclosure of fire towers shall be constructed of walls with a 2 h fire resistance rating without openings other than the exit doorways, with platforms, landings and balconies having the same fire resistance rating.

3. Pressurisation of Staircases (protected escape routes)

Pressurisation is a method adopted for protecting escape routes against ingress of smoke, especially in high-rise buildings. In pressurisation, air is injected into the protected escape routes, i.e. into the staircases, lobbies or corridors, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the escape routes will be prevented. The pressurisation system can be interconnected with the automatic/manual fire alarm system for actuation.

Pressurisation system can be of two types :

(i) Single stage, designed for operation only in the event of an emergency, and
(ii) Two stage, where normally a level of pressurisation is maintained in the protected escape routes, and an increased level of pressurisation can be brought into operation in an emergency.

The pressurisation levels for staircases should be as under:

Building height	**Pressurisation level**	
	Emergency operation (Pa)	**Reduced operation for stage 1 of a 2-stage system (Pa)**
Less than 15 m	50	8
15 m or above	50	15

If possible, the same levels shall be used for lobbies and corridors, but levels slightly lower may be used for these spaces, if desired. The difference in pressurisation levels between staircase and lobbies (or corridors) shall not be greater than 5 Pa.

It will be desirable to have all the staircases in a building pressurised, if pressurisation system is to be resorted to. Otherwise, the use of pressurised and naturally ventilated staircases in the same building may introduce difficulties and hence shall be avoided. Under no circumstances shall a pressurised staircase be connected by a corridor or lobby to an un pressurised staircase.

The normal air-conditioning system and the pressurisation system shall be treated as an integral one, especially for a two stage system. In such situation air-conditioning system shall satisfy the requirements as prescribed in the code.

4. Emergency and Escape Lighting

Escape lighting provided shall be capable of :

- Indicating clearly and unambiguously the escape routes,
- Providing adequate illumination along such routes to allow safe movement of persons towards and through the exits,
- Ensuring that fire alarm call points and fire-fighting equipments provided along the escape routes can be readily located.

The horizontal illuminance at floor level on the centre line of an escape route shall be not less than 0.2 lux. In addition, for escape routes upto 2 m wide, 50% of the route width shall be lit to a maximum of 0.1 lux. The recommended illuminance shall be achieved with a uniformity of not less than 0.025.

Emergency lighting shall be powered from a source independent of that supplying the normal lighting. The emergency lighting shall be provided to be put on within 5 seconds (preferably within 1 seconds) of the failure of the normal lighting supply.

Escape lighting luminaries should be sited to cover the following locations:

- near each intersection of corridors,
- at each exit door,
- near each change of direction in the escape route,
- near each staircase so that each flight of stairs receives direct light,

- near any other change of floor level,
- outside each final exit and close to it,
- near each fire alarm call point,
- near fire-fighting equipment,
- to illuminate exit and safety signs as required by the enforcing authority.

Note- For the purpose of this clause 'near' is normally considered to be within 2 m measured horizontally.

Emergency lighting systems shall be designed to ensure that a fault or failure in any one luminaries does not further reduce the effectiveness of the system. The luminaries shall be mounted as low as possible, but at least 2 m above the floor level measured to the underside of the luminaries. Emergency lighting luminaries and their fittings shall be non-flammable.

It is essential that the wiring and installation of the emergency lighting systems are of high quality so as to ensure their perfect serviceability at all times. The emergency lighting system shall be capable of continuous operation for a minimum duration of 1 hour and 30 minutes even for the smallest premises. Emergency lighting system, shall be maintained properly by periodical inspections and tests so as to ensure their perfect serviceability at all times.

Signs at all exits, emergency exits and escape routes, should comply with the graphic requirements of the relevant Indian Standards.

(C) Fire Alarm & Extinguishment Arrangements

It covers provisions of following installations :

1. Fire Detection/ Extinguishing System

In buildings of such size, arrangement or occupancy that a fire may not itself provide adequate warning to occupants, automatic fire detection and alarm facilities shall be provided, where necessary, to warn occupants early of the existence of fire, so that they may escape, or to facilitate the orderly conduct of fire exit drills.

Provision, selection, installation and maintenance of fire detection system for different occupancies shall conform to Indian Standards.

2. Fixed Fire Fighting Installations

All buildings depending upon the occupancy use and height shall be protected by wet riser, down comer, automatic sprinkler installation, high/medium velocity water spray, foam, and gaseous or dry powder system etc. These fire fighting equipment and accessories installed in buildings for use in fire fighting shall conform to appropriate Indian Standards and shall be maintained periodically so as to ensure their perfect serviceability at all times.

In situations where one occupancy is provided with all the required fire protection arrangements but due to proximity of unprotected buildings around, causing exposure hazard to the protected building, the protected building walls facing the unprotected building shall be provided with *water curtain/drencher system* which can be actuated, when necessary.

(a) First aid fire fighting appliances shall be provided and installed in accordance with Indian Standards.

(b) The typical requirements of wet riser/down comer installation and capacity of water storage tanks and fire pumps have been specified in the code for various occupancies, with the typical arrangements of down comer and wet riser installation. The wet riser shall be designed for zonal distribution ensuring that unduly high pressures are not developed in risers and hose pipes.

In addition to wet riser or down comer, first-aid hose reels shall be installed on all the floors of buildings of 15 m in height or more and shall conform to Indian Standards. The first aid hose reel shall be connected directly to the riser/down comer main and diameter of the hose reel shall not be less than 19 mm.

(c) Static Water Storage Tanks

A satisfactory supply of water for the purpose of fire fighting shall always be available in the form of underground/terrace level static storage tank with capacity specified for each building with arrangements of replacement by mains or alternative source of supply at the rate of 1000 litres per minute. When this is not practicable, the capacity of static storage tank(s) shall be increased proportionately in consultation with the local fire brigade.

The static storage water supply required for the above-mentioned purpose shall entirely be accessible to the fire engines of the local fire service. Provision of suitable number of manholes shall be made available for inspection repairs, insertion of suction hose, etc. The covering slab shall be able to withstand the vehicular load of 22.5 tonnes at any given point when the slab forms a part of pathway/driveway.

The domestic suction tank connected to the static water storage tank shall have an overflow capable of discharging 2250 litres per minute to a visible drain from which by a separate conduit, the overflow shall be conveyed to a storm water drain.

- To prevent stagnation of water in the static water storage tank, the suction tank of the domestic water supply shall be fed only through an overflow arrangement to maintain the level therein at the minimum specified capacity.
- The static water storage tank shall be provided with a fire brigade collecting head with 4 number 63 mm diameter (2 number 63 mm diameter for pump with capacity 1400 l/min) instantaneous male inlets arranged in a valve box at a suitable point at street level and connected to the static tank by a suitable fixed pipe not less than 150 mm in diameter to discharge water into the tank when required at the rate of 2250 litres per minute, if tank is in the basement or not approachable for the fire engines.

(d) Automatic Sprinklers

Automatic sprinklers shall be installed in:

- Basements used as car parks or storage occupancy, if the area exceeds 200 sq.m.;

- 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;
- Any room or other compartment of a building exceeding 1125 sq.m. in area except as in (*) (see Note), if so advised by local authority;
- Departmental stores or shops, if the aggregate covered area exceeds 750 sq.m.;
- All non-domestic floors of mixed occupancy which constitute a hazard and are not provided with staircases independent of the buildings;
- Godowns and warehouses, as considered necessary;
- *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);
- Dressing room, scenery docks, stages and stage basements of theatres;
- In hotels, hospitals, industries, low and moderate hazard mercantile buildings of height 15 m or above;
- In hotels below 15 m, if covered area at each floor is more than 1000 sq.m.;
- False ceiling voids which are used for storage or as return air plenums exceeding 800 mm in height in sprinklered buildings; and
- Canteen provided in upper floors of D-1 and D-2 occupancies shall be sprinklered.

Note- 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 un-sprinklered floors gathering momentum, spreading upwards from floor to floor through the un-sprinklered floor and reaching the first sprinklered floor as a fully developed fire. In such an event, the sprinklers can be rendered useless or ineffective.

(e) Automatic High Velocity Water Spray or Emulsifying System

Automatic high velocity water spray or emulsifying system shall be provided for protection of indoor oil filled transformers housed in basement.

(f) Fixed Foam Installation

Fixed foam generating system shall be provided for protection of oil storage area for boilers with its ancillary storage of furnace oils in basement. Fixed foam installations can be low, medium or high expansion types, which can cover fire risks in oil storage areas generally. High expansion foams are used for cable tunnels and other confined areas.

(g) Carbon Dioxide Fire Extinguishing System

Fixed carbon dioxide fire extinguishing installation shall be provided on premises where water or foam can not be used for fire extinguishing because of the special nature of the contents of the buildings/areas to be protected. For some special fire risk, carbon dioxide may not be suitable and hence Halon system may be necessary.

However, the use of halons shall be discouraged, as halons are Ozone Depleting Substances (ODS) and their use is being phased out throughout the world.

Fire fighting equipment shall be suitably located and clearly marked by luminous signs, except for occupancies A-2 and A-4 less than 15 m in height.

3. Minimum Requirement for Detection & Fire Fighting Installations, for residential, educational & institutional and assembly buildings as per code are as under:

Sr. No.	Type of Building	Detection & Fire fighting installations		
		Type of Installation	**Water Supply (in litres)**	**Pump Capacity With 0.3 N/sq.mm. pressure at terrace level (in litres)**
I	**Residential buildings**			
(a)	Lodging or rooming houses (A1)			
1	*Less than 15 m in height*			
i.	- For 10 rooms and upto 20 beds	*Automatic sprinkler system.	***Terrace tank-*** **(*** *10000 litres*)	*At terrace level* – (*900/min.)
ii	- For rooms more than 10 and beds more than 20 and upto 40	Hose reel, Down comer, *Automatic sprinkler system	*Terrace tank* - 2500 litres. (**10000 litres)*	*At terrace level*- 900/min *(*1620/min.)*
	***For basement area 200 sq.m. and more only.** **Note: Buildings above 15 m in height not to be permitted.**			
(b)	One or two family private dwellings (A2), dormitories (A3), apartment houses (A4)			
(i)	*Less than 15 m in height*	Same as I (a) 1 (i), (ii)		
	Note: Buildings of One or two family private dwellings occupancy above 15 m in height not to be permitted.			
(ii)	*15 m and above but not exceeding 30 m*	Hose reel, wet riser, down comer, *automatic sprinkler system, manually operated electric fire alarm systems (for above 24 m).	*U/Ground storage tank*- 50000 litres. *Terrace tank*-. 10000 litres. (**20000 litres*).	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 1620/ min and one electric pump of capacity 180/ min. *At terrace level* 450/ min (*900/min).
(iii)	*Above 30 m in height but not exceeding 45 m*	Hose reel, wet riser, yard hydrant, *automatic sprinkler system, manually operated electric fire alarm systems, automatic detection and alarm system.	*For U/Ground storage tank*- 100000 litres. *Terrace tank*- 20000 litres. (**30000 litres*).	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 2850/ min and one electric pump of capacity 180/ min.

(iv)	*Above 45 m in height*	Hose reel, wet riser, yard hydrant, automatic sprinkler system, manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 200000 litres. *Terrace tank* - 40000 litres.	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 2850/ min and one electric pump of capacity 180/ min.
	***For basement area 200 sq.m. and more only.** **Note: Buildings of *'Dormitories and Apartment houses (A3 & A4)'* occupancy above 60 m in height not to be permitted.**			
(c)	Hotels (A5)			
(i)	*Less than 15 m in height with covered area not exceeding 300 sq.m. on each floor*	Hose reel, Down comer, *Automatic sprinkler system.	*Terrace tank*- 5000 litres. (**10000 litres*).	*At terrace level*- 450/min (*900/min).
(ii)	*Less than 15 m in height with covered area exceeding 300 sq.m. but not more than 1000 sq.m. on each floor*	Hose reel, wet riser (above two floors), *Automatic sprinkler system, manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 10000 litres. for every 100 sq.m. covered area subject to minimum of 50000 *Terrace tank*- 10000 litres.	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 2280/ min and one electric pump of capacity 180/ min.
(iii)	*Less than 15 m in height with covered area exceeding 1000 sq.m. on each floor*	Hose reel, wet riser (if more than ground floor), yard hydrant, automatic sprinkler system (in entire building), manually operated electric fire alarm systems, automatic detection and alarm system (if building is not sprinkled).	*U/Ground storage tank*- 100000 litres. *Terrace tank*- 10000 litres.	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 2280/ min and one electric pump of capacity 180/ min.
(iv)	*15 m and above but not exceeding 30 m*	Hose reel, wet riser, yard hydrant, automatic sprinkler system (in entire building), manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 150000 litres. *Terrace tank*- 20000 litres.	*Near U/Ground tank* - one electric pump and one diesel pump of capacity 2850/ min and one electric pump of capacity 180/ min.

(v)	*Above 30 m*	Hose reel, wet riser, yard hydrant, automatic sprinkler system, manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 200000 litres. *Terrace tank*- 20000 litres.	*Near U/Ground tank*- one electric pump and one diesel pump of capacity 2850/ min and one electric pump of capacity 180/ min.
	***For basement area 200 sq.m. and more only.**			
II	**Educational and Institutional Buildings**			
(a)	Buildings other than hospitals and nursing homes (B1, B2, C2 & C3)			
(i)	*Less than 15 m in height*	Hose reel (for more than two storeyed buildings and covered area exceeding 1000 sq.m), down comer, *automatic sprinkler system (for educational only).	*U/Ground storage tank*- 50000 litres if total covered area exceeds 1500 sq.m. *Terrace tank*- 20000 litres in case of hose reel (**20000 litres*).	*Near U/Ground tank* -Same as in I(b)(ii). *At terrace level*- 450/ min. in case of hose reel (*900/min. in case of hose reel and for *).
(ii)	*15 m and above but not exceeding 30 m*	Hose reel, wet riser (in case of institutional buildings), down comer, yard hydrant, *Automatic sprinkler system (for educational only) manually operated electric fire alarm systems, automatic detection and alarm system (except for educational).	*U/Ground storage tank*- 10000 ltrs. for every 100 sq.m. with a minimum of 50000 litres. upto maximum of 100000 ltrs. *Terrace tank*- 20000 litres (**30000 litres*).	*Near U/Ground tank* - Same as in I(c)(iv). *At terrace level*- 900/ min. (*1620/min.).
	***For basement area 200 sq.m. and more only.** **Note: Buildings above 30 m in height not to be permitted.**			
(b)	Hospitals, sanatoria and nursing homes (C1)			
(i)	*Less than 15 m in height*	Hose reel, wet riser (for two storeys and above), down comer (if building is G.F., F.F. and the covered area exceeds 300 sq.m per floor), manually operated electric fire alarm systems (if building is more than G.F., F.F. & total covered area exceeds 1500 sq.m).	*U/Ground storage tank*- 10000 litres upto 750 sq.m plus 10000 litres. for every additional 250 sq.m *Terrace tank*- 2500 ltrs in case of hose reel & 20000 ltrs in case of down comer.	*Near U/Ground tank* - Same as in I(c)(iv). *At terrace level*- 900/ min.

(ii)	*15 m and above but not exceeding 30 m*	Hose reel, wet riser, yard hydrant, automatic sprinkler system, manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 200000 litres *Terrace tank*- 20000 litres.	*Near U/Ground tank* - Same as in I(c)(iv).
	Note: Buildings above 30 m in height not to be permitted.			
III	**Assembly Buildings (D1 to D5)**			
(i)	*Less than 15 m in height*	Hose reel, wet riser (for two storeys and above), down comer (if seating capacity exceeds 1000 persons), automatic sprinkler system (in case of seating capacity is 1000 persons or cover-ed area above 1500 sq.m or in case of basement area 200 sq.m and more), automatic detection and alarm system (wherever sprinklers are not installed).	*U/Ground storage tank*- 50000 litres *Terrace tank*- 500 ltrs for hose reel & 10000 litres in case of basement area 200 sq.m and more and down comer.	*Near U/Ground tank* - Same as in II(a)(i). *At terrace level*- 450/ min. in case of hose reel, 900/min. in case of down comer and 1620/min. in case of sprinkler.
(ii)	*15 m and above but not exceeding 30 m*	Hose reel, wet riser, yard hydrant, automatic sprinkler system (in case of seating capacity is 1000 persons or area above 1500 sq.m or in case of basement area 200 sq.m and more), manually operated electric fire alarm systems, automatic detection and alarm system.	*U/Ground storage tank*- 100000 litres *Terrace tank*- 10000 litres for basement area 200 sq.m and more.	*Near U/Ground tank* - Same as in I(c)(iv).
	Note: Buildings above 30 m in height not to be permitted.			

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⇒ NOTES ⇐

OUR OBJECTIVE

To upgrade Maintenance
Technologies and Methodologies
and achieve improvement in
productivity and performance
of all Railway assets and manpower
which inter-alia would cover
Reliability, Availability,
and Utilisation.

*The contents of this handbook are for guidance only & are **not statutory**. It also does not supersede any instructions from Railway Board, RDSO, and Zonal Railways & the provisions of IRWM, BIS Codes/Reports on the subject. If you have any suggestion & any specific comments, please write to us :*

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