FIRE HAZARDS AND SAFETY MEASURES IN MULTISTORIED STRUCTURES

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of the requirements for the award of the Degree
of
MASTER OF ARCHITECTURE

By

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CERTIFICATE

Certified that the dissertation entitled "FIRE HAZARDS AND SAFETY MEASURES IN MULTISTOREY STRUCTURES" submitted by R. N. Singh in partial fulfilment for the award of the Degree of 'Master of Architecture' (Design) of University of Roorkee is the record of student's own work carried out by him under our supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

This is further to certify that he has worked for a period of six months from January 1976 to July 1976 for preparing this dissertation at this University.

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CHAPTER - I

INTRODUCTION

Fire, like air and water is one of the greatest assets of man, but in return it demands a greater responsibility, without which it can turn in to most distructive enemy. Over many thousand of years since man first discovered the characteristics of fire, he has been trying to discipline himself to a point whereby through inherited instinct he takes obvious precautions against fire. Why is it, then man continues to disregard his survival in this respect ? Perhaps because only few of us have experienced what an uncontrolled fire can do and majority of us feel that it will never happen to him.

But due to the increased frequency of fire accidents all over the world people have started recognising the potential danger from the fire. Building acts, byelaws, which are provided for fire protection and safety measures have been presched and discussed by eminent scientists and architects in several "tall building" conferences and symposiums, all over the world.

Multistorey structures are coming up very fast, and has become a common features in every city of India.

This is largely because of scarcity of land, caused by rapid urbanisation and optimum utilisation of available land. Whatever may be the reason, one factor remains common, that is all multistorey structures require careful planning of the factors which directly or indirectly affect the safety of persons occupying them. Further more concept of comfort are changing rapidly and air conditioning of a building, no longer considered as a luxury and privilege of few, it is increasingly being installed in multistorey structures, some of the new building materials manufact red, which support, ignition or spread of fire. All these factors further add to the problem of fire protection and fire fighting in multistorey structures.

1.1 SCOPE OF THE SUBJECT

The recent[1] L.I.C. fire at Madras and Multistorey building fires at Calcutta and Bombay has made the fire hazard problem more burning than ever. Therefore, it demands special regard for fire prptection and safety measures in multistorey structures. For a low rise and sprowling buildings the fire-brigade with fire fighting equipments and personnel can control and extinguish fire from the ground itself. But when the structure of an equivalent floor space is planned vertically, beyond a certain height externalised efforts of the firemen will be of no use, in the event of not being able to reach the danger zone.

More the number of floors added the problem will become more complex as it goes further beyond the reach of the firemen's ladder and hose. Normally, this reach is taken to be about 25 meters. It is therefore necessary to fight fire internally.

At the time of fire, casualities are more often due to ill planned escapes and exits. These routes often formulate battleneck and create panickey and confusion during the time of evacuation. Normally a multistorey building can resist fire upto 2 to 4 hours. Any thing longer than this time may not be possible because before that the structure may charred to ashes. For the aging occupants and childrens it is not possible to endure evacuation through obstructed routes from such a great height as a multistorey structure may involve. Therefore properly designed, suitably located and equately provided exits and escape routes are a dire necessity. In the latest thinking the philosophy of evacuation has thus given way to the philosophy of refuge zone.

Most of the fire death's are due to asphyxiation because of spread of smoke and the toxic gases or a general absence of oxygen and the sergices. System is the most serious culprit in this respect.

Comparing fire hazards in the multistoreyed structures to those existing in low ones, a more realistic analysis of the whole problem may show that undesirable specifi fire hazard can and must be efficiently restricted. This can b done by means of safety measures in planning and construction o multistoreyed structure. With this we can make them at least as safe and possibly even safer than low ones.

12. OBJECTIVES OF THE THESIS

A great number of multistorey structures are alread piercing through our urban skyline and many more are expected t rise in the near future. Author feels that, like wind and earthquakes the ill effects of fire must be defeated. These multistoreyed structures should be designed technologically, sound economical and safe. Author in his dissertation intend tc offer the impact of fire hazards on the multistoreyed structure and the safety measure to encounter and control them. This task may be achieved by a rational approach to fire oriented problems which may be derived by considering the basic fire problems like, fire prevention, human safety, fire containment and fire extinguishment. For the safety of the occupants the design should have provision of offering occupants good opportunities of safe refuge and escape. It should also avoid the envolvement of persons outside the fire effected areas.

As far as the architect is controlling the choice of materials for the interior finishings he is able to contribute to safety by prohibiting the use of heavy smoke and toxic gas generating materials. This may apply to types of plastic linings and other interior furnishing and finishing materials which may ignite and release large quantity of such toxic gases. Some of these flamable materials may even quickly produce considerable amount of heat after ignition and immediately convert into flames. This does not even allow the safe evacuation of the affected fire compartments if not done promptly. One of the recent solution to the problem of disposing of gases and smoke in fire situation has been solved mainly with the help of the "Ventilation System" by creating a over pressure and working as smoke exhaustor.

Due to the importance and specific problems which arise in fire situations, tall buildings need special considera tion and equipments to meet these situations. Therefore, they may be treated more carefully and with more specific means tha small low buildings.

Author in his dissertation wish to assimilate and analyse all standard trends researches and practices pertainin to fire safety and fire hazards in the multistoreyed structure which may help in formulating the safety criteria for the desi of multistoreyed structure.

1.3 PURPOSE AND OBJECTIVE OF FIRE PROTECTION

The prime objective of fire protection in the multistorey structure is to eliminate all possible hazards like conflagration hazard, smoke hazards and hazards to the human life and properties. Had it been possible to eliminate all fuel from the construction of building and make it fully non combustible, the fire hazards would have been greatly reduced.

First and foremost purpose of fire protection is to (1) reduce the possibility of fire out-break. Presuming tha the fire could not be confined or controlled, then the second objective will be (2) the reduction of the property losses which can be done by designing suitably fire resisting structur and non combustible construction. Last but not the least is (3) human safety, which cannot be neglected at any cost. The occupants of the building can escape to safety or evacuated provided if building has efficiently designed escape routes and proper compartmentation of the building to confine fire at the place of its origin.

The objectives are dealt in more details in their respective chapters.

1.3.1 REDUCTION OF PROPERTY LOSS

Before considering how it may be possible to reduce material loss from fire it is well to consider, in broa terms, the extent of the problem as it exist in our country at present. Unfortunately no uptodate statistics regarding the fire losses are available, in this respect, all information in the form of pesemeal is available with different authorities. The estimated direct loss in the field of fire services is abou 100 crores[2] which do not include the loss of uninsured building This also do not include reusability period and reproduction loss, rehabilitational loss, loss due to unemployments, etc., which all sum up may go well over few hundred crores of rupees per year.

For controlling the possible material losses due to fire, at the tolerable minimum it is necessary to understand the present trends considering the changing pattern of industry and commerce and the use of material in daily life. The introduction of high value equipment, such as complex data processing installation in offices, costly instrument in engineering and chemical plants all tend to increase material loss. The increase use of more readily combustible materials of construction and finishing coupled with more sophisticated method of packing the goods we buy and use in our daily lives, all tend to increase the potential source of ignition.

From the earlier findings and general study of fires in buildings certain desirable precautionary measures become apparent to minimise the property loss which may be summarised as below :

(i) Adequate fire resisting of structure

(ii) Farming of fire fighting compartments of limited floor area and cubic capacity, to reduce the area and cubic capacity, to reduce the area at risk.

(iii) The segregation of occupancy hazard

(iv) The isolation of high fire risk areas within the occupancies.

(v) The provision of suitable means of controlling outbreak of fire.

(vi) The provision of suitable and adequate means of fire warning.

(vii) The provision of first-aid fire fighting equipment and personnel with the knowledge to use it

(viii) Adequate access facility for the fire brigade with sufficient water supply readily available.

The adoption of whole or part of these precautions depends upon the type of occupancy. These basic fire protectio measures should be kept in check and one hopes to reduce the property loss from the outbreak of fire.

1.3.2 HUMAN SAFETY

With the designers point of view safety of life is of the prime importance. To consider the reduction of outbreak fire and the reduction of material loss however are the aspects which provides a background to the overall problem. It is unfortunate that as a building designer, this point is generall neglected.

Safety of life being the most vital and importan
multistorey structures, it is necessary to provide
fire protection measures to solve the problem. A
when fire breaks out in a building the immediate
to the occupants. If sufficient fire preventive
ions like fire detectors, fire alarm and prompt
tion systems are adopted, then the occupants get
t time to escape to safety before the fire takes a
urn. Therefore, location and size of escape routes
ent significance for human safety.

Apart from all possible precautions absolute
n a multistorey structure is never secured because
ilure to maintain the precaution prescribed or to d
ing when an emergency demands it.

URE AND CHARACTERISTICS OF FIRE SPREAD IN
TISTOREY STRUCTURE

Normally one thinks of fire in a building as
with ignition and then spreading but the process
is important even after the fire has started becau
ead often involves further ignition. Sometimes a fi
of a room will ignite a combustible item some dis
radiation or hot gas and the continuous spread of
he surface occurs theoritically due to a rapid

succession of ignitions. Usually the fire spread is not because of the ignition of a piece of wood or plastic, but of gases evolved by these materials as they are heated.

"Combustible materials evolve volatiles more rapidly as they are heated and if oxygen is present the flamable vapours may ignite. When some heating takes place the solid surfaces, walls and ceilings themselves begin to emit heat in the form of radiation because radiation increases more rapidly with a rise of temperature than does conviction or conduction it is, therefore, most important means of spreading fire throughout a building or from one building to another"[5].

Considering a large space of which a relatively small part contains burning materials the floor on which burning material is resting can become heated due to conduction (Fig. 1A). The ceiling immediately above the burning material and some distance away will become heated by conviction (Fig. 1B) and since conviction currents travel at several feet per second materials quite away from the fire will be heated by hot gases. Nearer to the fire other combustible materials just surrounding the burning area will be heated by radiation from the flames (Fig. 2).

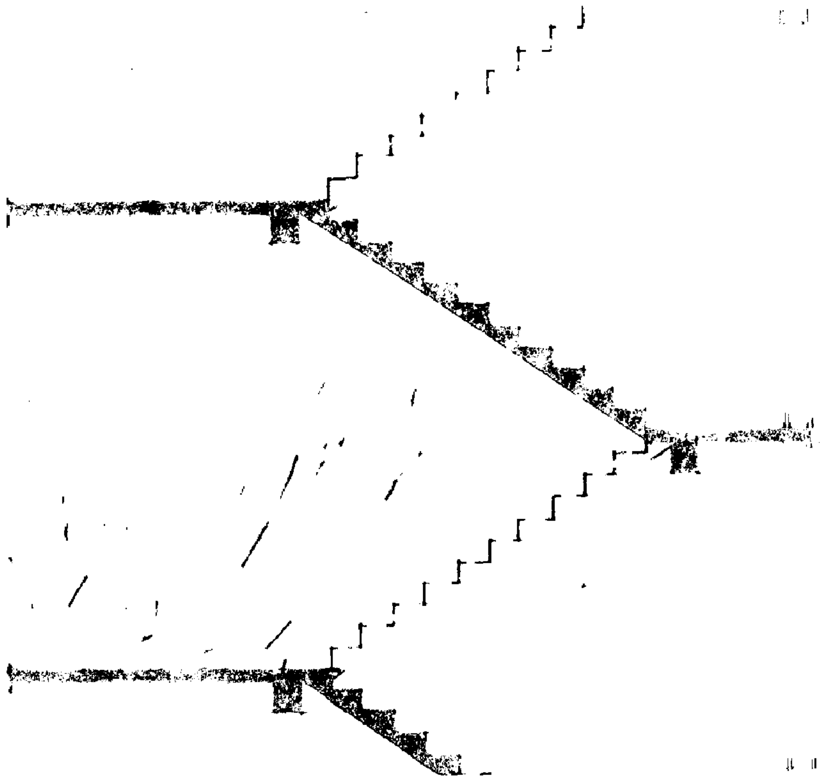
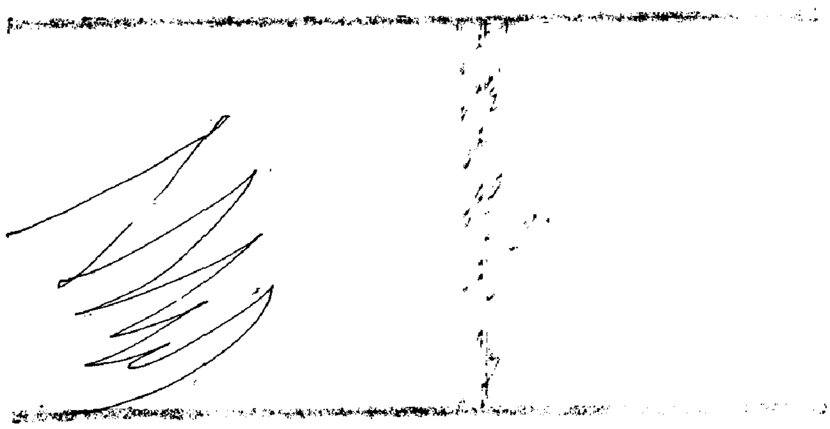


FIG 3b

SPREAD OF FIRE [illegible]
FLOOR VIA AN [illegible]

[illegible]
[illegible]
[illegible]



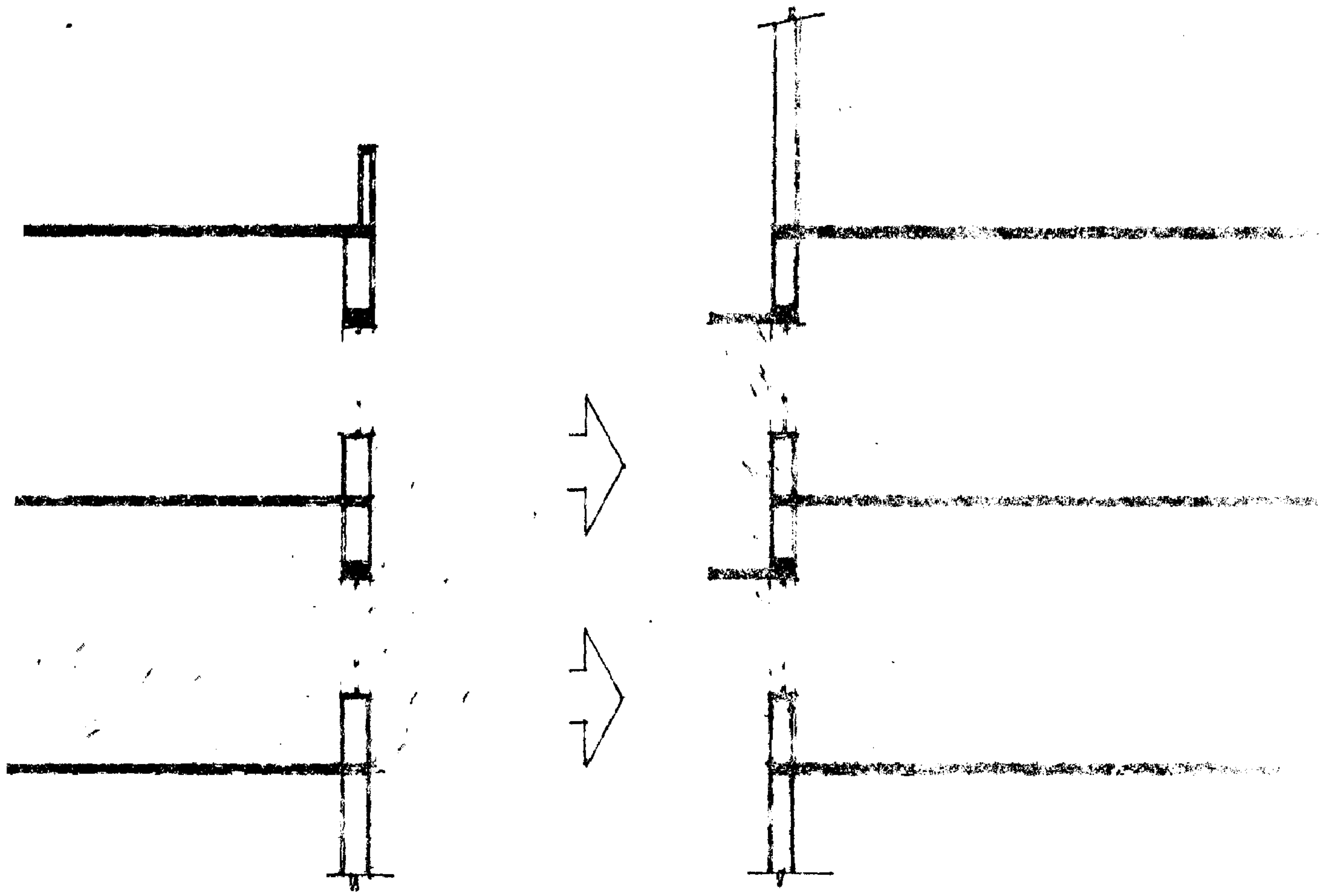
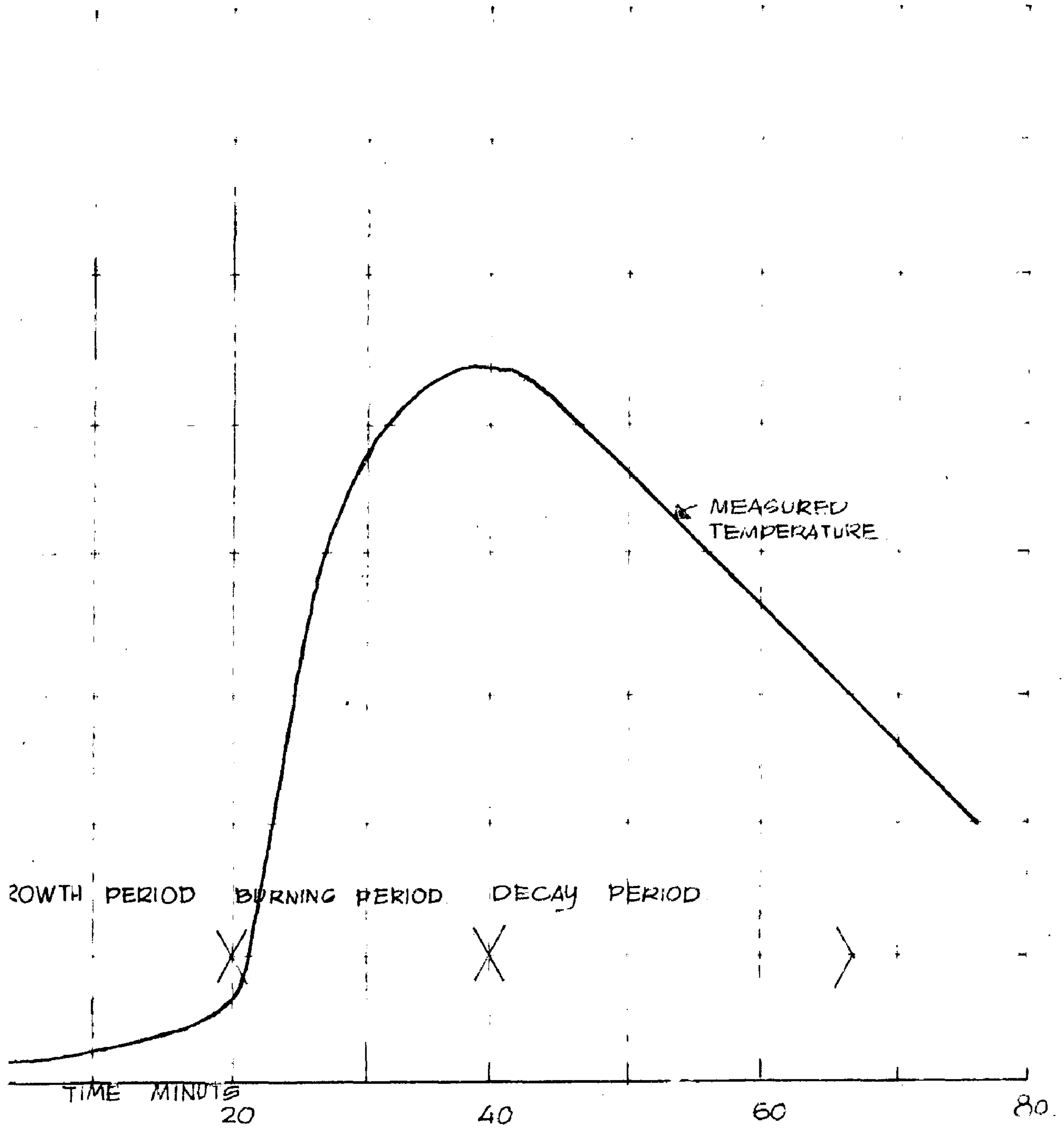


FIG. 2. SPREAD OF FIRE BY RADIATION VIA OPENINGS TO COMBUSTIBLE MATERIAL ON THE FACE OF AN ADJACENT BUILDING.

1.4.1 GROWTH PERIOD OF FIRE TEMPERATURE

After studying the nature and characteristics of fire spread it is very necessary to know about the development of temperature during the fire, from the ignition to the decay period of fire. This growth in the temperature is shown clearl in a graphical form in (Chart 1) by the help of smooth curve. Period of fire before the actual burning or flash over is show by A.B. This is the period when ignition starts taking place and temperature of the room and even temperature near the ignited material is low. During this period the damages are comparatively less, and chances of escapes from the building remains fair. The flash over or real burning starts at B. This period is called fully developed period when the room temperature reaches to the highest. Then the temperature start falling from the point C and burning period ends and the period of decay starts. During burning and part of the decay period the temperature rises so high that, the spread of fire can take place through radiations, by fire penetration through partition walls etc.



TEMPERATURE COURSE OF A FIRE[4]

CHART - I

CHAPTER - II

HISTORICAL DEVELOPMENT OF FIRE SERVICES IN INDIA AND ABROAD

"It has been stated that the Egyptian had some 4000 years ago organised fire-fighting for the first time and the first Government Fire Service Department known to history was set up by the Roman Emperror Augustus Ceasar. The fire service in our country however started much late but certainly earlier than the establishment of organised Fire Services in U.K. viz the London Fire Brigade was started in 1866 only and Calcutta Fire Brigade was established in 1822"[5].

2.1 DEVELOPMENT OF FIRE SERVICES IN INDIA

In 19th century with the establishment of East India Company's trade and commerce, first organised fire service was established at Major port of Calcutta. Because of the severe losses due to few bitter fires in the storages, East India Company acted seriously to formulate an organisation which could safeguard, and fight out fire under such situations. Chamber of Commerce and Insurance Company which were mainly responsible in establishing fire services in the continent and U.K. has also encouraged and convinced East India Company, the necessity of such organisation in safeguarding their interest with the result two major organisations developed one at Calcutta and the other at Bombay.

At the initial stages the Calcutta and Bombay Fire Brigade stations were not very well organised but by and large the necessity of providing protection to life and property was much felt by the people and government of this country, with the result in 1871 fire stations were built as per the recommen dations of special committee of the Justice under the Jute Ware House Act II of 1872[6]. First time in history the cost for the fire services were attached to Calcutta Municipality, and more appliances and horse drawn equipments and steam engine were brought to reinforce the Calcutta Fire Brigade.

The importance of fire protection was so much felt in 1910 that government appointed a committee to reorganise the Fire Brigade, and as a result in 1912 Capt. Bernard A West Brook, O.B.E. M.I. Fire E was brought from England and horse driven steam engines were replaced by petrol driven fire engine.

2.2 THE PERIOD OF MODERNISATION

Necessity of fire protection was largely felt all over the world and every country made an effort to well equip its fire fighting brigade. Road propulsion was introduced for the first time by M/s Merry Weather & Sons Ltd. It is in the 1903 that Calcutta and Bombay fire station also added first petrol fire engine combined a chemical apparatus, hose tender and a fire escape being Merry Weather's sliding carriage pattern which was designed to reach a height of 50 ft. and was also capable of propelling the machine up to 25 m.p.h. In 1907 at Bombay station a 82 ft. long turn table ladder mounted on an automobile was introduced.

2.3 LATER PHASE OF DEVELOPMENT OF FIRE SERVICES

World War II brought a radical change into fire services, due to the changed method of warfare, civil defence was introduced as the fourth arm of defence services, in which fire services played an important role. The allies Survey India and found that its fire fighting organisation is very much below standard, and to bring it to the standard, the fire pumps, engines, and fire fighting equipments started pouring under civil defence rearmament programme.

2.4 ADMINISTRATIVE SET UP OF FIRE SERVICES IN INDIA

Fire services in India is unfortunately not under the control of Central Government which would have been an ideal administration although the country. To-day Indian Fire Service fall into four categories, as follows :

(i) Maintained by the Central Ministries, like Defence, Home, Railways, Communication & Transport (Civil Aviation, Docks, Post & Telegraphs)

(ii) Those directly under the control of State Government.

(iii) Those managed by municipalities, District or local boards and other local bodies.

(iv) Those owned by private parties, factory mills and other industrial and commercial establishments.

The number of fire stations and statistics of certain fire services of 1970-71 and 72 is given in the table No. 1 (APPENDIX - A).

2.5 HISTORICAL DEVELOPMENT OF FIRE SERVICES

Egypt was the first country who gave regular training to their fire men. Though the exact method and technique employed by them is not yet known. In 150 B.C. Ctesibius; a scientist in Alexandria was the first man who has the credit of inventing the first fire fighting equipment, a reciprocating pump.

While the first Govt. Fire Services Department known to history set up by the Roman Emperor Augustus Caesar. The Romans being efficient and technically minded introduced fire fighting as one of the essential duties of the citizen. Hundreds of young Romans known as Vigiles were trained in fire fighting and were organised into cohorts or companies. The equipments used by them were large water filled leather bags with metal spouts from which water was forced out towards the fire. During the emergencies, thousands of slaves used to be ordered by their masters to carry buckets and fill the empty water bags.

There used to be about 1000 Vigiles in each cohorts or companies. The entire department was organised by a Commandent a Siphonarius or Chief for in Rome. As it is today there were criminals who not only took advantages of the confusion caused by the big fire to steal, but often deliberately started it to get an opportunity for this. It may, however, be added that barring Egypt and Rome the rest of the world till about three centuries ago fought the fire as it could, without any organisation.

~~2.6~~ 2.9.1 EARLY EQUIPMENTS OF THE FIRE SERVICES

The Roman firemen were equipped with the hand pumps and leather hoses, hammers, saws, water bags buckets, ladders and even the large pillows to break the fall of men, who had to jump out of the upper storeys of burning houses. The scene around a building house in ancient Rome was much the same as we find to-day in our modern cities, except for the equipments with operations, being directed by the Chief Officer of Fire Brigade.

2.5.2 POSITION DURING THE MIDDLE AGES

During the middle age many old cities and towns were destroyed by fire, and in this period the fire services were at its ebb. London, and Constantinople were perhaps the greatest sufferers from the calamity point of view. Some of the worst fires recorded in history are; Rome in AD 64 when entire city was burned by Emperror Nero, London A.D. 798 and 982, Copenhagen A.D. 1728, Chicago A.D. 1871 and Bombay 1966 A London also had been a victim of a great fire in 1966 A.D. when the greater part of the city was destroyed.

In 1650 a German Scientist invented hand operated pump capable of throwing a steam of water upto 80' distance.

In 1725 Richard Newsharm produced an improved type of fire engine with pumping levers running along its length (required less people for operation). In 1672 two Dutch brothers Jan and Nicolaas Vander Heijden introduced leather hose for suction and delivery as well as couplings for joining length of hose. In next 100 years "Fire Bomb" was unsuccessfully introduced.

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quality of materials, the details of method of its application or construction, their dimensions and thickness of protection all these factors affect the fire resistance and even a slight change or modification in this may have a considerable effect on the fire-resistance rating. The properties of some of the building materials are given as following:

3.2.1 STEEL

Like any other metal steel is also a noncombustible material. In case of fire steel cannot withstand fire for a longer period " For temperature upto 250° C (482° F) there is a gain in the ultimate strength of mild steel which returns to its normal value of 400°C (752°F). The temperature at which the yield and ultimate stresses for mild steel have fallen to the working stress is about 550°C (1022°F) but on cooling most of the loss of strength is recovered. The critical temperature of steel work is therefore considered to be 550°C (1022°F). Any other high strength alloy steel follows similar behaviour when heated. Cold worked high strength steel on the other hand, shows a markedly greater reduction in strength and the critical temperature for steel used for pre-stressed concrete work has been shown within the range of 400°C - 450° C (752° - 842° F)"[9].

The most serious behaviour of the steel under fire is its high thermal expansion which can lead to deformation and failure of the structure.

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C H A P T E R - III

FIRE SAFETY CRITERIA FOR THE STRUCTURAL SYSTEM AND NON STRUCTURAL ELEMENTS

3.1 STABILITY OF STRUCTURAL ELEMENTS

Here it must be stressed that stability or safety is a concept which has to be applied to the whole object and to cover all aspects. Missing to consider a single point can result in serious mishaps. Fire protection therefore is an integrated process and any of these aspects can be overlooked only at the cost of entire set up. To quote Mr. J. G. Bodhe, President I.E.I. "The provisions for fire safety constitute a chain of measures whose efficiency is jeopardised if a single link, i.e. a single aspect, is neglected or subjected to weakness or failure".

3.2 BEHAVIOUR OF BUILDING MATERIALS AT HIGH TEMPERATURE

Stability or fire resistance of any building structure is related to the characteristics of its structural elements (wall, floor, columns, beams). Fire resistance of these elements depend upon whether they are made out of the combustible or noncombustible materials, and the time it could resist severity of fire at certain temperature without failure. Behaviour and properties of most of the building material are changed under high temperature. The kind and quality of materials, the details of method of its application or construction, their dimensions and thickness of protection all these factors effect the fire resistance and even a slight change or modification in this may have a considerable effect on the fire-resistance rating. The properties of some of the building materials are given as following:

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3.2.2 MASONRY

Masonry work in the form of brick tiles, concrete and other types have been since long used for fire protection, purposes, particularly in wall and partitions of the buildings. The fire resistance quality of the material depends upon the ingredients of the bricks and tiles. In construction of a wall with hollow masonry units, the total thickness of solid material in the unit, rather than overall thickness thickness of the construction is a factor in its fire resistance, for example "a wall of 8 inches masonry unit, of calcareous gravel aggregate which are 78 per cent solid will have 3 hours fire resistance rating, while the same wall construction with units 57 per cent solid will have a lower; 2 hours fire rating"[10].

3.2.3 BRICK WORK

Ordinarily clay bricks have tremendous capacity to resist temperature. It is only under very severe and prolonged fire exposure the surface of brick may split but such condition very rarely comes. Clay bricks can withstand temperature upto 1000^{o} C (1832^{o} F)[11] or more without any material damage. Possibility of bricks failure because of disruption is almost nil, but the expansion of brickwork or of steel work in contact with it may cause cracking or bulging due to expansion.

3.2.4 ALUMINIUM

Though aluminium is not used as the structural member like steel, but still its behaviour in fire must be know

The melting point of aluminium and its alloys is 650° C (1202° F) which is considerably lower than steel.[12] However, there is a time lag before fusing actually takes place, this also depends upon the thickness of the metal. Aluminium has twice the rate of thermal expansion, less heat capacity, and a greater thermal conductivity than steel. Its critical temperature is about 250° C (482° F)[12] depending upon the use of particular alloy. When it is used as structural element. The fire protection required for it will be so much that it will not remain the economical proposal.

3.2.5 ASBESTOS PRODUCT

The ability of asbestos based products to resist fire depends to a large extent upon the amount of asbestos fibres incorporated in the product. Asbestos in its pure form used as sprayed insulation in conjunction with a cementacious binder is highly fire resistive. "Asbestos cement contains about 10 per cent of asbestos and high proportion of portland cement. This is though noncombustible but it may shatter voilently in the early stage of fire. This shattering will largely depend upon the its moisture content"[12]. Board and sheet of materials which contains a much higher proportion of asbestos fiber and may be bonded with materials other than Portland cement are known as "asbesto wood" or asbestos insulation board. The majority of these products are non-combustible; but some in order to improve their workability contain a small proportion of organic material which may make them technically combustible. Asbestos in general provides valuable protection for structural metal work and help in overall increase in fire resistance of the material.

3.2.6 GLASS

Generally the glass pane cracks because of the temperature difference between two faces, which usually happens when building is on fire sheet glass specially in windows, may remain in position for considerable time, but is also unpredictable, and therefore cannot be a dependable medium of fire protection from radiation.

Fire resisting glazing is provided by reinforced glass which has embedded wire mesh, and used in limited size. Other variety is the copper comes (or electro copper glazing) glass panes. These glasses retain their integrity in fire for a limited period.

3.2.7 TIMBER

Timber and all its byproducts are combustible in nature. Wood over 100° C will become over dry and discoloration, distortion and loss in weight will take place; "the rate of these processes roughly doubles for each 10° C (50° F) rise above 100° C (212° F) and hotter wood becomes more sensitive to other source of ignition"[14].

When wood burns it produces a large quantity of smoke, the amount of particles depends upon the rate of burnin Temperature during fire will be related with the density of wood and amount of air mixed with it.. As wood is an organic material it contains carbon and can therefore produce carbon monoxide which is highly toxic in nature.

3.2.8 PORTLAND CEMENT

Portland cement is one of the useful fire protective materials. When subjected to high temperatures it releases water in a manner similar to gypsum, although to a lesser degree. The fire resistance of concrete is dependent to a great extent on the type of coarse aggregate used in the concrete. It is for that reason the type and size of aggregate is specified in most of the list of fire-resisting ratings of concrete. "Aggregates containing 60 per cent or more of quarts or granite is not as fire resistance as lime stone or trap rock and therefore the concrete must be increase in thickness to obtain a comparable fire rating. The use of light aggregates instead of stone greatly improves the fire resistance of concrete. Concrete now is used largely for fire protection in reinforced concrete"[15].

Cement plaster is also used for fire protection. If it is mixed with light weight aggregates and mineral fiber its fire resistance is greatly improved.

3.2.9 MINERAL FIBER

Mineral fiber has gained wide recognition as an effective fire protection material. Combined with a mineral binder, the fiber (usually asbestos) is directly sprayed by machine to the surfaces of steel or concrete or other material. In some instances, an adhesive applied to the surface of steel or concrete, is necessary to assure bond of the fiber. Mineral fibers as used in certain acoustical tiles is also found to have sound fire resistance.

3.2.10 GYPSUM

"The calcining process of gypsum, which involves the slow release of the water of crystallization when exposed to fire, gives it unusual fire resistive proper ties. The water that is released in the form of steam serves to maintain relatively low temperatures on the side away from the fire exposure"[16]. Gypsum plaster on metal or gypsum lath, or in the form of tile or wall board is used widely as fire-protecti Combined with light-weight insulating aggregates the fire resistance of gypsum plaster is highly increased.

In assemblies where gypsum plaster is used as fire protection, it is important that the thickness, type of aggregate, proportions and the type and method of fastening the lath be carefully followed.

A special type of gypsum wall board with a special core and usually of greater thickness than conventional wall board has been developed. Tjis type has greater fire resistance than conventional wall board.

3.2.11 METAL LATH AND PLASTER FIRE PROTECTION

Plaster provides most effective fire protection to floor, slab partition and wall constructions. Plaster applied to metal or wire lath, has been proved to be very effective against fire. The other advantage being the economical it is widely used in building construction.

3.3 CLASSIFICATION OF BUILDINGS BY TYPES OF CONSTRUCTION

Purpose of classification of buildings by types of construction is to provide a general grouping of buildings base on relative fire safety. Each of these construction types can be further classified according to the degree of fire resistanc or fire protection which is provided to various structural parts of the building and according to the relative fire safety it provides for its occupants and for the adjoining property and surrounding community.

The classification of buildings by types of construction has been prescribed in National building Code[17] and I.S.I. No. 3609[18].

When a building is of noncombustible construction, not contributing fuel to facilitate spread of fire, and structural fire protected to prevent structural failure in a fire such as may result from a complete burn-out of the contents of the occupancy, the building may be considered as "fire proo Such building need not be subjected to limitations of size or of location, within the scope of occupancy with the degree of fire safety, which it affords.

In determining the degree of fire resistance and the other fire safety requirements to be prescribed as a minimu requirement for the several types of construction it is necessary to anticipate the probable scope of use for which the building may be suited during its period of useful service. As far as possible, it is desirable to base the requirements for each type of construction upon a degree of fire protection that will provide adequate fire safety and meet the expected fire severity of the occupancy it is likely to accommodate.

3.4 DEVELOPMENTS IN REINFORCED CONCRETE MEMBER UNDER FIRE AND ITS REUSABILITY

Lot of laboratory fire test of structural members are carried out all over the country in India, and abroad, to acquire wide range of data from which structures can be designe so that these structures should have sufficient fire resistanc to permit the scope of the occupants, access by fire servicem and to restrict the spread of fire. But it has never been the intention of either the fire tests or the fire resistance regulation to ensure the possibility of reuse of the structure after the occurrence of the actual fire.

Due to the economical and technological limitations multistorey structures in India are restricted to reinforce concrete construction. In reinforced concrete bath concrete and cement are essentially a non-combustible material. When these materials are exposed to fire, it undergoes a reaction which in structural engineering terms are primarily those reaction which undergo temporary or permanent changes in its physical and potential properties. For the assessment of the possibility of the reinstatement of reinforced concrete structural member these physical changes are to be considered in deeper details. Mr. J. Keith Green in his paper in concrete has suggested that following factors will have considerable impact on the possibility of re-instatement.

" (A) The course of temperature development during the fire.

(B) The duration of fire

(C) The temperature reached within the internal section of the structural member-

(D) The effect of estimated temperatures while hot and after cooling on the engineering properties of the concrete and steel.

(E) The significance which any permanent change in materials characteristics may have on the future structural performance of the member.

(F) The feasibility of repairs to components for any unacceptable reduction in structural performance durability etc., and the influence which fire exposure of individual members may have on performance of the entire structure".

3.4.1 INCREASE IN THE TEMPERATURE OF STRUCTURAL MEMBERS AND STRUCTURAL ELEMENTS

During fire outbreak temperature development in the structural members may broadly be divided into three stages:

(1) First stage will be when a combustible material has ignited and fire has just started spreading over.

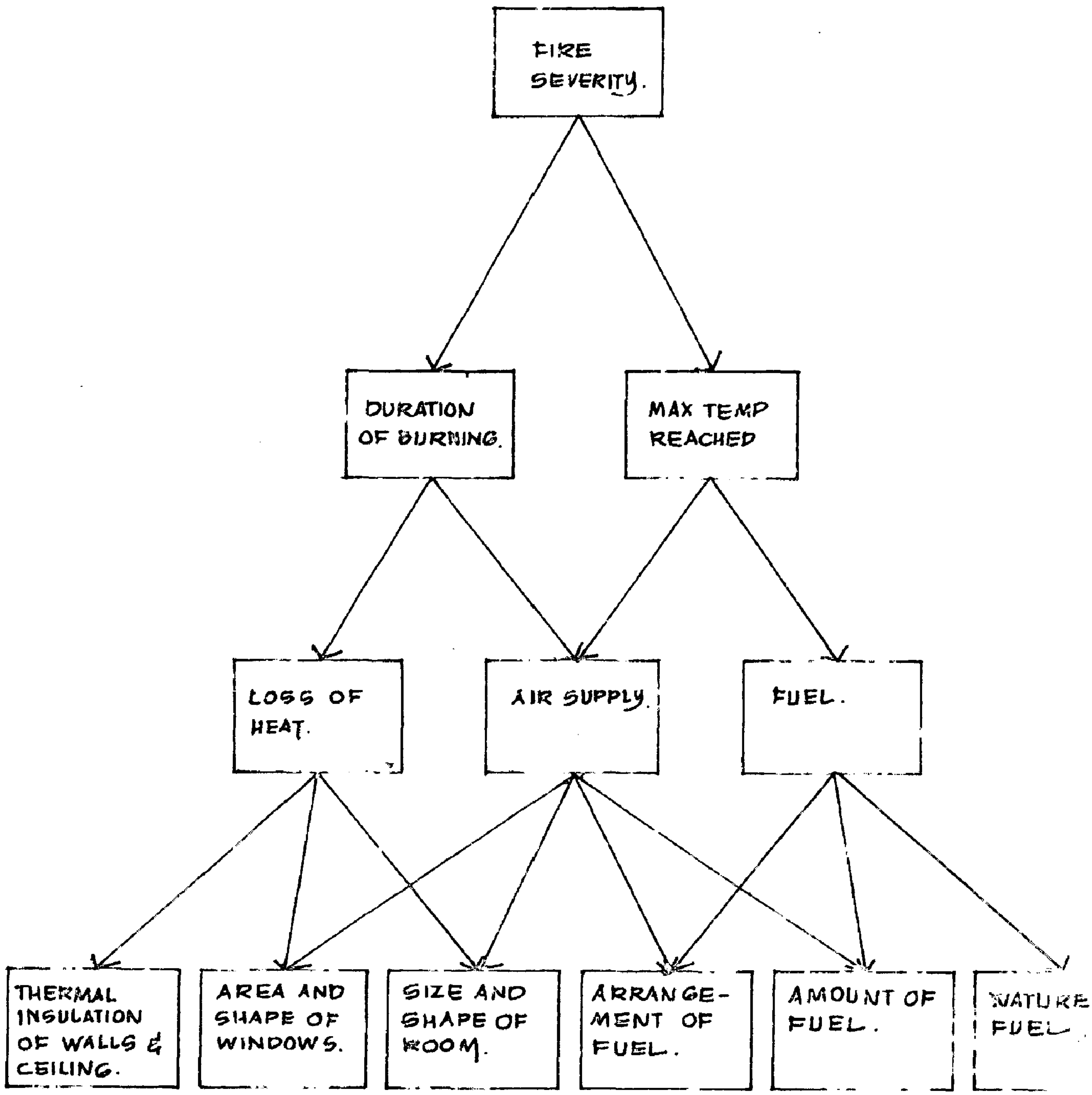
(2) This may be called the "peak period" after the flash over and fire is well established within a room or compartment, where fuel and fresh air is readily available.

(3) Third period is when combustible material is burnt out and the flames are replaced by burning of residual charcoal.

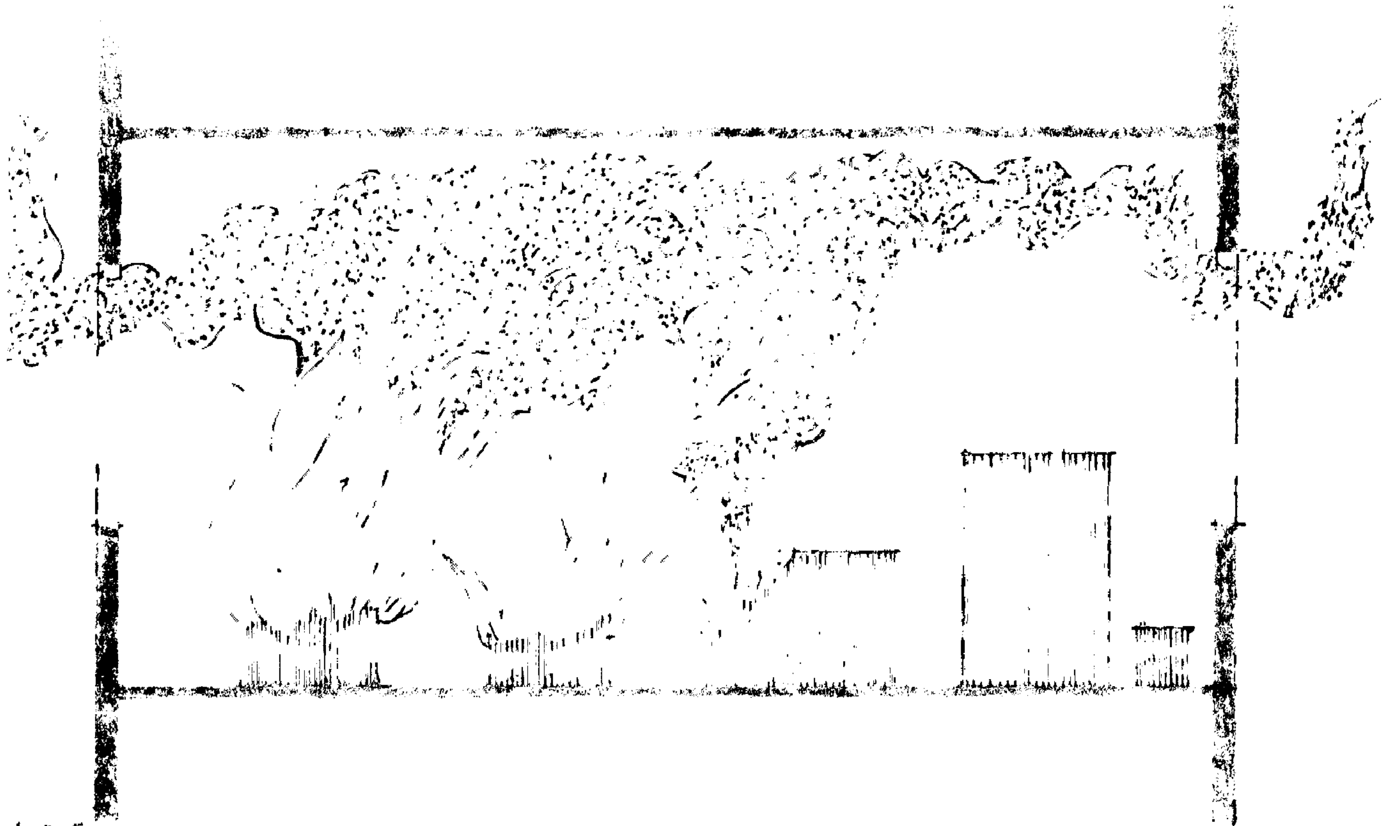
During the first period of burning there will be very little structural damages, whereas the third stage and some part of second stage are usually controlled by the action of the fire services. Actually second period is very importan since at this period when the fire is fully developped with very high temperature and the structural deterioration occurs or initiated.

For fires in compartments with a high degree of ventilation, the increase in the temperature of structural member will depend upon rate of burning and the temperature of hot gases which are controlled mainly by the amount and surface area of fuel available (Fig 3/A) whereas in a compartment with little ventilation the progress of fire is largely controlled by rate of air flow into the compartment (Fig 3/B). Ventilation controlled fires usually burns for longer duration than fuel controlled fire and reaches higher temperatures. For determining the relation between ventilati and temperature, it is to be considered from the centre of the experimental fire compartments.

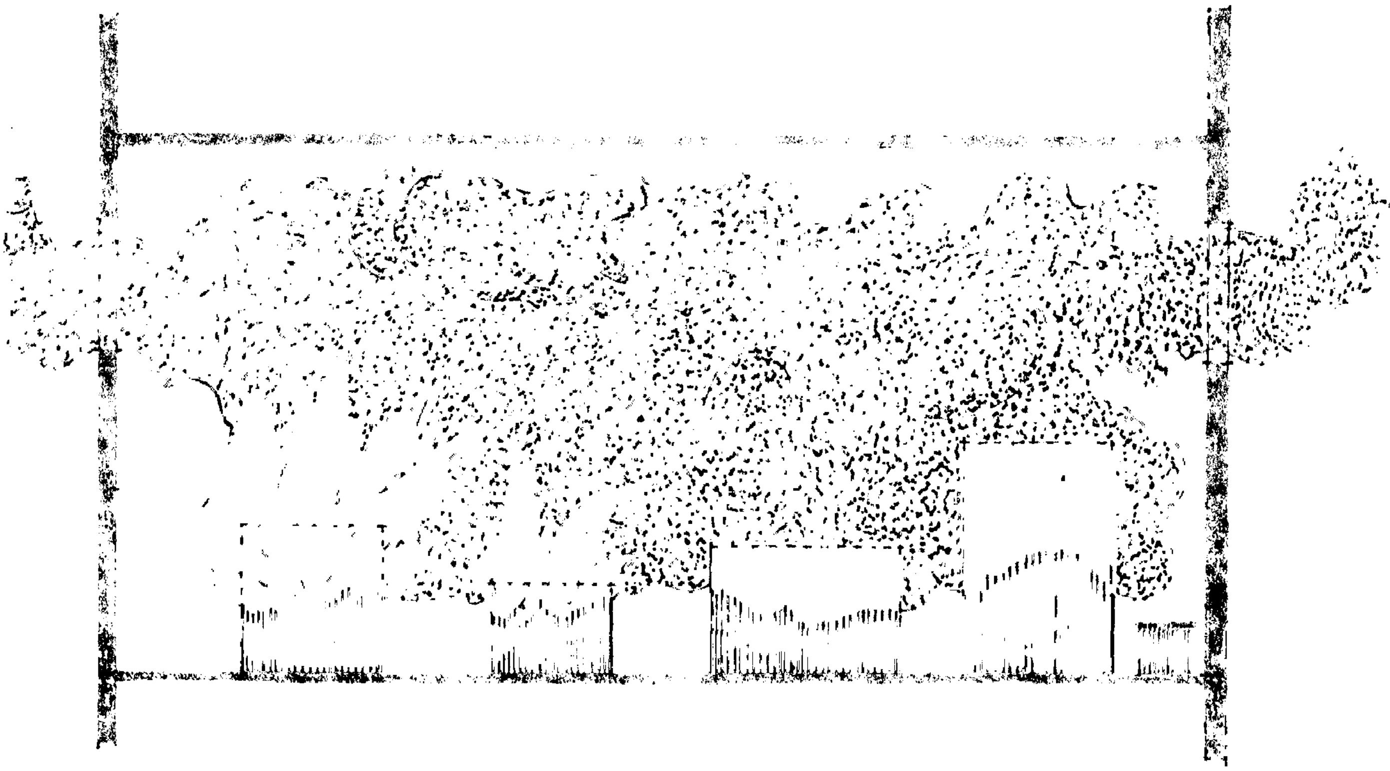
The factors which govern the development of fire temperature or "fire severity" in the compartment are as following (Chart 2)



FACTORS AFFECTING FIRE SEVERITY. CHART-2.



ADEQUATE VENTILATION WITH NO LACK OF OXYGEN TO INTERFERE WITH BURNING. FIRE SPREADS BY HEATING OF UNBURNT FUEL WHICH WHEN IGNITED BURNS FREELY



-RESTRICTED VENTILATION : SOME OF THE FUEL CANNOT BURN FREELY AND SO HEATS OF UNBURNT FUEL LESS QUICKLY THE SPREAD BEING SLOWER

13- EFFECT OF VENTILATION ON BURNING

(i) Nature of the fuel : its combustibility

(ii) Amount of such fuel in the compartment

(iii) Arrangement of storage of such fuel

(iv) Size and shape of the room or compartment

(v) Area and shape of the windows and other ventilators

(vi) Thermal insulation of wall and ceiling

First three factors if not dealt with caution and care will encourage the outbreak of fire, and there is no proper thermal insulation or fire protection to the structural elements the fire will spread more quickly. The shape and sizes of room and windows will further add to the fire severity.

3.4.2 [illegible] STRUCTURAL [illegible] AND [illegible]BILITY OF REPAIR

The structural elements which are suffered fire damages, short of total collapse or severe distortion can most often be satisfactorily reinstated at considerable economic benefit when compared with the cost and disruption resulting from complete demolishing and replacement.

"Normally any structural concrete which exceeds sit or spalled or been disrupted by closely spaced cracks. For re-instatement of structural elements the residual strength beyond temperature much above 300° C is unlikely to be of any real value, and thus the elements will most probably require replacement"[20].

Defective or spalled concrete may be replaced by "in-situ" concrete. There should be sufficient allowance for the practical operation of compacting structural grade concrete in and around thin section of existing or added reinforcement.

3.5 WATER COOLED HOLLOW STEEL COLUMN

A new form of theory is introduced by structural engineer S.W.L. Bond of London, which gives fire protection for multistoreyed structures using water cooling in hollow steel section. This form of protection in which the columns are normally interconnected by piping system which permits gravitational circulation during fire allowing the steam generated to be vented to the atmosphere and replacement of water to be supplied from a storage tank connected to the mains provides an economic alternative to the more conventional methods of protecting with fire proof materials.

The principle advantages claimed from water cooling of columns are reduction of over all column size ; the ability to express the structure of the building architecturally and the fact that the columns are more likely be serviceable after the fire with a consequent reduction in insurance cover.

Although the idea of fireproofing steel columns by water was conceived at the end of the last century "the first practical use of the concept has only recently been adopted for the united states steel corporation 64 storeyed building in Pittsburgh. It has also been used for recently built Multistoreyed Buildings in France and Germany"[21].

3.6 DEFORMATIONS DUE TO CREEP DEVELOPMENT IN MULTISTOREY STRUCTURE

Most of the material undergo instantaneous deformation when it is subjected to loading. If this loading is continued, the deformation properties will proportionately increase with time and this time dependent deformation under the contineous pressure is called 'creep' in that material. Under normal circumstances and normal room temperature the creep is negligible, but at the time of fire outbreak with rapid increase in temperature and stresses the creep deformatio is deemed to be quite serious. In (Chart 3) the graph shows that the creep can be divided in three parts, from initial stage of creep up to the rupture stage. Actually the deformation in any material starts on loading (A). This is followed by (AB) which is the "primary creep period". The creep rate decreases until a moment is reached when practically the creep rate becomes constant. The secondry creep starts from the stage (B). The creep rate with the increase in temperature starts deforming faster at point (C) and rupture takes place

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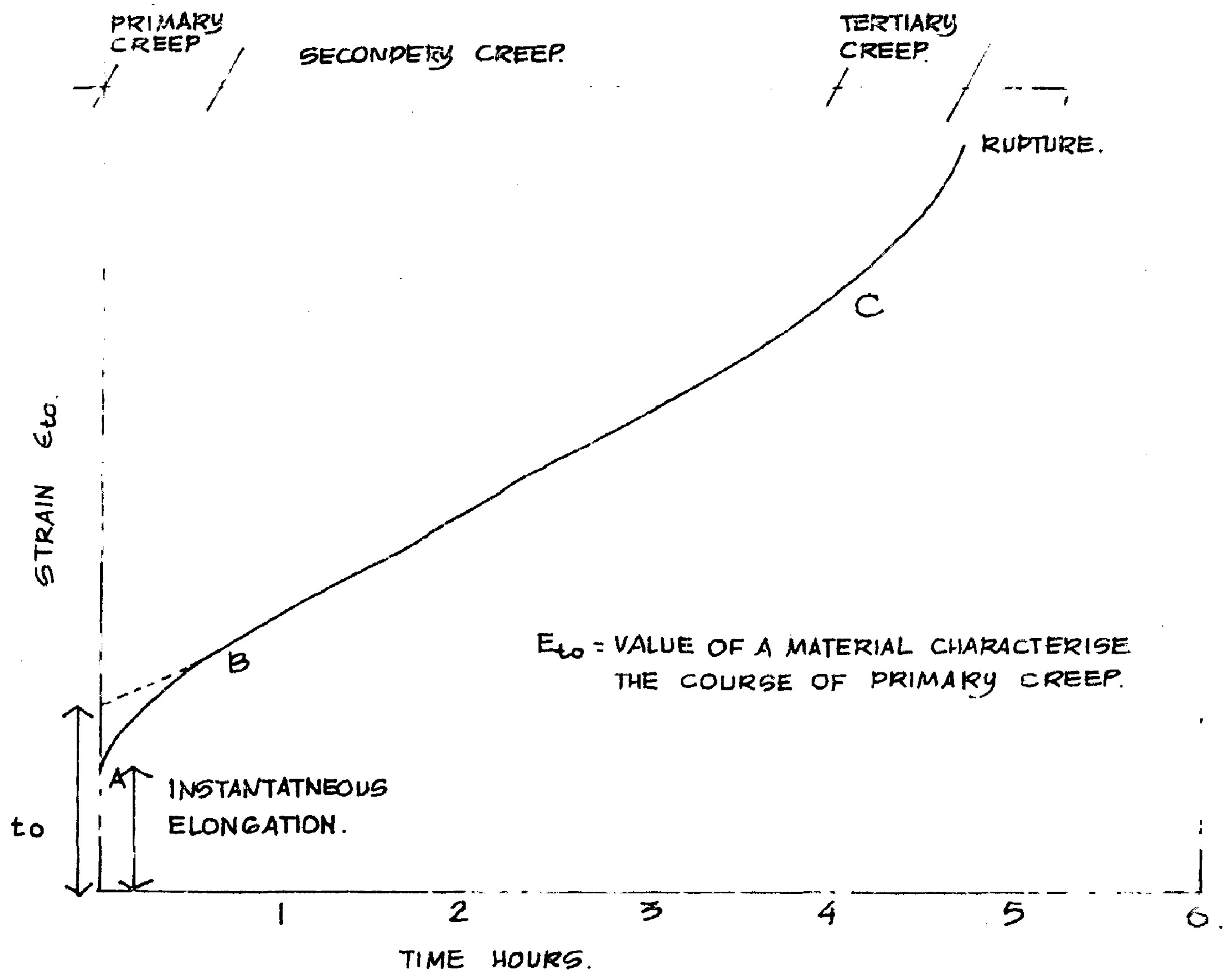


TYPICAL CREEP CURVE

CHART- 3.

after some time. The period of increasing creep rate is known as the tertiary creep period. The creep rate of any material is dependent on stresses involved, the temperature of the material and the time factor of loading.

3.6.1 DEVELOPMENT OF THERMO-MECHANICAL [illegible]

All multistorey structures are designed and constructed in accordance of local building bylaws and national building codes, but still the losses of property and life due to fire outbreak are very much unexpected with the structural safety point of view, following factors should be considered in deeper details.

(i) The stability of structures under fire

(ii) Load carrying capacity of structure and

(iii) possibility of total structural collapse, be because of excessive thermo-mechanical creep deformation. Dr. C. Lai and C.C. Chang has further simplified this problem; as per their theory, it is as following:

"Behaviour of the structural steel member in a fire compartment of a very high building is very complex. Generally the temperature of the hot gas in a fire compartment is known to rise rapidly, while the temperature attained by the steel members would depend on the level of fireproofing. At the same time mechanical load on the slowly decreases as the combustible materials are consumed and the occupants evacuate the premises. Prior to the outbreak of fire, the stresses in the structure members due to mechanical load may be well below elastic limit of the material at room temperature, the mechanic physio-chemical material properties deteriorate, failure of structural component member exposed to fire may be precipitated by excessively large deformation"[23].

These studies will help in evaluating the detail behaviour of steel structure under fire. This will help in formulating a rational design procedure for fire safety in high rise steel structure. The new theory of Mr. Mak & Cheng suggests a radical departure from the normal practice. The usual practice is to adopt the standard furnace fire test temperature for all structural calculations. But the above studies reveal that actually in practice the structural members having fire protection will attain lesser temperature and strain.

C H A P T E R - IV

FIRE HAZARDS AND PREVENTIVE MEASURES IN MULTISTOREY STRUCTURES

4.1 CORRELATION OF FIRE HAZARDS WITH THE FIRE PREVENTION

The increase in building fire losses does not mean that improvements in building construction technique have failed to control fire hazards over the past decade. Instead, the increase in fire losses can be attributed to increases in the number and value of multistorey structures and their contents and to new chemical and other processes. The total figure of fire loss may be more today but in relation to the amount of property burns now has smaller proportion of losses than in the past. Among the factors contributing this downward trend of relative fire losses are an increase in the use of fire-resistive and non-combustible material for construction.

Fire hazards may be greatly reduced, if it would have been possible to eliminate all fuel from the construction of building and to make them of fire-resistive or non-combustible construction. It has long been realized that without fuel there can be no fire and that the intensity of a fire is related to the fuel upon which the fire feeds. It is therefore very essential for preventing any fire, to determine (1) the degree of fire hazard that exist under pre-determined conditions, (2) the average weight of the combustib contents associated with various occupancies for which the building is used, (3) the relationship of between the weight of combustible content and its potential degree of fire hazard and (4) the degree of fire resistance provided by variou materials used.. These are the important factors that need adequate consideration to obtain perfect fire prevention.

For the reasonable fire safety, the degree of fire protection prescribed should be proportionate to the fire hazard involved. If the protection prescribed is too less, then fire safety may be sacrificed, and if it is too high it will unnecessarily increase the cost of construction.

4.2 CLASSIFICATION OF OCCUPANCY

For fire prevention, classification of buildings are based on the use group which is known as occupancy. Fire hazards are related to respective occupancies because of the contents and combustibility of the materials used by the occupants. This grouping helps in aggregating the fire severity of the buildings. National Building Code 1970 in its chapter four : Fire Protection covers the requirements of fire protection of buildings through the classification of buildings based on occupancies, like residential, educational, institutional, assembly, business, mercantile industrial and storage.

4.2.1 FIRE AND CONFLAGRATION HAZARDS IN DIFFERENT OCCUPANCIES

The safety of the occupants is involved every time a fire occurs in a building and with this the safety of the community also becomes endangered. It becomes a matter of concern as every time when fire spreads beyond the limits of the building structure, thereby threatening to become a conflagration. Primary aim of fire protection is to give adequate safety to the occupants of the buildings and to the community against the occurrence of a conflagration.

"From the detailed assessment of the conflagration hazard due to these occupancies made by the National Bureau of Standard U.S.A. it is noted that the weight of the combustible contents in each occupancy (excluding the combustibility of the structure) can be expressed in the term of equivalent weight of wood and paper having clorific value of 7000 to 8000 Btu/lb. per sq.foot as lbs/ft^2 of floor area. On the basis of actual survey of the different occupancies in America and also as a result of many state building codes, it can generally be said that the weight of the combustible contents in different occupancies are as following"[24].

TABLE No. 1[25]

Occupancy	Combustibles in occupancy (psf)
Residential	5 to 10
School	5 to 10
Institutional	5 to 10
Assembly	Less than 10
Business	10 to 15
Mercantile	15 to 20
Industrial	25 ±
Storage	30 ±
Hazardous	40 ±

It has been also established that the amount of combustible content can be related to the fire severity of the fire hazard represented by that given weight by the National Bureau of Standards as a result of test determination and in general the relation of amount of the combustible content of fire severity would be as given in below.

TABLE NO. 2[26]

RELATION OF AMOUNT COMBUSTIBLE CONTENT TO FIRE SEVERITY		
Average weight of combustibles	~~Equipment~~	Equivalent fire severety (hrs.)
5		1/2
7½		3/4
10		1
15		1½
20		2
30		3
40		4½
50		6
60		7½

4.2.2 FIRE HAZARDS IN VARIOUS OCCUPANCIES

For the purpose of evaluating the fire hazards that exist in various occupancies, many agencies, municipalities and research institutions have conducted survey and on the basis of their observations and reports, the weight of combustible materials in respective occupancy is determined. In survey report[27], the weight of combustibles were those that include all furnitures and furnishings including other combustible contents within the structure. It also includes combustible finishes such as wood trim, windows, frames, shelves etc. To arrive at the total conflagration hazard involved in a building, the weight of the combustibles included in the structure must be added to the combustibles of the particular occupancy.

4.2.3 FIRE HAZARDS AND COMBUSTIBLES IN RESIDENTIAL OCCUPANCIES

Weight of the combustibles in the residential occupancies are termed as light. The survey report of the National Bureau of Standards, shows that the average weight of movable combustible furnishings or contents of residential buildings are about 3.4 pounds per square foot of floor area, other combustibles like, doors, windows, shelves, cubboards, floor finishes, mouldings etc., has average of 5.4 lbs/ft. of the floor area. The overall total average is worked out to be about 8.8 pounds per sq.foot of the floor area.

Following tabulation has been done on the basis of the survey data provided by Bureau[28].

TABLE No. 3[29]

RESIDENCE AND APARTMENT BUILDINGS	AVERAGE COMBUSTIBLE CONTENTS (psf)			
	Movable property	Floors	Exposed woodwork other than floor	Total
Bed room (including closets)	5.0	2.8	2.6	10.4
Dining rooms	3.2	2.0	2.0	7.2
Hall ways	1.0	3.0	6.5	10.5
Kitchens	1.2	2.5	3.1	6.8
Living rooms	3.9	2.4	1.8	8.1
Store rooms	6.4	0.5	0.3	7.2
Closets:- Clothes average area 8.75 ft.	5.1	2.7	11.6	19.4
Linen (average area 4.77 sq.ft.)	11.7	3.0	21.4	36.1
Kitchen (average area 5.0 sq.ft.)	4.0	3.0	23.2	30.2
Entire Apartment or Residence (Average for all areas surveyed)	3.4	2.6	2.8	8.8

On the basis of above observation, the Bureau report summarises, that in the apartments and residences, even with combustible floors and other woodwork the amount of combustible contents was found to be relatively light, with the average below 10 pounds per square foot of floor area.

4.2.4 FIRE HAZARDS AND COMBUSTIBLE IN SCHOOL OCCUPANCY

The severity of fire hazards as represented by the combustible contents of school building is reported to be light. The data indicate that the combustibles represented by the furnishings of school rooms will range from less than 3 pounds per sft of floor area for class rooms and lecture rooms, to about 6 to 7 pounds/sft. for the rooms used for special instruction purposes. The total weight of combustibles over the entire area of the school devoted to usual class room instruction may be expected to average less than 8 lbs/sft. of floor area.

TABLE NO. 4[30]

SCHOOL BUILDINGS	AVERAGE COMBUSTIBLE CONTENTS			
	Movable property	Floors	Exposed wooden work other than floor	Total
Typical class rooms	2.7	2.1	2.1	6.9
Laboratories :				
Biology	5.0	2.2	1.2	8.4
Foods & Clothing	4.4	1.8	2.2	8.4
Physics	3.3	2.6	1.4	7.3
Mechanical Drawing	6.0	2.6	2.0	10.6
Book Keeping and Typewriting	6.7	2.6	2.2	11.5
Art room	6.5	1.8	1.5	9.8
Geography, Music and Lecture rooms	2.4	3.7	2.3	8.4
Library (Stack room)	28.4	2.1	5.4	35.9
Lunch room	2.6	2.6	1.5	6.7
Woodworking shops	6.1	2.6	0.7	9.4
Store rooms - Janitors	35.9	0.9	1.5	38.3
Lumber	43.7	1.3	0.7	45.7
Paint	4.0	2.6	13.1	19.7
paper	97.5	0.0	0.7	98.2
Text books	172.3	0.7	0.6	173.6
APPROXIMATE AVERAGE FOR TOTAL USABLE AREA				7.6

4.2.5 FIRE HAZARDS AND COMBUSTIBLES IN INSTITUTIONAL OCCUPANCIES

The institutional occupancies include, occupancies such as hospitals, sanitoriums, nursing homes, home for aged, it also includes jails and other correctional institutions where the liberty and freedom of movement of the occupants are restricted. Survey report of hospitals reveals very low combustible content. The weight of the furnishings in the wards averaged from 3.0 to 4.3 pounds per sq.ft. of the floor area.

TABLE NO. 5[31]

HOSPITAL BUILDINGS	AVERAGE COMBUSTIBLE CONTENTS (Psf)		
	Movable property	Exposed wood work and floors	Total
Rooms (Single)	0.5	3.2	3.7
Corridors	0.0	2.6	2.6
Waiting rooms	1.7	1.5	3.2
Janitors closets & supplies	3.1	3.4	6.5
Doctors offices	5.7	2.9	8.6
Nurses offices & rooms	3.1	1.9	5.0
Nurses Infirmary	0.8	2.2	3.0
Diet, kitchen & dining rooms	1.2	2.4	3.6
Laundries	4.4	0.6	5.0
Laundries & cloth storage	12.5	0.6	13.1
Dormitories	0.8	2.0	2.8
Pharmacy, Dispensary and stores	5.8	1.9	7.7
Lockers, toilets & barber shops	0.2	1.2	1.4
Approximate Average for entire usable floor area			5.7

4.2.6 FIRE HAZARDS AND COMBUSTIBLES IN BUSINESS OCCUPANCIES-OFFICE BUILDINGS

As per the survey report of Bureau the Business Occupancies of the office building type have a uniformly low combustible contents except the floor area which is used for filling and storage purposes, but these areas are comparitively much less to overall area. As regards the steel containers, cabinets, metal lockers, the survey report suggest that for the combustibles stored in such containers etc., a corresponding corrected weight should be determined for expected fire severity, the survey report suggests that, to use the percentag of the weight of combustibles stored in steel containers in estimating the fire severity is fairly accurate.

TABLE No. 6[32]

PERCENTAGE OF CONTENTS OF FOUR KINDS OF STEEL CONTAINERS TO BE CONSIDERED AS CONTRIBUTING TO COMBUSTIBLE OF OCCUPANCY

	Proportion of total combustible contents enclosed in steel containers.		
	Less than one-half per cent	One-half to three fourths per c ent	More than three fourth per cent
Filling cabinets and desks	40	20	10
Backed and partitioned shelving	75	75	75
Shelving with doors and transfor cases	60	50	25
Safes and cabinets of 1 hour or more fire resistance rating	0	0	0

The average combustible contents table based on the Bureau report for the office buildings is as following :

TABLE No. 7[33]

OFFICE BUILDINGS	AVERAGE COMBUSTIBLE CONTENTS (psf)			
	Movable property	Floors	Exposed wood work other than floors	Total
Offices (only)	4.4	1.6	1.9	7.9
Office and Reception rooms	2.5	1.7	2.4	6.6
Office and light files	7.3	1.7	1.9	10.9
Heavy Files	41.5	1.0	0.4	42.9
Law offices and libraries	16.9	0.0	1.9	18.8
Libraries	25.1	1.6	0.8	27.5
Approximate average for total usable area				12.6

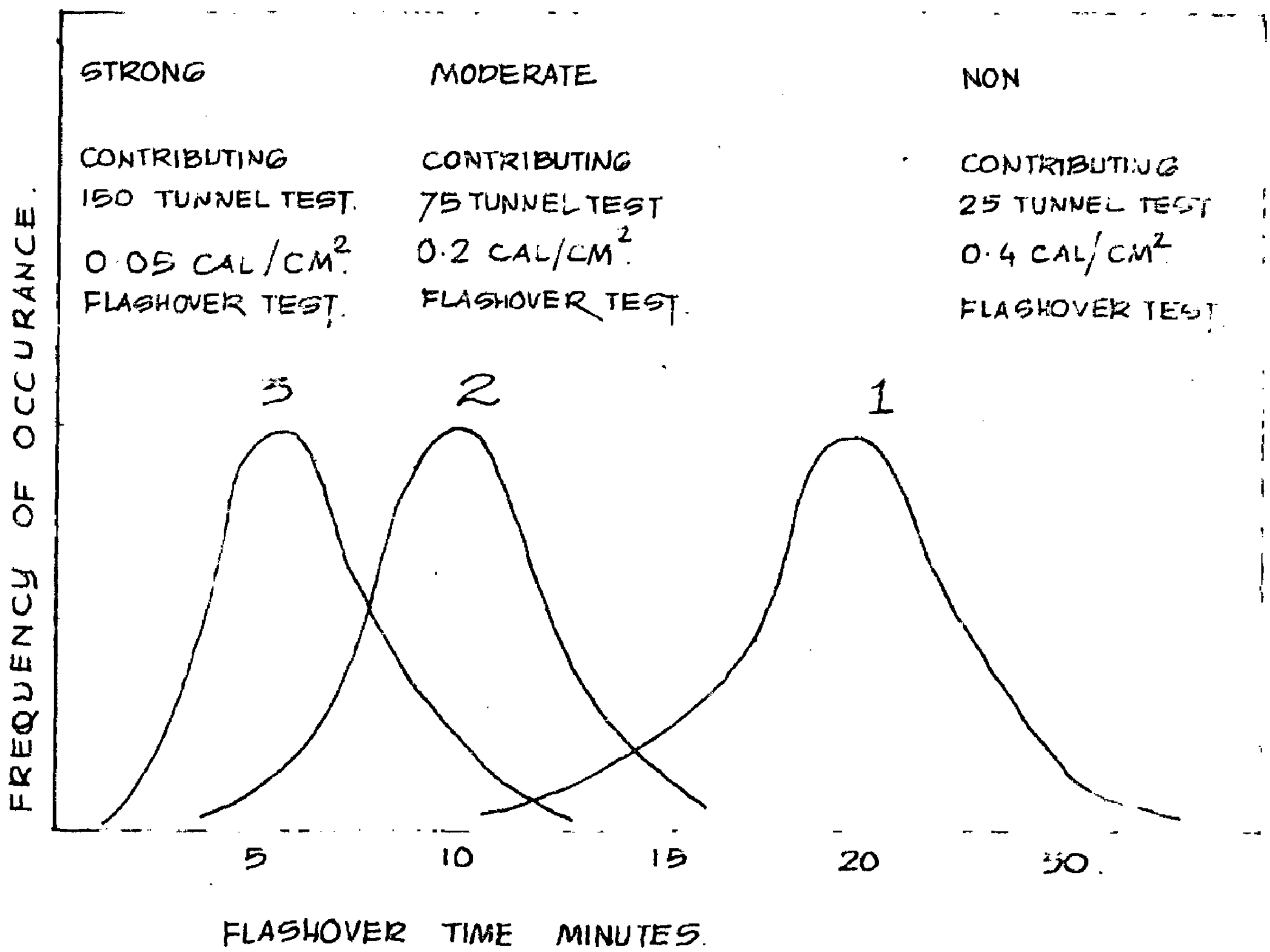
4.4.3 FREQUENCY OF FIRE IN COMBUSTIBLE CONTENTS

For prevention of fire it is very essential to know the nature and characteristics of various materials which may be strong contributing moderate contributing or non contributing to fire hazards. The time taken for a fire to grow to the flash over or fully developed stage largely depends on the nature of the material, and to some extent the circumstances under which the fire occurs. For a room with the contents whic are rated as non-contri-buting has more probability of the fire occurrence due to a longer growth period, than that for a room with a strongly contributing contents.

Mr. T.T. Lie in his book "Fire and building" has described that he has performed few laboratory Tunnel tests for finding the speed of flame spread and heat generation criteria for the contribution of the material to fire growth and a "Flash-over test', a criteria for the contribution of a material to fire growth.

"As per the tunnel test flame spread rating of non-contributing material is 25 and flash over test rating is 0.4 Cal/cm^2. Now the duration of the growth period and the frequency with which the fire occurs will be similar to that of curve 1 in (Chart 4). Therefore the room contents which are mostly of non-contributing nature will have growth time of fire around 20 minutes but so me of the contents will have shorter flash over time, say about 5 minutes. Thus the probability of growth of fire with shorter time of flash over remain very less as shown in the Chart - 4 (Curve 3)

Likewise if a room is having the contents in stron contributing nature with tunnel test and flashover test of



FREQUENCY OF FIRES WITH A CERTAIN FLASHOVER TIME. FOR ROOMS LINED WITH MATERIALS WHICH ARE STRONG CONTRIBUTING MODERATELY CONTRIBUTING AND NONCONTRIBUTING TO THE FIRE GROWTH.

CHART- 4.

150 and 0.05 Cal/cm^2 respectively, the majority of fire will have duration of about 5 minutes and the probability of the fire growth for longer duration will be very less (curve 3) of Chart 4 .

Moderately contributing material are rated accordin to tunnel test and flashover test as 75 and 0.20 Cal/cm^2 respectively. Curve 2 of Chart 4 illustrates the frequency distribution of its flashover time[34].

4.4 RELATIONSHIP OF SIZE TO BUILDING HEIGHTS

Until very recently the theory of cubical relationship to the multistorey structure was not much realised by the building industry. In many countries abroad, a maximum cubic capacity has been enforced and any construction above which needs special consent to build. The by-laws and subsequent building regulations have imposed limitation of height, floor area, and cubic capacity which is related to the use and occupancies. The combination of these limitations are determine after considering the fire resistance of structural elements of construction.

Broadly speaking the larger the area at risk, the greater can be the possibility of life risk, as well the potential losses. The task of the fire fighting to control the fire also becomes more difficult. Almost on the similar basis of cubical theory the latest principles with certain modifications have been introduced as the theory of 'volume' which operates satisfactorily in relation to multistorey structures in relation both to life hazards and property loss. One more important aspect of this theory must be considered, that is height. If a building is properly compartmented, adequately fire resisting and if its means of escapes both horizontally and vertically are in accordanc with established design practice, height is not a significan factor in relation to life hazard. On the other hand property loss may be increasing because of the greater difficulty of fighting fires at greater heights. Thus we may conclude that height may control the size and the greate the height the smaller should be the cube and floor area at risk.

In our country the N.B. Code, the byelaws of different municipalities, corporations and town planning author ities cover the area and height limitations by specifying it in terms of 'floor area ratio (F.A.R.) or Floor space index' (F.S.I.). This with open space requirements could fix the covered area and height of the building. Unless there is specific height restriction with F.A.R. But in all this regulations of F.A.R. the lacuna

is that F.A.R. is specified only in terms of the occupancy grou
There is no different F.A.R. for different type of construction within same occupancy group.

4.4.5 SITE PLANNING AND ACCESS TO FIRE BRIGADE

It has been observed that this important aspect of the fire protection has in the past, been sadly neglected. Thi could be very well seen from the narrow streets, lanes and congested courtyards of our major cities. It is further disappointing to note that even today site planning beyond th enforcement limits of law makes little effort to provide good environmental planning for safety from fire. However, satis-factory the fire resistance of a building structure may be or however safe the means of escape may be but still speedy and adequate access for fire fighting personnel and their appliance to a building should be an essential feature of good urban planning.

It is therefore suggested to redevelop areas, and t segregate, and isolate living area from shopping and office are away from the Jumble of motor cars which can create a problem o access in many ways, as bad if not worse than those with the fire fighters have to face in the older areas of the city. This problem is becoming more acute because our buildings are becoming higher with their greater build up areas.

The problem of access becomes more serious when in housing colonies foot path access are only provided to large areas. Even if the width of access may is sufficient to allow the approach of an appliance the chances are that the design is in gener-al inadequate to support its load.

Though directly not related to space planning and but an important factor is the numbering of the dwellings and addresses. Immediately after the fire call the fire brigade vans rushes to the address and complex address and numbering system can produce considerable delay. These problems of colony layout and numbering is not difficult if it is handled on early stage of design.

The size of the building can influence access require-ments. The type of appliance which is sent to a fire can vary according to the size and height of the building concerne since different types of appliances may require different access. An ideal building should be accessible on all sides.

4.6 PLANNING TO REDUCE EXPOSURE HAZARD

Separation distance of the buildings and the space between them is important not only to enable fire fighters to bring the necessary appliances to control fire but also to reduc the possibility of fire spread from one building to another adjoining one. Many of the extensive fires in the past have

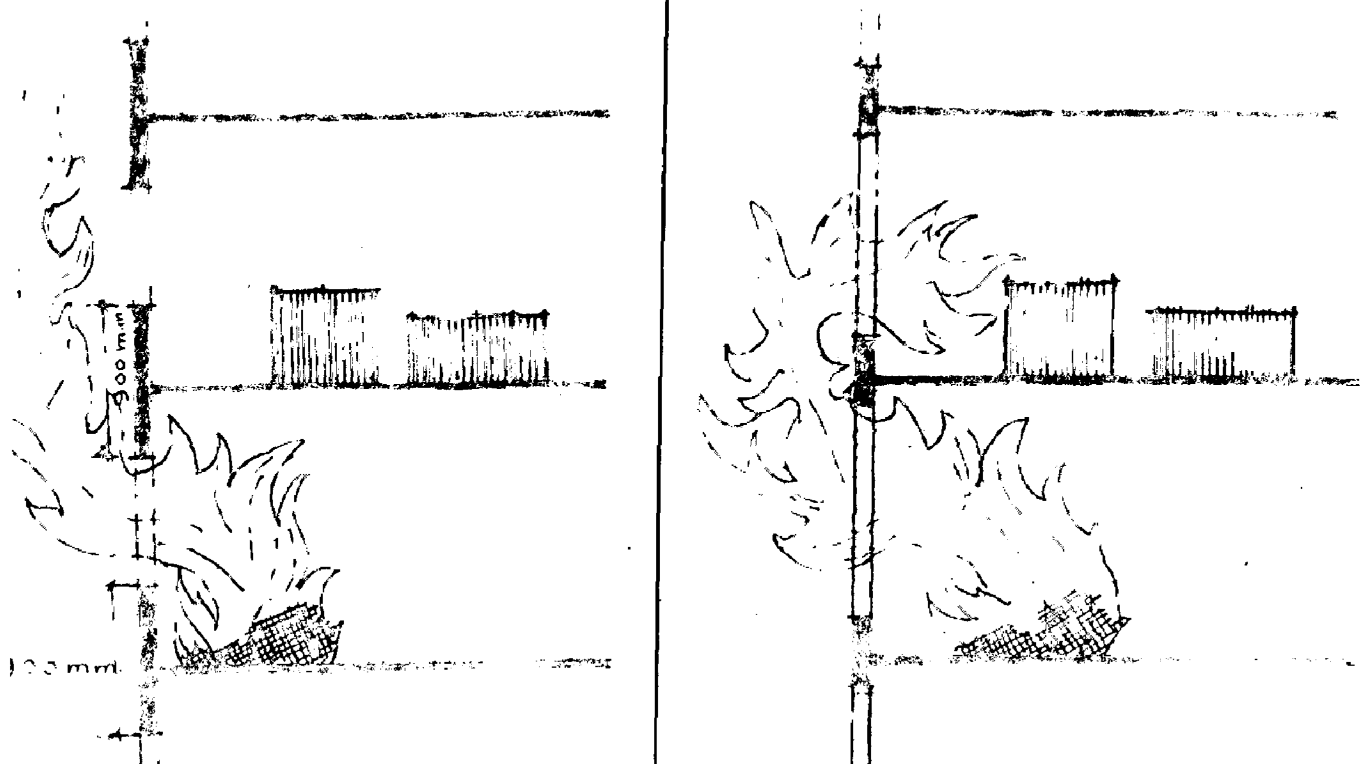
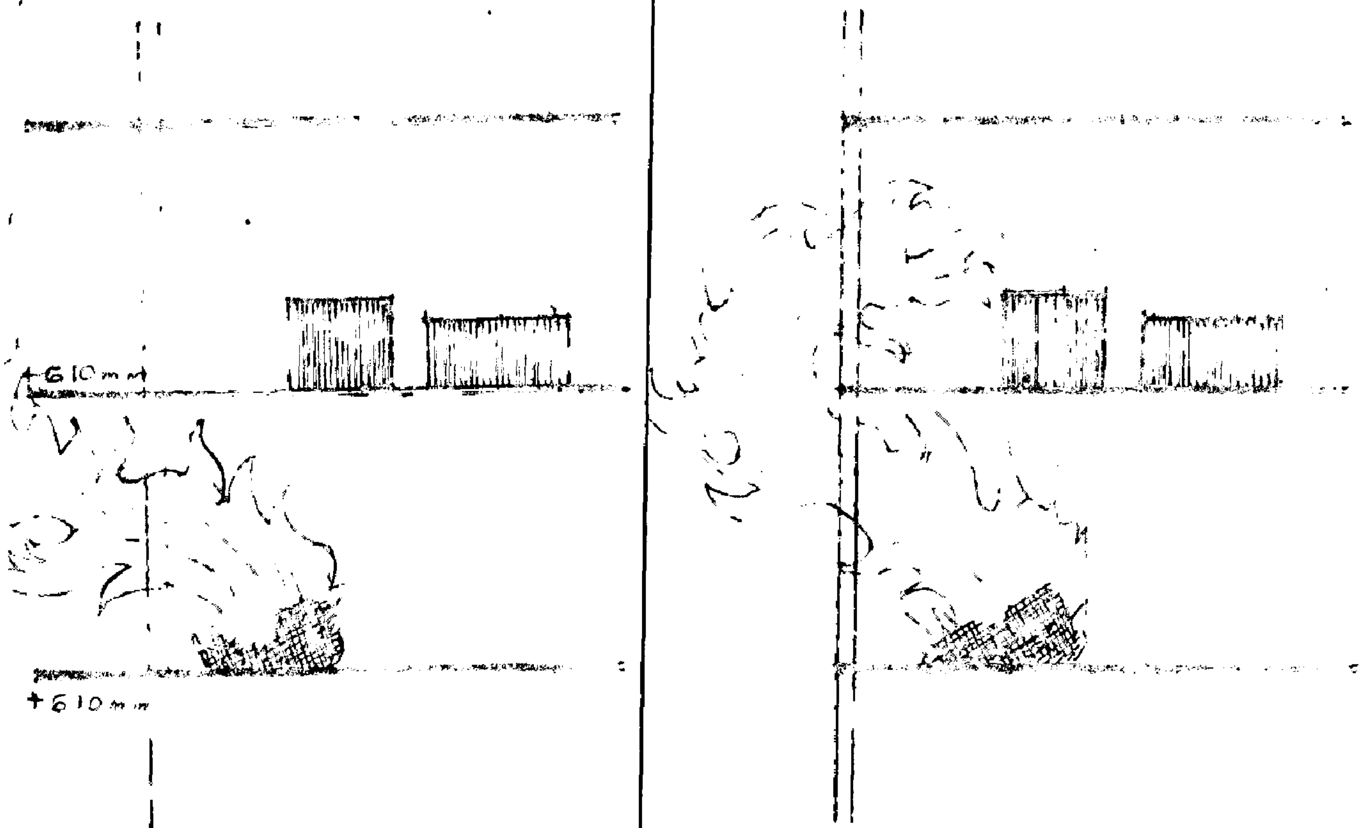


Fig 4-A

WITH 900 mm VERTICAL SEPERATION WITHOUT THE REQUIRED SEPERATION

4-A FIRE BEHAVIOUR AND EXTERNAL WALL VERTICAL SEPERATION



WALL WITH HORIZONTAL SEPERATION WALL WITHOUT THE REQUIRED SEPERATION

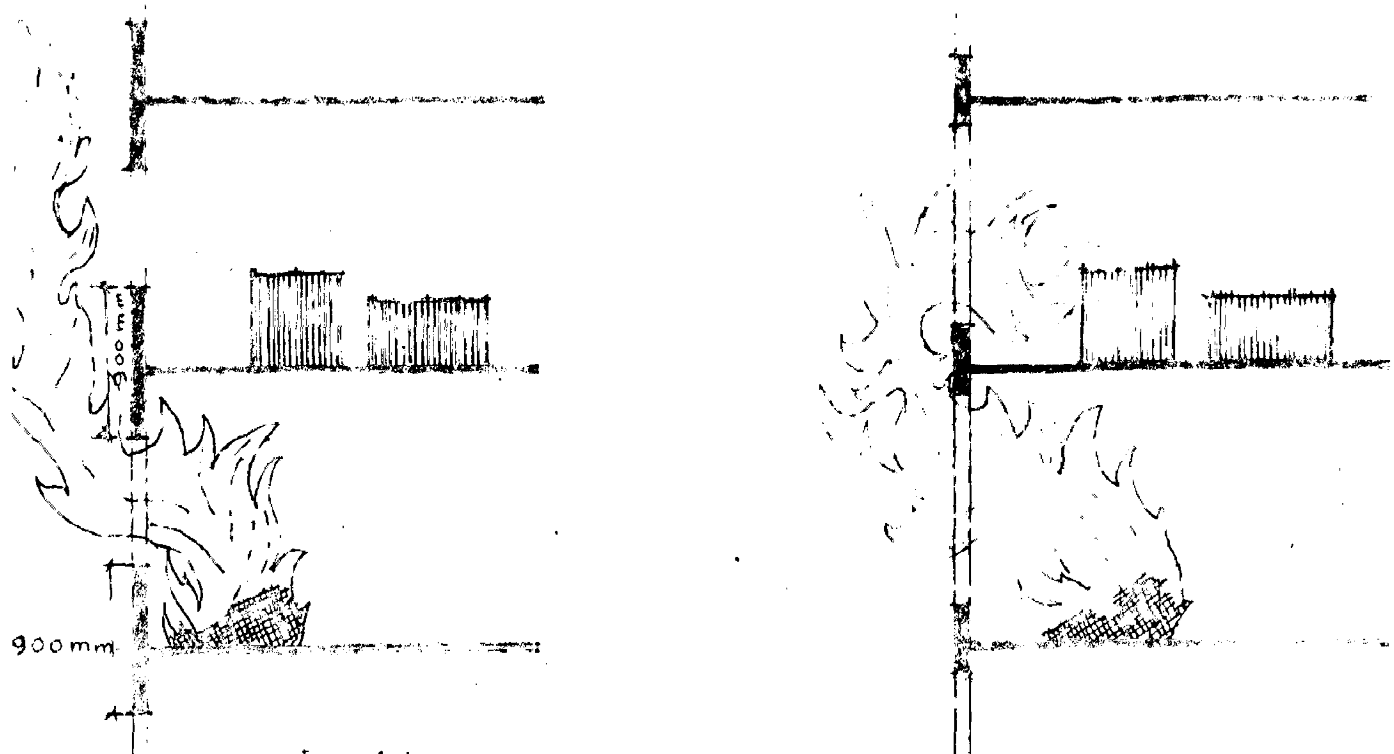
4-B FIRE BEHAVIOUR AND EXTERNAL WALL HORIZONTAL SEPERATION

FIG 4 - BEHAVIOUR OF EXTERNAL WALL

occurred due to the close proximity of the buildings. Due to heat radiation fire can spread too easily from one building to another one.

During the internal fire in the building there are two main functions which are to be considered for reducing the fire spread, (a) to prevent spread of fire from storey to storey and (b) to confine the fire within the building until it is burn out itself or brought under control. Behaviour of the fire spread is peculiar and quite different than what we assume In (Fig 4/A) the fire behaviour on the external wall, when vertical separations are provided is shown In (Fig 4/B) fire behaviour to horizontal separation is shown. It has generally been considered that for preventing spread of fire from storey to storey windows it is necessary to provide a vertical separation of at least 900 mm of fire resisting wall between th top of one window and sill of the window above or if a non-combustible fire-resisting projection not less than 610 mm wide is provided at floor level, fire can be prevented.

Another important factor which helps the faster fire spread is due to adequate ventilation. With free availability of oxygen there is no interference with burning. Fire spreads by heating of unburnt fuel which when ignited burns freely (Fi 5/A). In (Fig 5/B) there is restricted ventilation in which some of the fuel cannot burn freely and so heats up unburnt fuel less quickly and the spread of fire becomes slower

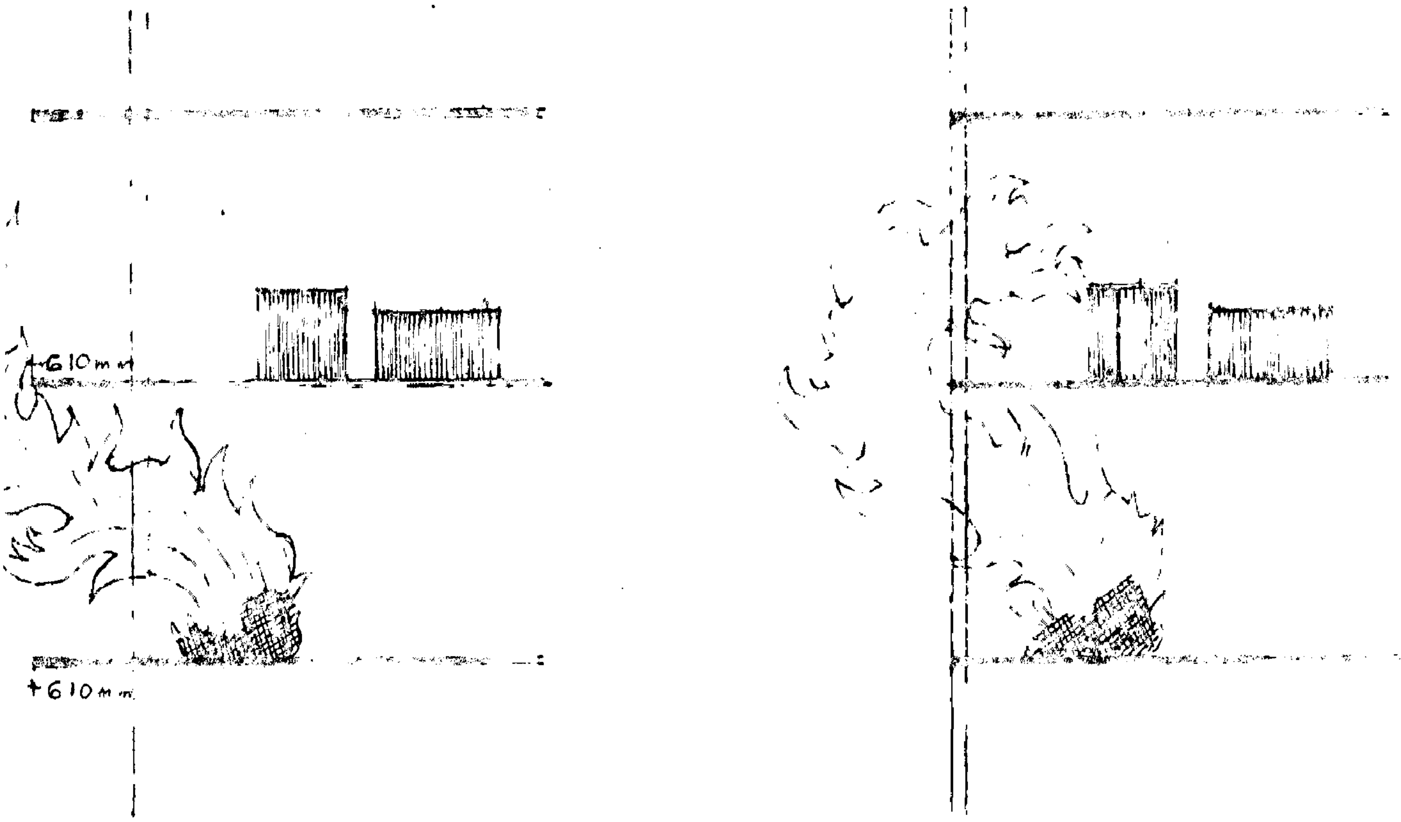


F. 4-A

WITH 900mm VERTICAL SEPERATION

WALL WITHOUT THE REQUIRED SEPERATION

4A-FIRE BEHAVIOUR AND THE EXTERNAL WALL VERTICAL SEPERATION



WALL [illegible] HORIZONTAL SEPERATION

WALL WITHOUT THE REQUIRED SEPERATION

4B-FIRE BEHAVIOUR AND EXTERNAL WALL HORIZONTAL SEPERATION

FIG-4-BEHAVIOUR OF FIRE WITH EXTERNAL WALL.

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Heating by radiation even at the substantial distance from the fire can be considerable, if higher be the intensity or heat flux on an object shorter will be the period of ignitio At the time of fire if it also have strong wind the effect of radiation on adjoining building will be more severe because of the added convective heat flow and heating be flying brands which are carried on the wind. With the practical view point, often the fire brigade will be in time to protect adjacent buildings and the loss expectation by fire exposure may be too small to justify additional protection methods within non-hazardous occupancies. But still in many cases when the adjoining building is of any specific importance, or very costl etc., it requires to be protected. There are several measures to reduce the spread of fire from one building to another building. This can be done by (a) spatial separation of buildi (b) By avoiding the use of combustible material as surface finish of external facade or (c) by installing drenchers.

4.6.1 DETERMINATION OF SAFE DISTANCES WITH THE AID OF APPROXIMATE FORMULAS

For working out the spatial distance between the two building to prevent ignition by radiation heat T.T. Lie in his book "Fire and Building" has given the mathematical and graphical solution which are as following.

"For exposed objects, whose surface is parallel to the plane of the facade of the radiating building, the safe distances can be easily be derived with the aid of the approximate formulae of Williams - Leir. This can be done as following

First calculate R and from

$$R = \frac{(h/b) + (b/h)}{2}$$

where, h = height of the radiating part of the facade of the radiating building.

b = breadth of the radiating part of the facade of the radiating building.

and φ_R = $R\phi$ crit

where, ϕcrit = the critical configuration factor

If is less than 0.75 use equation as following for determination of the safe distance.

$$d = \sqrt{\left(\frac{Rhb\ [1 - \quad (1 - \varphi_R)]}{2}\right)}$$

where d = the safe distance

If is greater than 0.75 but less than 3.6 use equation as following to calculate the safe distances

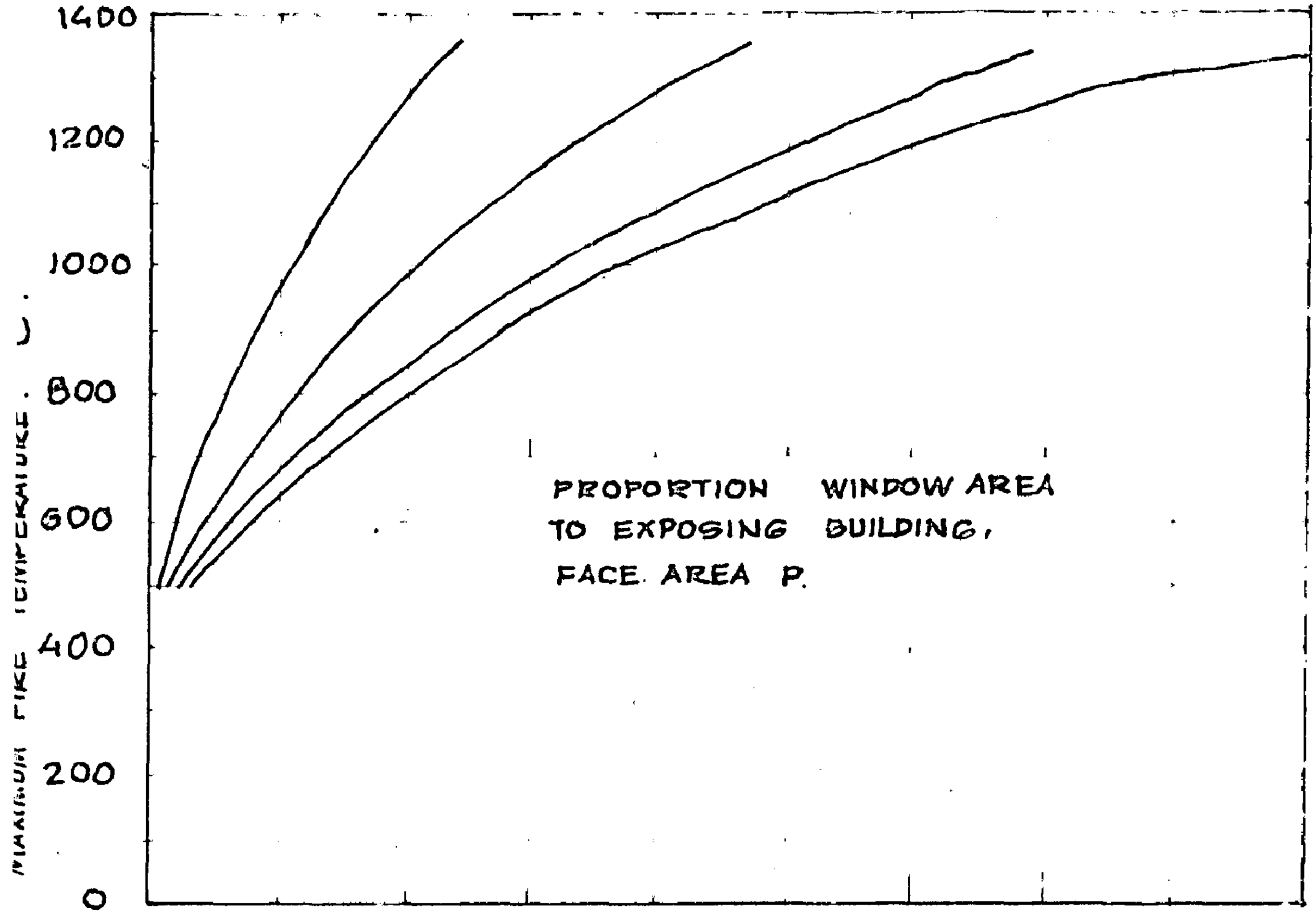
$$d = 0.34^4 \sqrt{\left(\frac{h^2 b^2}{\phi crit^3\ R}\right)}$$

Finally if   is greater than 3.6 use the following equation :

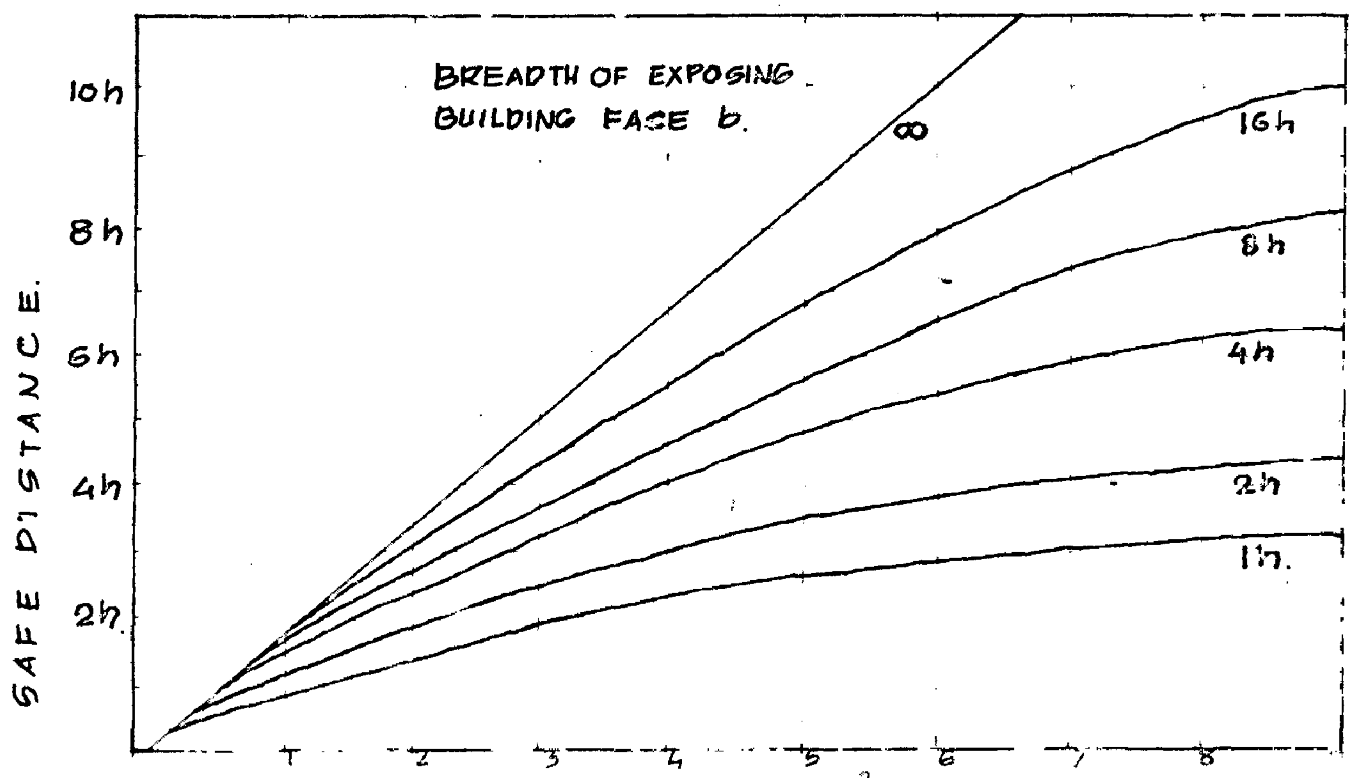
$$d = \frac{1}{\beta_{crit}} \sqrt{\left(\frac{hb}{8\pi} \right)}$$

Same results can be obtained by graphical method which T.T. Lie has suggested (Fig. chart 5). For exposed objects whose surface is parallel to the plane of the facade of the radiating building and of which the critical intensity is about 0.3. Safe distance can be determined from (CHART 5), and (Chart 6). In these graphs the safe distance are related to the maximum fire temperature for various window and facade dimensions. Starting from the maximum fire temperature the safe distances can be derived in the following way.

For the considered building the maximum temperature reached during a fire will be 1230° C. The proportion of window area to facade area p is 0.60. From Chart   , it follo that for the above values of the maximum fire temperature and p the average intensity of the radiation a t the facade of the building I, will be 4.2 Cal/cm^2. The safe distance can then be derived from the graphs in (FIG. 6) which relates the safe distances to the average radiation intensity at the facade I for various breadth b and height h of the facade of the radiating building"[38].



5. AVERAGE RADIATION INTENSITY AT THE EXPOSING BUILDING FACADE FACE FOR VARIOUS MAXIMUM FIRE TEMPERATURE AND VARIOUS PROPORTIONS WINDOW AREA TO EXPOSING BUILDING FACE AREA.



SAFE DISTANCE FOR VARIOUS AVERAGE RADIATION INTENSITIES AT THE EXPOSING

4.7 SMOKE HAZARD

More casualties in building fires are caused due to smoke than actual burning. In United Kingdom about half the death during fire is attributed to smoke and toxic gases. The smoke and toxic gases produced by combustible building material during fire, reduces the chances of escape and due to very poor visibility and suffocation create panicky in the occupants.

Amongst the modern building materials plastic is the most hazardous material as it releases dense smoke and noxious fumes when it is charged with fire.

"Although wood and other cellulosic matter at present form the major part of the combustible material in buildings, materials incorporating plastics are being used to an increasi extent, both in the structures and in furnishings. In additio cellulosic products are being used that have been treated with compounds to confer special properties, such as flame retardance etc. The experimental test result of the U.P.V.C. material which was used as wall lining suggest that when a fir start in a [illegible] compartment of a building the risk due the evolution of carbon monoxide is an immediate one, but the delay in evolution of hydrogen chloride from a compartment containing both cellulosic material and poly (vinyl chloride) is significant only if the ventilation is low. If the ventilation is higher than the risk due to hydrogen chloride evolved from plastic occurs soon after the emission of carbon monoxide"[39].

4.7.1 CONTROL OF SMOKE SPREAD

Though the control of smoke spread in the multistorey building is more serious, however, the efficient compartmentation is one of the possible remedy to restrict the smoke and confine it to its place of origin. The basic objective of smoke control is to enable the occupant of the building to use fully the escape facilities provided and to enable the fire brigade to entire the building and extinguish the fire.

The methods of limiting the smoke and hot gases spread in the building can broadly be divided in two parts.

(i) Natural ventilation by means of permanent openings, openable windows and roof lights etc.

(ii) By mechanical ventilation

Mechanical ventilation is very much essential where the building is not adequately ventilated. In multistorey structures, when the service core is centrally located it, may become more like a smoke channel during fire if it is not ventilated mechanically. The severity of smoke would depend upon the volume of mixture and its composition and combustibility. It is preferable that the action of mechanical ventilation should be automatic and should open during the earlier stage of smoke spread and allow smoke gases to be rapidly discharged to atmosphere. The rise in pressure with in the structure is thereby controlled and may be kept to a low value.

4.8 SURFACE FINISHING

The use of flamable surface finishing over the walls or ceilings affects the safety of the occupants of the building. Such finishes encourage fire spread, even though the structural elements may be adequately fire resistant. This may create a serious danger to life and property. It is therefore essential to consider the fire resistive rating of all such finishing materials before specifying them for the use. For further simplification, this surface finishes are classified on the basis of there flame spread qualities. They are explained as following :

"In fact on the basis of some informations available, some of the finishes have been classified into the following four categories.

CLASS I :- Surface of very low flame spread. These are those surfaces on which not more than 19 cm of effective spread of flame occurs.

CLASS II : Surface of low flame spread. These surfaces on which the effective spread of flame neither exceeds 30 cm during the first 1½ minutes nor exceeds a final value of of 60 cm.

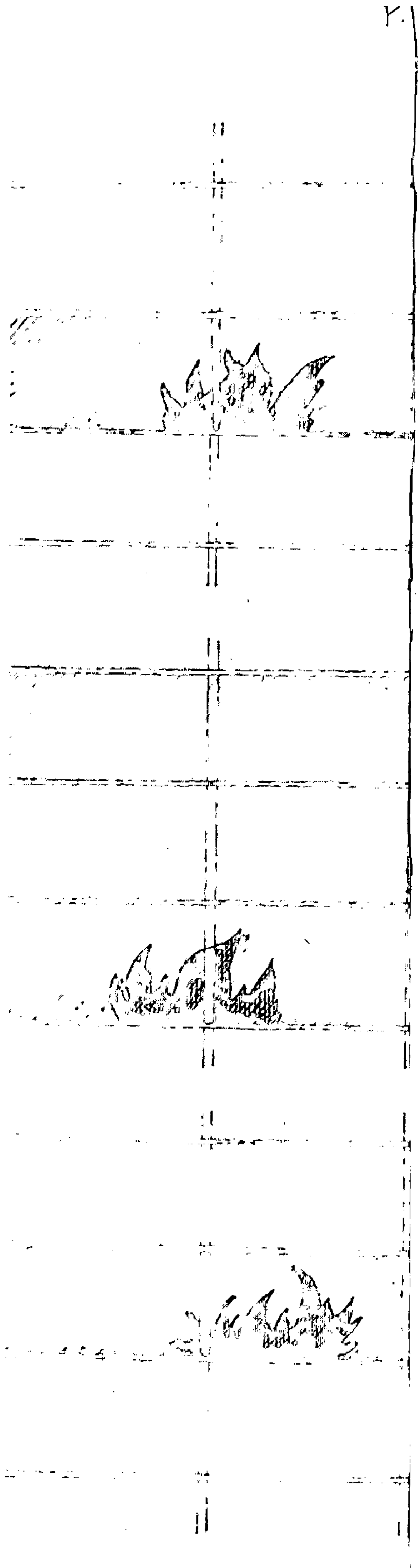
CLASS III: Surface of medium flame spread. These surface on which the effective spread of flame neither exceeds 30 cm during first 1½ minute no exceeds 85 cm during the first 10 minutes.

CLASS IV Surface of rapid flame spread. These surfaces on which the effective spread of flame exceeds 30 cm during the 1½ minutes or exceeds 85 cm during the first 10 minutes"[40]

These classifications should be considered for the purpose of establishing the fire spread rating for different finishes inside the building so that the possibility of for spread may be low,

4.9 COMPARTMENTATION

For limiting the fire or confinement of fire the building should be co npartmented in such a way that in case of fire occurrence, fire could be confined to its compartment until it is extinguished or it bruns out. Theoretically it seems logical to adopt compartmentation easily (Fig. 5) but in practice designer faces many problems. A building which is fully subdivi both horizont lly and vertically would be completely unworkable



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4.9.2 AIR CONDITIONING DUCTS

In whatever material the air-conditioning duct are constructed, they will normally have negligible fire resistance therefore at the occurrence of fire they will quickly distorted and collapse leaving a 'hole' in any wall through they pass. The fire may then developed in the duct and here again they wil collapse. Therefore at any penetration of fire resisting wall provision to seal to the hole should be made independently of the duct trunking or air conditioning dampers. Fire damper control fed by fusible link, which will be of steel close fitting to its frame but with sufficient space to prevent distortion.

4.9.3 STAIR CASE, LIFTS AND DUCTS

Enclosing walls of staircase, lift and duct walls, whic passed from one floor to another needs special consideration fc fire resistance or fire ratings. It is also necessary to takc all due precautions to protect top and bottom of the shaft and any access way should also be protected with same amount of fi resistance. It is preferable for stair case enclosures to be ventilated at the top since this will reduce considerably the tendency for an out break of fire in the saft. The fire resis- tance standards for enclosing the lift well and service ducts should be the same as that of the staircase shaft. Doors to stc cases and doors and shutters to lift are potential source of wc ness in the compartments. All such doors and access may must al have 1/2 hr fire ratings except in particular occupancies wher it may be minimum of 1 hour or more.

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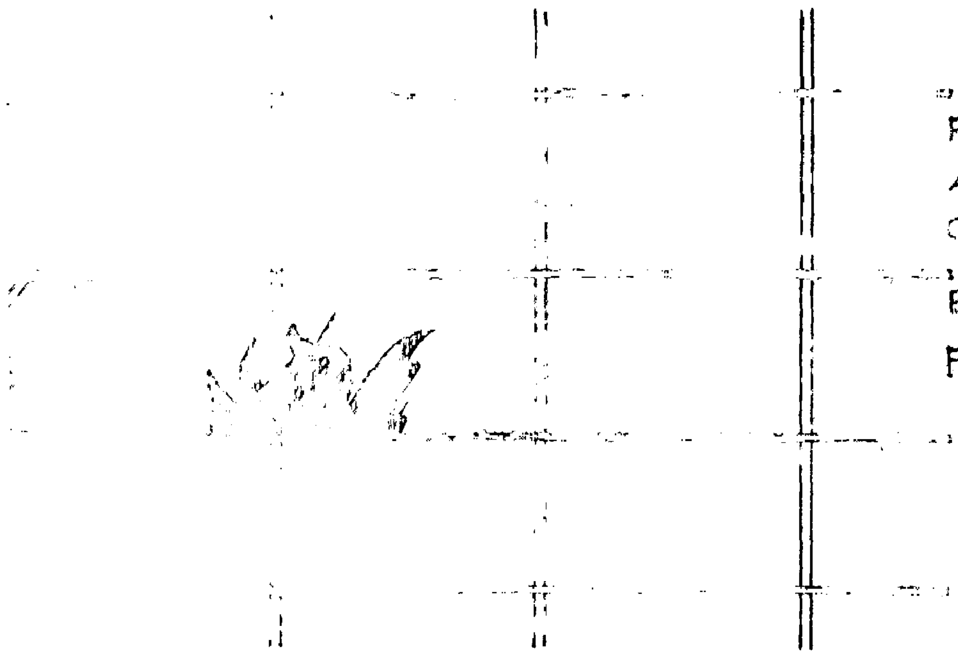

FIG. A - HORIZONTAL COMPARTMENTATION SPREAD OF FIRE CONTAINED BETWEEN FIRE RES[illegible] FLOOR.

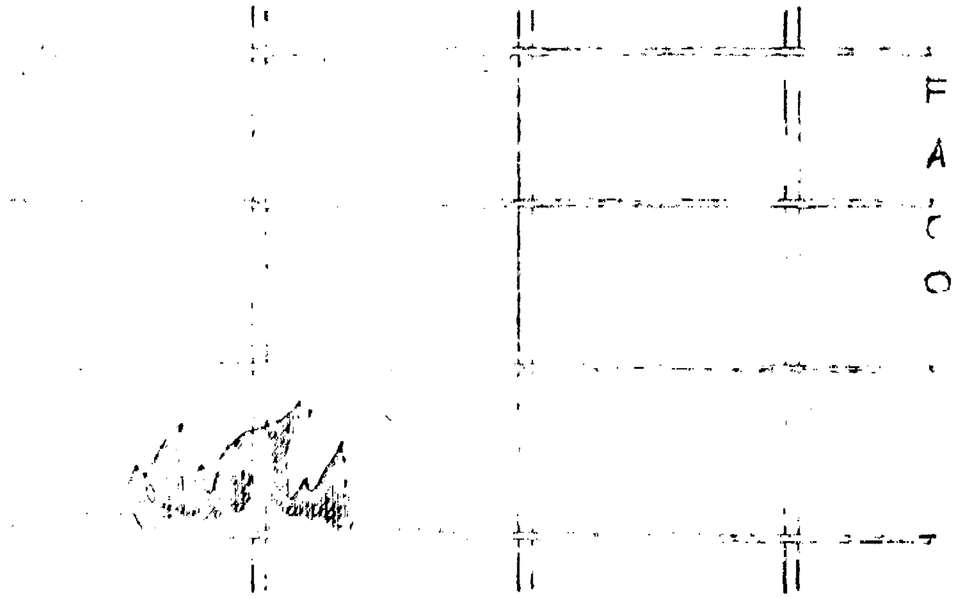

FIG. B - VERTICAL COMPARTMENTATION SPREAD OF FIRE VERTICALLY [illegible] OPENINGS IN FLOOR.

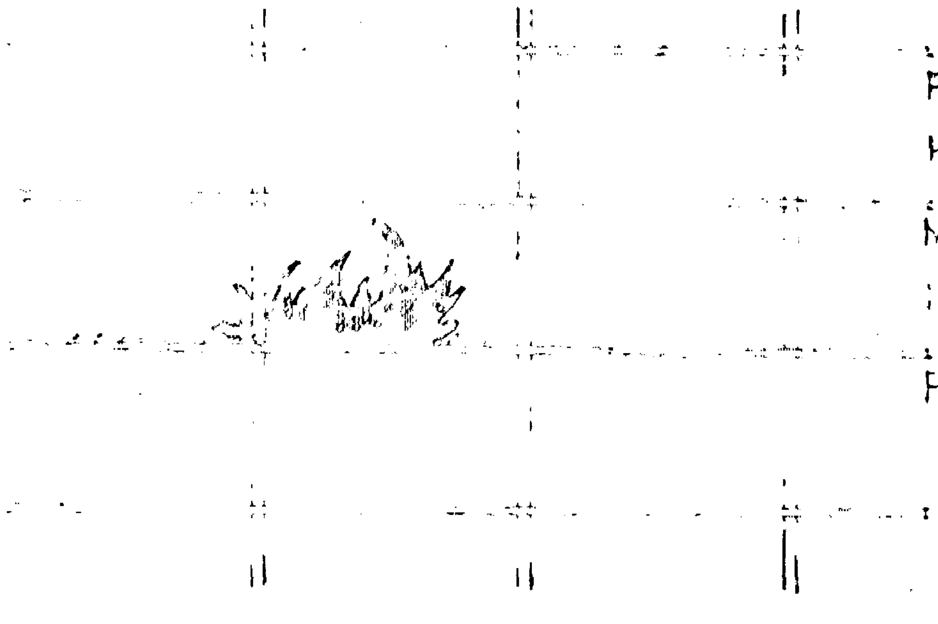

FIG. C VERTICAL AND HORIZONTAL COMPARTMENTATION, ALL OPEN[illegible] IN [illegible] FLOOR AND [illegible] FIRE PROTECTED.

FIG. 5 [illegible] OF COMP[illegible]

without a whole series of interconnecting links in the form of doors, corridors, staircases, lifts escalators and a multiplicity of ducted services. All of this without exception represent a potential source of weakness in the overall fire integrity of the structure. The designer is faced with many problems to be solved to keep the efficiency and integrity of the compartments.

Compartmentation can be studied under three major heads as follows :

(1) The integrity of the compartment wall
(2) The integrity of the compartment floor
(3) The structural integrity.

4.9.1 DOORS

All doors of the compartment walls should provide full fire resistance to the walls in which they are placed. Normall the fire resistance rating for the timber door is never to be taken more than 1 hour. This rating can exceed only when doors are constructed as composite doors. Such doors may be heavy and unsatisfactory for normal every day use. Where fire resista is required for more than 1 hour, there use of composite type o fire doors to ensure the continuity of fire resistance at the openings. It would be desirable to limit the amount and extent of the openings in the compartment walls. A thumb rule which is commonly in practice is to provide the aggregate width of openings should not exceed half the length of the wall.

4.9.2 AIR CONDITIONING DUCTS

In whatever material the air-conditioning duct are constructed, they will normally have negligible fire resistance therefore at the occurrence of fire they will quickly distorted and collapse leaving a 'hole' in any wall through they pass. The fire may then developed in the duct and here again they wil collapse. Therefore at any penetration of fire resisting wall provision to seal to the hole should be made independently of the duct trunking or air conditioning dampers. Fire damper control fed by fusible link, which will be of steel close fitting to its frame but with sufficient space to prevent distortion.

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CHAPTER - V

FIRE HAZARD AND CURATIVE MEASURES

5.1 IMPORTANCE OF QUICK DETECTION OF FIRE

Major losses of property and life during the fire is due to lack of quick detection of fire. Fire can be fought by first aid, or internal fire fighting squad and could be well brought under control, if the fire is detected as soon as it ignites. But in most of the cases of large fire severity it has been found that fire occurred either in a place which was unoccupied at particular period or late at night time when it normally is not possible to immediately notice the outbreak until it becomes alarming. Some of the general observation of such fires are given below which indicate the difficulties of quick detection of fire.

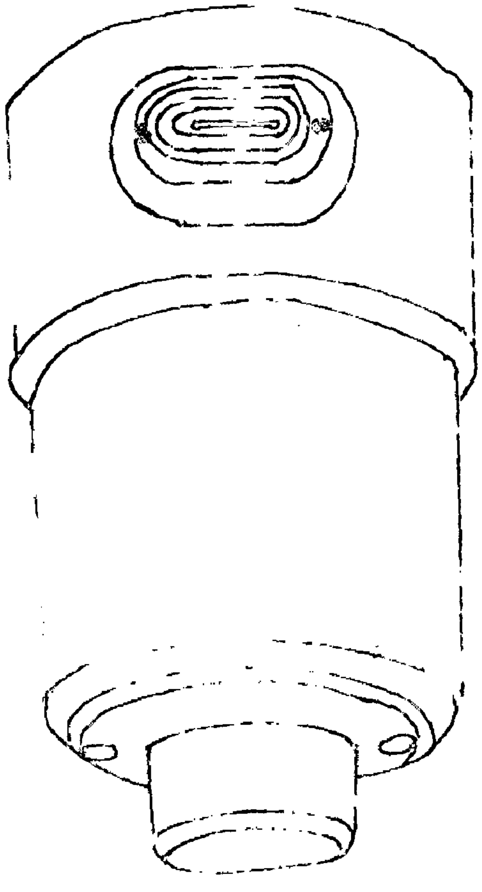
(i) Possibility of fire discovery in the early morning

(ii) at the end of the working day

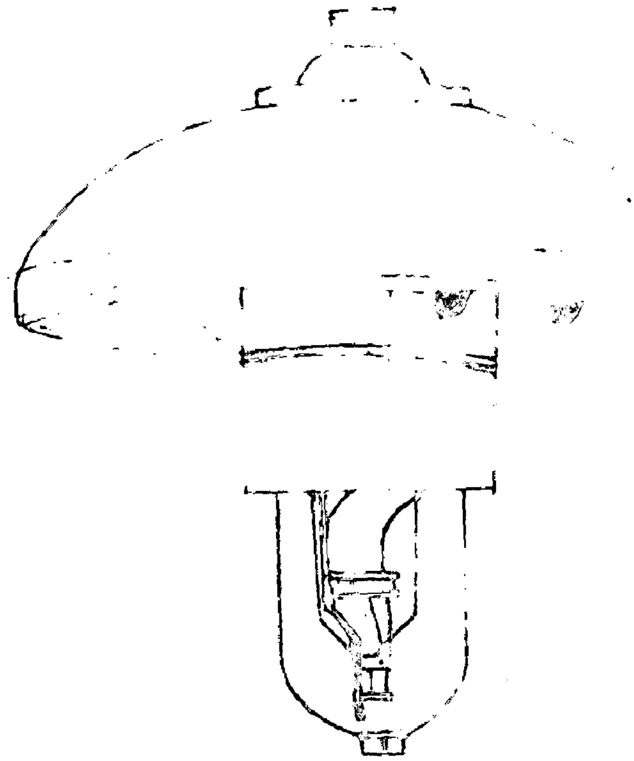
(iii) a tendency for delay in calling the fire brigade

(iv) a tendency for fires to occur in the part of the building which are unoccupied at night or are infrequently visited.

It may be then such fires could be kept out of large fire category by installing a suitable automatic detection system. However, fire detection of large fire report shows that sometimes early fire fighting effort did not reduce the



HEAT DETECTOR (SPOT TYPE)



INFRA- [illegible]

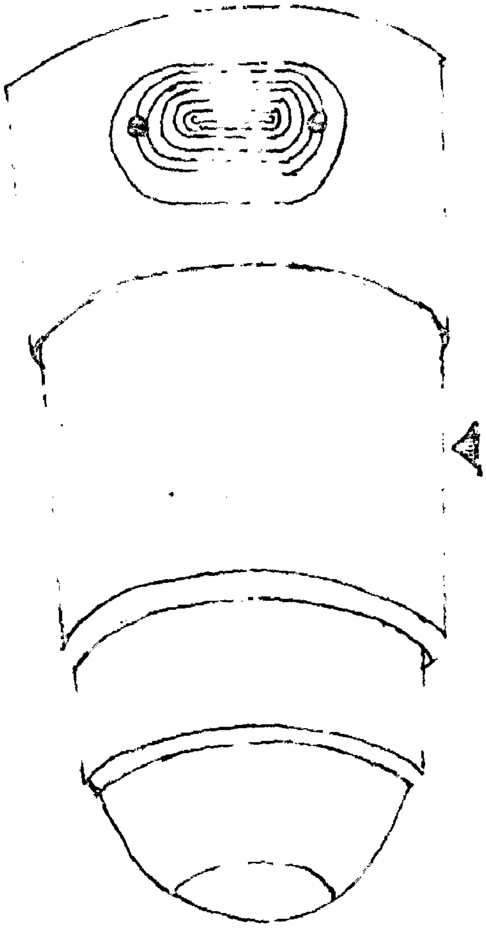
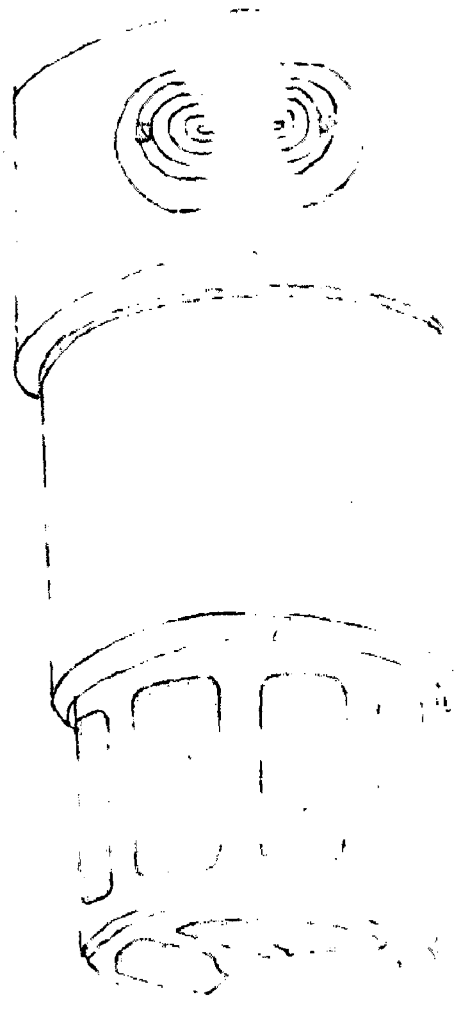


FIG. . INFRARED FLAME DETECTOR

FIG. . PHOTO ELECTRIC SMOKE DETECTOR.



less substantially because of the nature of the risk involved was such that automatic detection alone was not enough. In such cases automatic detection and autmatic fire fighting measures like sprinklers etc., are necessary.

5.2 FIRE DETECTORS

For detecting the fire at its very inception the fire detectors are essentially used. There are two types of fire detectors largely used in multistorey structures. One is the smoke sensitive detector and other one is the heat sensitive detector. Infra-SCAN Detector and Infra red flame detectors are generally used in hazardous occupancies (See Fig. 6).

5.2.1 SMOKE DETECTORS IN AIR SYSTEM

Smoke detector is perhaps the greatest advancement in rapid detection of fire. By experience it has been observe that for discovering the fire ignition peo ple may lag by half an hour whereas in the smoke detector even a small particle of smoke can be detected in less than a minute.

These fire detectors are fixed to the ceiling when put to operation, they automatically open ventilators on the roof and start the exhaust fans to throw out all super heated air and smoke which might otherwise spread into the hall. When air conditioning ducts are introduced for recirculation of air for ventilation, smoke detectors in the ducts promptly shut do blower that might spread smoke and fire through the ducts.

Secondary protection in duct is provided by fire dampers actuated by fusible links.

When any detector goes in action a bell rings and its location is shown on a panel. Advanced thinking now favours a design by which any smoke detector will ring the general alarm

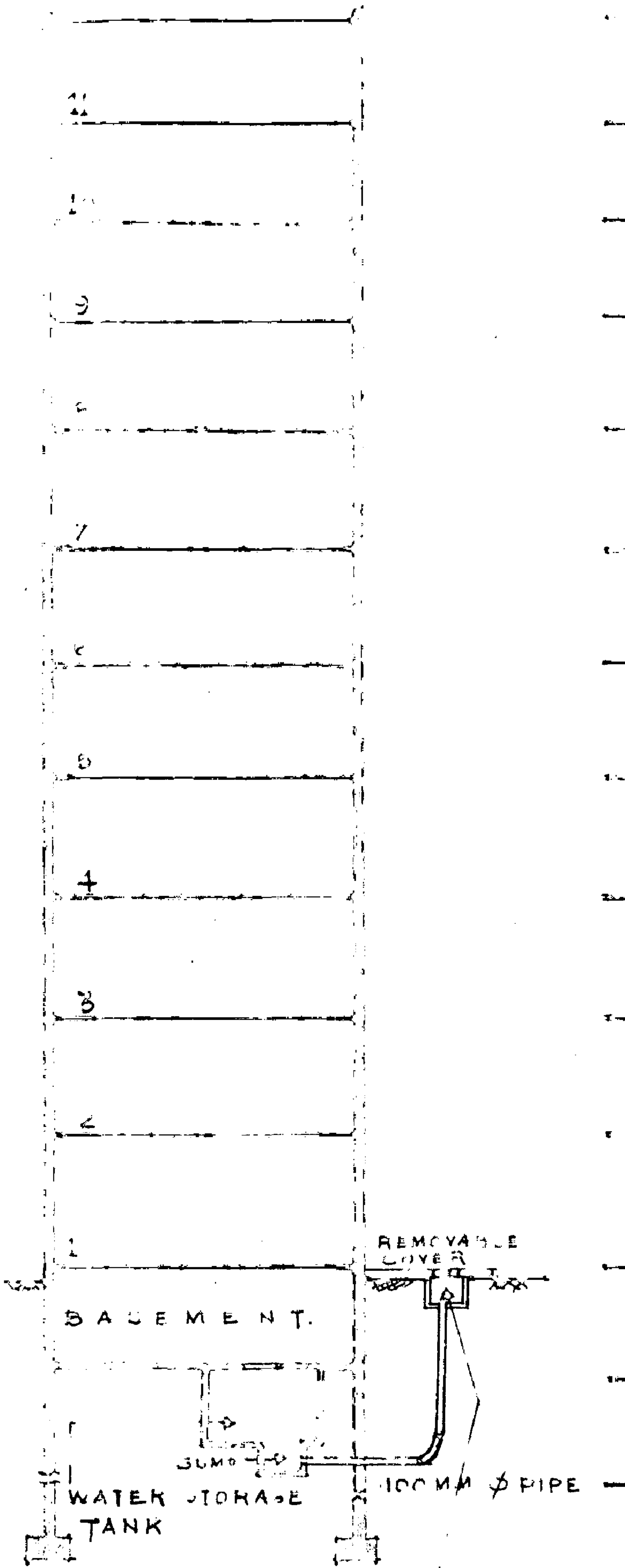
5.2.2 HEAT DETECTORS

This type of fire detector has basically similar function of fire detection as that of smoke detector. Heat detectors are heat sensitive. The "thermal heads" of the detector are fixed at the ceiling level. These detectors are very effective and responses quickly. In most current installations they ring the local alarm, as do the smoke detectors and identify on a panel their location in the building.

5.3 WATER SUPPLY FOR FIRE FIGHTING

"Water is almost as essential to fire-fighting as oxygen is to life and fire. Notwithstanding the development of other extinguishing agents water remains by far the cheapest, most efficient and most popular means of fighting fires in materials for which it is appropriate. There can in fact, be hardly any fire protection without water".

Adequate water supply must be available, immediately round the clock, to fight fire in multistoreyed structures.



AN ARRANGEMENT FOR DRAWING THROUGH REMOVABLE COVER.

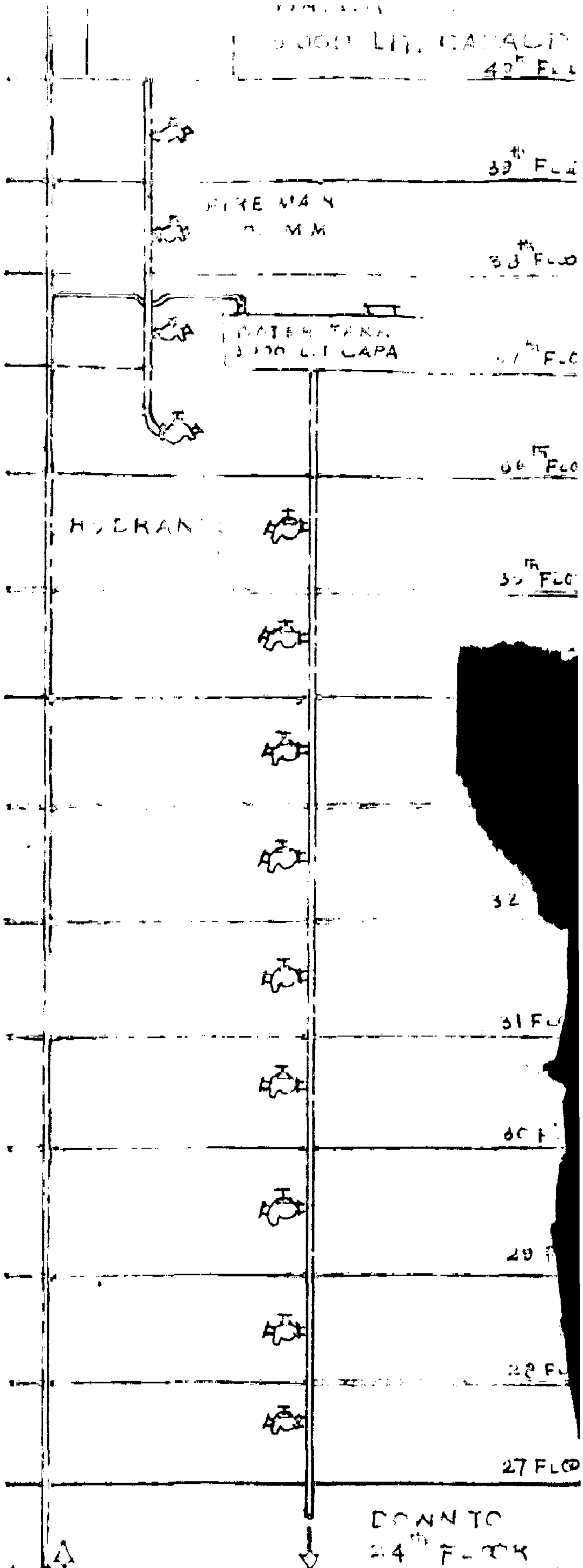


FIG 7/B AN ARRANGEMENT OF
HEAD TANK FOR WATER SUPPLY

The best way of ensuring this is to provide stored water exclusively for the purpose of fire fighting. Such stored water should not be used for any other purpose. In buildings upto 25 meter height, it is possible to provide storage facilities at ground level for effective use by the fire services. Such facilities are normally located in the basement of the building, these facilities must be so located that it should have suitable arrangements for thefire engines to draw water quickly. A typical arrangement is shown in Fig. 7/A.

In the taller building, water stored at ground level cannot be effectively utilised through normal fire appliances. The storage tank must therefore be located at higher floors, and fire hydrants installed at every floor on main running down from the storage tanks (Fig. 7/B).

The total storage capacity of tanks depends upon the nature of occupancy and total floor area of the building. For an average residential business, or mercantile multistoreyed occupancy it may be worked out at 30 litres per s.m. of the floor area subjected to a minimum of 2,25,000 liters[42].

In addition to the requirement of water supply mentioned in the above paragraph additional water supply should be provided separately for the automatic sprinkler installation. The quantum of such additional water supply depends upon the side of the building and a firm specialising in sprinkler installations should be consulted before hand.

5.4 GENERATOR

As a stand by generator should be installed in each multistoreyed building to supply power to staircase, lifts and corridor, lighting circuits, standby fire pumps, pressurisation blower motor and damper system in case of failure of electric supply. The generator should preferably be automatic and should be of adequate capacity to take the load of all machines and circuites when started simultaneously. It should be located in a separate fire resisting enclosure in a separate fire resisting enclosure in a basement or in a detached building.

5.5 FIRE ALARM AND COMMUNICATION

Leaving automatic fire extinguishing system aside for the moment and considering only public or private fire departments, the expeditiousness with which extinguishment or control of fire is achieved is influenced by the operational efficiency and adequacy of the departmental personnel and their equipment. The promptness of detection of fire and of communication of the fire alarm to the department, by the response time speed of detection and of communication of alarm essentially dependent upon the sophistication and efficiency of equipment used.

It is believed that number of fires can be reduced to half only if the communication systems are improved. Most of th protective and curative precautions and most sophisticated fire fighting appliances are of not much avail, if the fire is not detected and communicated promptly to the nearest fire station.

For good communication the entire building including th basement should be equipped with automatic fire alarm system. The system should

(i) give an automatic audible alarm on all floors on the occurrence of fire. In non-residential buildings the arrangements should also be made for automatic transmission of fire alarm to nearest fire station control room, unless there is a person on duty who could get in touch with the fire station round the clock.

(ii) Provide a main indicating panel in the control room where the fire fighting staff would be available.

To enable the fire fighting service to give escape instruction to the occupants in an emergency, a public address system should be installed in the building with loud speakers on all floors and microphone on the main indicating panel on the ground floor.

5.6 FIRE EXTINGUISHERS

Having considered automatic detection devices it is logical to move on to automatic extinction, but before that it is worthwhile to understand the nature of fire risk and related problems.

Choice of the extinguishing system will depend upon in first place on the nature of risk for which following points are necessary to study :

(i) The way in which the fire most likely to develop

(ii) Whether the risk is isolated

(iii) Where combustible material and goods are in close approximity.

Looking into the type of risk involved suitable extinguaching agent may be selected, in absence of such agent, a water supply be adequate for particularly the domestic needs of a building but may be quite inadequate for extensive fire control and other agents such as inert gas, or high expansion foam may have to be considered. Some fire fighting agents are toxic or become so when used on a fire.

Water although the cheapest available nontoxic agent, has certain disadvantages which must be considered, It is very expensive when delicate electrical and scientific instruments are involved or where unique material and works of art are displayed or stored. Where large volume of water may be used it is necessary to provide adequate facility to drain out from all levels within the building and near at. It must be also borne in mind that many of the extinguishing agents considered in relation to both automatic system and first-aid appliances can present problem of corrosion and may damage plant and machinery with which they may come into contact. Selection of right type of extinguishing agent can not only make certain and rapid extinction but also ensure that the resultant total damag to building and contents is kept to the minimum.

5.7 FOAM SYSTEMS

The main purpose of foam extinguishing agent is to prevent the access of air to the surface which is under fire, to seal flammable liquids from flames, and to cut off the suppl of vapour. Unlike other extinguishing agents foam has the advantage that it can remain in position long enough to allow the burning liquid cool and thus prevent reignition.

Foams broadly fall in two categories :

(i) Low expansion protein foams and

(ii) Medium and high expansion synthetic foams

(i) LOW EXPANSION FOAM

These foams are derived from waste protein material and are stabilished by the addition of suitable metal salts. This type of foam is largely used for extinguishing fires of deep tanks solvent tanks or similar flammable liquid risks. For such risk automatic application system may be used. This consists of foam producing device and a pump to drive the foam solution through the nozzle. The foam may also be applied from the open spray heads fitted with aerating gauges.

(ii) MEDIUM AND HIGH EXPANSION FOAM

This air foams are made from 1-2 per cent aqueous solut of synthetic foaming agent. Medium expansion foams are in the range of expansion 80-500 and high expansion foam 500-1200[43].

It is extremely difficult to get rid of the high expans foams, especially in the basements after the fire is controlled or extinguished. This foam contains a very low percentage of water, therefore, damage to material is minimum and the use of water for removing the foam will not be advisable as it will spoil its advantages. Method of sucking the foam from a buildi by fans can also present considerable problems. That is why an antifoaming agent is deviced[44] which may be sprayed on to the foaming surface - and the foam starts collapsing. The advantages to these agents are the access to the building is cleared from the outside and that on moving inside the space between machinery and stacks of goods can be quickly cleared an additional water damage can be minimised.

5.8 FIRST AID FIRE EXTINGUISHERS

First aid fire fighting equipments are of vital importance to the occupants of the building as they have to deal wit them in case of fire out break. Therefore it is very necessary for them to know as what particular type of extinguisher may be used for specific type of fire. To simplify this, fire authorities have issued fire regulations and recommendations which divides the fire into the following classifications[45].

Class 'A' Fire : Fires which occurs in ordinary combustible materials such as wood, cloth, paper where cooling by water is the most effective way of reducing the temperature of burning materials. Generally most of the fire fall in this category.

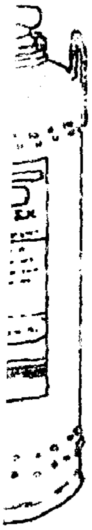
Class 'B' fire : In this type, fires in inflammable liquids petrol, oil greases and fats, where the blanketing or smothering effect of agents which exclude oxygen is mos effective.

Class 'C' Fires : Fires involving live electrical equipment where the non-conductivity of the extinguishing agent i of first importance.'

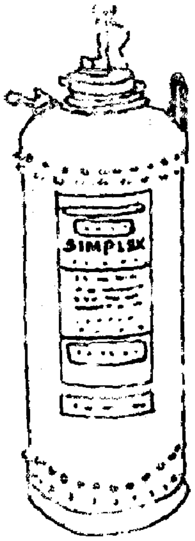
Taking into account the above three types of fire following are the different types of first aid fire extinguishe which are used to control the respective fire.

5.8.1 WATER TYPE EXTINGUISHER

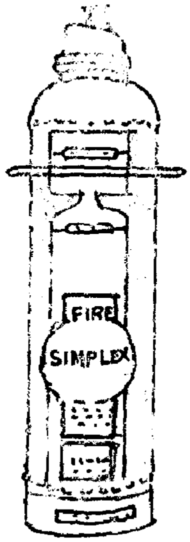
(a) Water is most economical and effective medium of fire control for the class A type of fires water type extinguishers



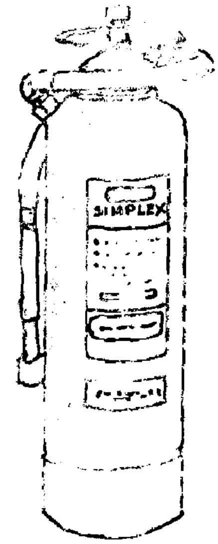
(GAS PRESSURE
NGUISHER
/A



WATER TYPE (SODA-ACID) FIRE EXTINGUISHER
FIG 8/A_2

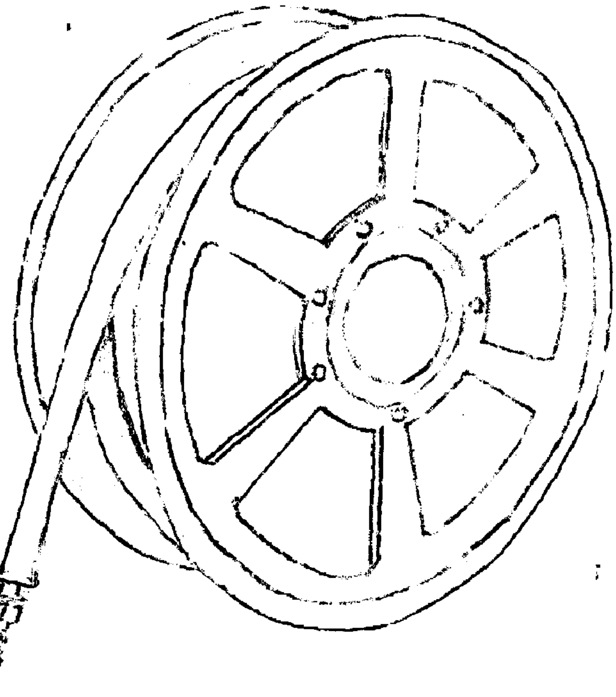


CHEMICAL FOAM FIRE EXTINGUISHER.
FIG 8/B

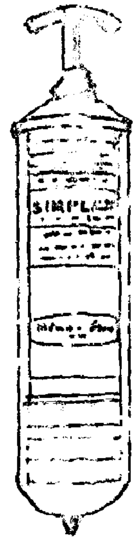


DRY POWDER [illegible] EXTINGUISHER.
FIG. 8/C

ORDON
xtinguisher



HOSE REEL
FIG 8/F



SIMPLEX CARB
CHLORIDE PUMP-TY
EXTINGUISHER
FIG 8/E

TYPES OF 'FIRST AID' FIRE EXTINGUISHERS.

are normally available in two sizes of 1½ and 2 gallons capacit Body of this type of extinguisher is made out of steel cylinder filled with chemical dissolved water to prevent corrosion. Ins the cylinder there is a smaller steel cylinder which is support ing the cap and filled with carbon dioxide under high pressure. This cylinder is sealed with a small metal disc. When this extinguisher is to be used, the knob of the extinguisher is struck and a plunger pierces the sealing disc and compressed carbondioxide gas escapes from the cylinder into the space of the extinguisher body above the water level. The pressure of the carbondioxide gas from below forces a powerful jet of water through its discharging tube (Fig. 8/A).

(b) The other water type extinguisher is known as soda-acid extinguisher, the construction of the body is very much same as that of (a) type of extinguisher. The jetting pressure in wate is created by chemical reaction between a sodium bicarbonate solution and sulphuric acid which is kept in a glass bottle which is broken when the extinguishers knob is struck for the operation (Fig. 8/A_2).

5.8.2 FOAM TYPE EXTINGUISHERS

Foam has a quality that it blankets the burning materi and restricts the oxygen supply needed for combusion. This ty of extinguishers are good for 'B' class fires which involves inflammable liquids petrol, oil,s greases and fats etc. It is normally available in one and two gallon sizes. The extinguish ing cylinder is filled with sodium bicarbonate solution and a foam producing compound. In the cylinder there is a plastic container with aluminium sulphate solution. When two solution are mixed a large amount of foam is generated and this is discharged by the high pressure due to liberation of carbon dioxide from the chemical reaction. Normally there are two types of foam extinguisher one is unsealed type in which the inner container has an open top. For its operation only the cylinder is being turned upside down. In the sealed type of extinguisher inner container has sealed top with a spring loaded valve to prevent accidental operation. For using this type of extinguisher care should be taken to remove the valve before inverting the extinguisher (Fig. 8/B).

5.8.3 DRY POWDER TYPE EXTINGUISHERS

In dry powder type extinguisher the cylinder is X filled with a finely divided nonconducting noncorrosive, non-toxic and water-repelled powder, which comes out in great speed because of the compressed gas which is released as the knob is struck for the operation. This type of extinguisher are recommended for 'B' and 'C' class of fire. There are two major advantages, first it smothers fire very quickly and secondly the cloud of powder acts as a screen which helps fireman to go nearer to fire. This type of extinguishers are available in 3 lb. 7 lb, 20 lb, 25 lb, 50 lb, and 150 lb sizes (Fig.8/c).

5.8.4 CARBONDIOXIDE TYPE EXTINGUISHER

In this type of extinguisher carbon dioxide (CO_2) gas is filled under pressure. When this gas is released under high pressure on the burning material the air around it will be replaced by CO_2 gas and as there will be no oxygen left flames will be smothered. The portable models of this type of extinguisher are having a trigger type operation. This type of extinguishers are generally used for 'B' and 'C' types of fire. The available sizes are in 2½ lb. 5 lb. 7 lb and 10 lb containers (Fig.8/).

5.8.5 CARBON TETRACHLORIDE EXTINGUISHER

This extinguisher is constructed out of either brass or copper. The cylinder is filled with carbon tetrachloride which vaporises on contact with heat, forming a thick cloud of gas which smotheres the small fires quickly. This type of extinguisher is good for class 'B' and class 'C' type of fires. While using this type of extinguisher care should be taken as carbon tetrachloride vapour is very highly toxic. The extinguisher should not be used in confined spaces or otherwise he should have immediate access to fresh air[46]. There are two types of this extinguisher, one constant pressure type operated by striking the knob and other one the pump type is operated by drawing out and pressing in the handle attached to body. These are available in two sizes 1 point and 1 quart. containers (Fig.8/E).

5.9 FIRE HYDRANTS

As the multistorey buildings go higher and higher the external fire fighting becomes more hazardous, therefore it is necessary to fix equipments which can fight the fire internally, one of such equipment which is manually operated is the "Hydrant". Hydrants are of two types one is "dry hydrant risers and other is "wet hydrant risers". The selection of appropriate type of hydrant in the building is to be decided by the local authority.

The "dry hydrant risers" are good enough if the modern fire brigade mobile pumping sets are capable of providing sufficient pressure for discharging the water at the top of the building. Where this arrangement is not possible there wet hydrants risers are to be used, with an automatic water supply permanently within the risers.

5.9.1 DRY HYDRANT RISERS

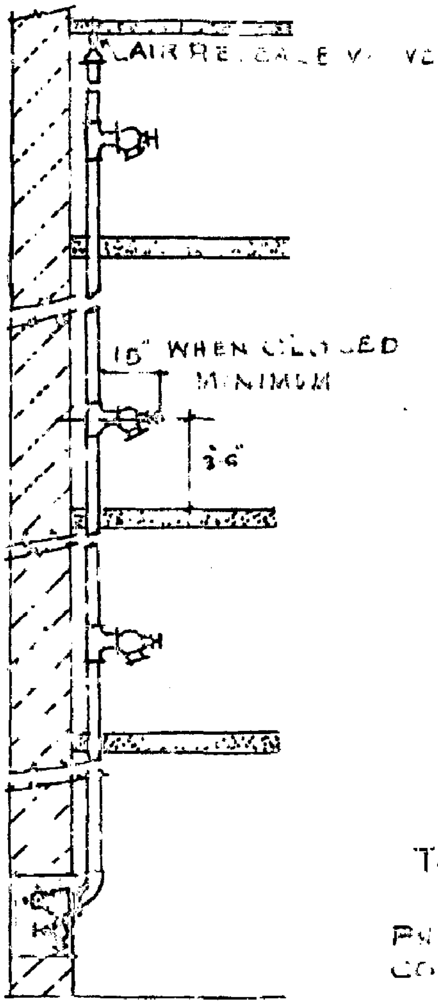
A dry hydrant risers consist of empty pipes without water rising the full height of the building. Provision is made at the ground floor level to connect the modernised fire fighting pumps of fire brigade to immediately pump the water into the riser and from there it can be drawn at the differen floors or place to fight the fire in the building. This type of hydrant system should be installed only where fire brigade can attend immediately or the local trained fire fighting personnel are promptly at disposal.

For the installation of dry type hydrant following points are to be taken into account.

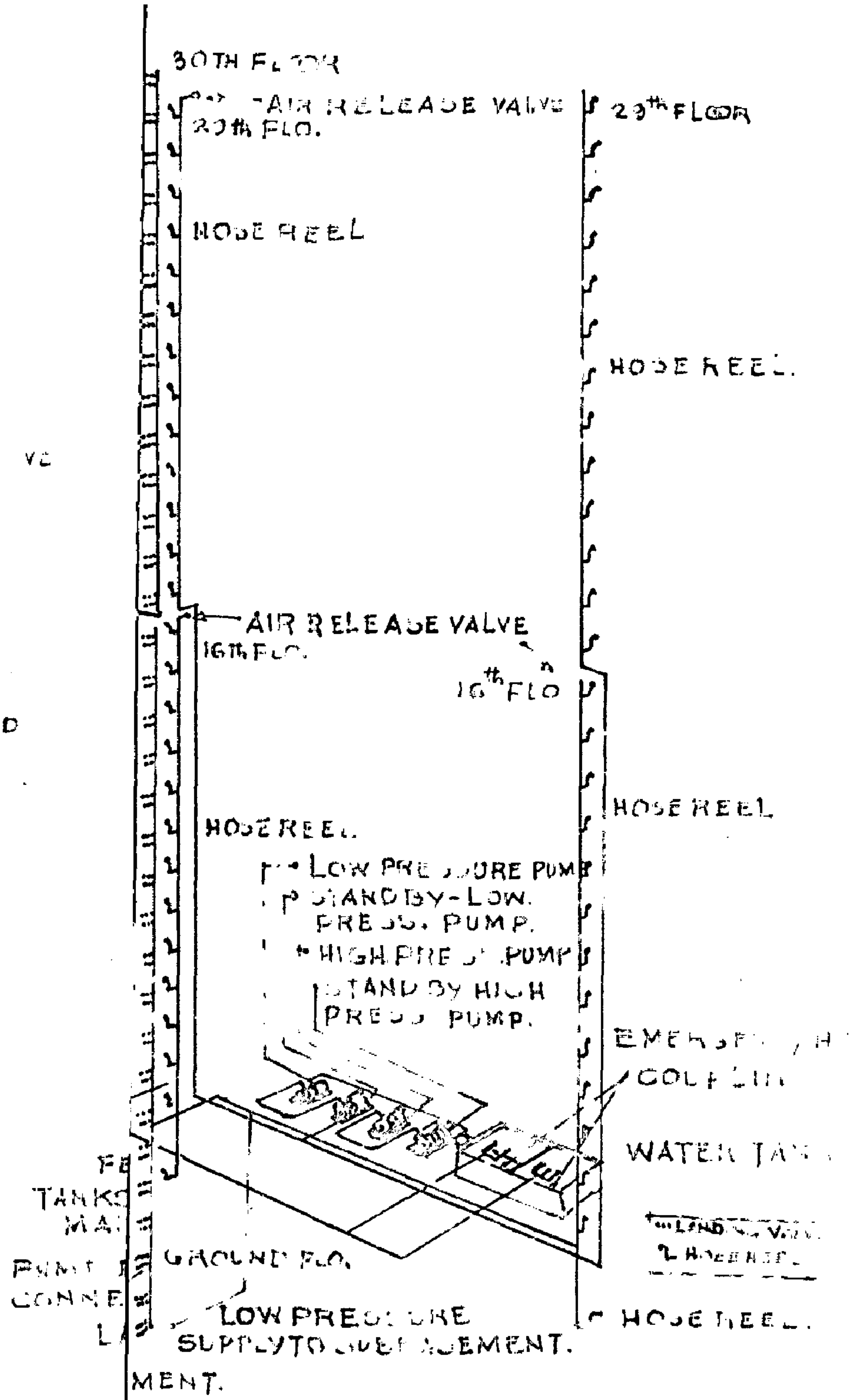
- For the floor area of 10,000 sq.ft. each; one riser should be installed
- Dry risers should be located at place where it is easily visible and accessible
- Riser is normally 4 inches dia. upto the height of 150 feet and 6" dia. for building height of 150 to 200 feet.
- A suitable outlet or landing valve is provided on every floor of the building
- Outside the building a suitable fire brigade breaching connector is to be provided (Fig.9A).

5.9.2 WET HYDRANT RISERS

Wet hydrants are generally used in building which is more than 200 feet high. In this type the riser or the pipes are always filled with water under pressure, which is fed by the pumping set, drawing water from corporati-on main or different level tanks or reservoir.

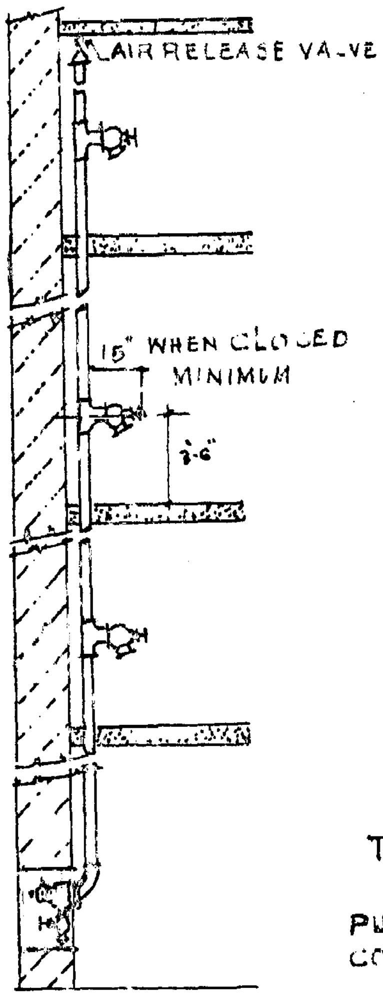


9(A) TYPICAL DRY
HYDRANT RISER



PICAL ARRANGEMENT OF WET
HYDRANT RISERS

FIG.9 TYPICAL ND WET RISERS



'9/A TYPICAL DRY HYDRANT RISER

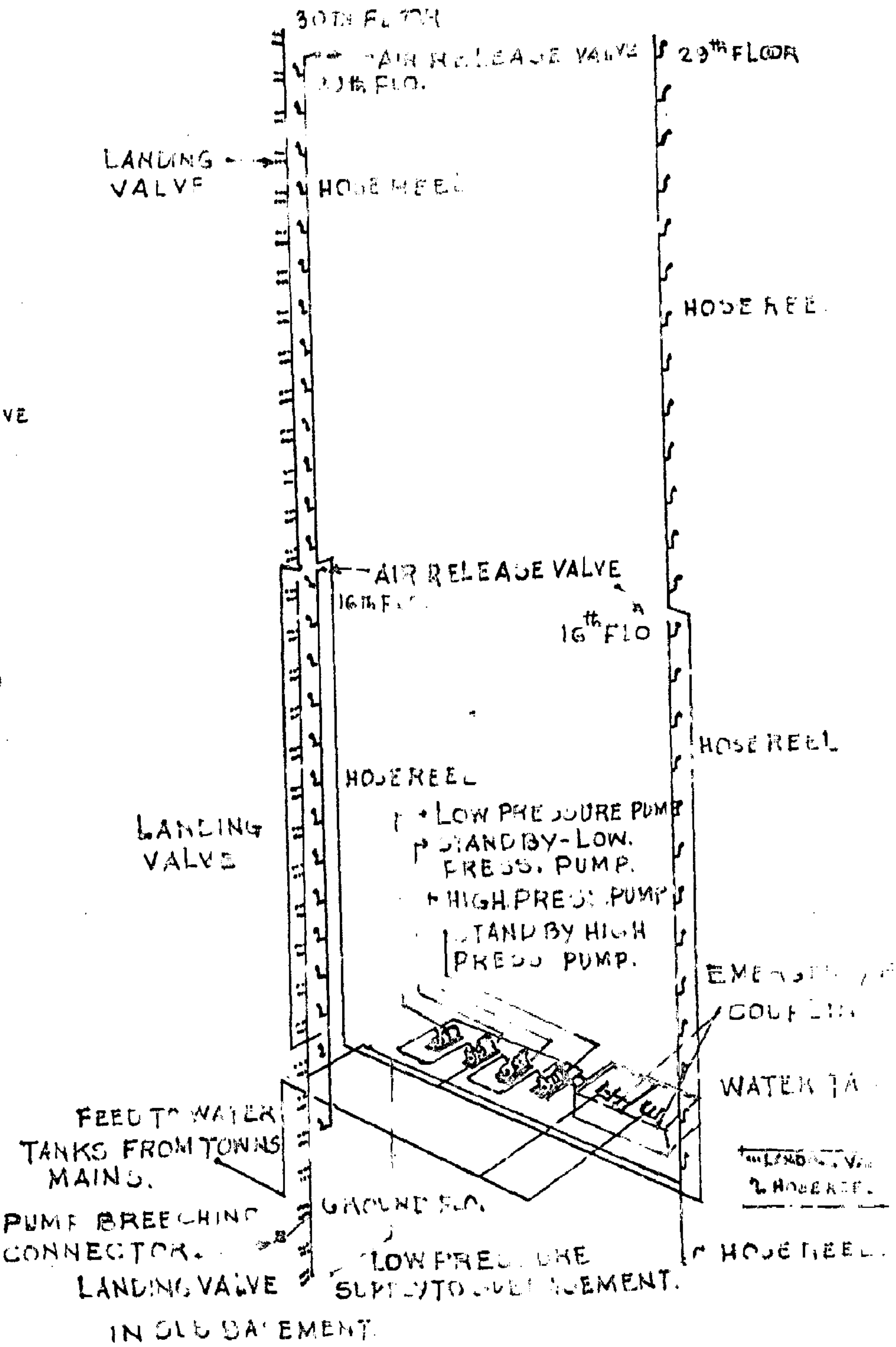


Fig 9/B TYPICAL ARRANGEMENT OF WET HYDRANT RISERS

FIG. 9 TYPICAL DRY AND WET RISERS

In the Fig. 9/B. a typical wet hydrant riser installation is shown. One riser or number of risers depending upon the height of building is permanently charged with water under pressure. As soon as the water is taken off from the hydrant landing valve, the automatic pump starts and supplying water. This ensures that in this system adequate and immediate supply of water at all levels of building is available to fight out fire.

Like in the dry hydrants, following points are to be taken in to account for the installation of wet hydrants[48].

- For the floor area not exceeding 10,000 sq.ft. one riser is to be provided.
- The risers should normally be of 6" dia.
- The risers should be located at suitable place or in a lobby approach staircase
- The landing valves should be so designed that the "shut off" static pressure in the hose should not exceed 100 lbs/sq.in.
- Each wet hydrant riser should be provided with water by two automatic pumps, out of which one will act as a standby. To provide a pressure of at least 45 lb/sq.in at the highest outlet each pump should be rated at 500 gallons per minute
- There should be water supply to the wet risers from two distinct sources
- There should be fire brigade inlet connection fixed on an external wall to feed the each water storage tank

5.9.3 HOSE REELS

Now-a-days the hose reels are largely preferred to the portable or mobile extinguisher particularly in multi-storey structures. They provide a continuous supply of water for first aid fire fighting and can easily be used by untrained persons. These types of hose reels are recommended where the floor area is more than 1000 sq.yds. One reel is sufficient enough for each 500 sq.yd. of floor area. These reels should be preferably located near the exits or stair-case landing. The standard hose on reel is normally 3/4" in dia. which is fitted with 1/4" nozzle. For easy handling and smooth operation the maximum length of 3/4" hose should not be more than 120 feet but the maximum length of such hose can be upto 150 feet. This type of hose is suitable enough to withstand the working pressure of water upto 100 lb/sq.in. (Fig. 8/F).

5.10 AUTOMATIC SPRINKLERS

Automatic sprinklers are used to extinguish confinement or control a fire at its earlier stages, before it has time to develop. In this system water is used in the form of fountain jets, through the sprinkler heads fitted to the pipe and spaced at regular intervals, throughout the protected building. The water supply has to be very reliable and available at all times. These sprinklers are connected with automatic fire alarms. When fire occurs the sprinklers only in the effected area will automatically start, and confine or control the fire, operation of any one sprinkler will cause an alarm to sound, which brings fire extinguishers and as soon as the fire is extinguished the water may be shut off. Usually the water discharge from the sprinklers is sufficient to extinguish an ordinary fire, but due to any obstruction; if the water does not fall on the burning material, fire will be held under check till the first aid help arrives.

5.10.1 FUNCTIONAL SYSTEM OF AUTOMATIC SPRINKLERS

First and foremost thing for the operation of sprinkle system is that water should be carried to all parts of building which is to be protected, this may be done by different size of pipes which may be suspended from the ceilling or roof. Water is held back in the pipes with the fire occures. Every sprinkler head is fitted with automatic valves, spaced at regular intervals in the pipe work. When fire occurs with the increased temperature beyond the predetermined limit, the strut holding the valve is closed and collapses and allows water to rush through the open valve of sprinkler heads.

5.10.2 TYPES OF SPRINKLERS

5.10.2.1 SOLDERED SPRINKLER

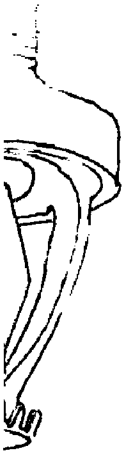
This is one of the old types of sprinklers, in which the strut is made out of three pieces of metal joined together by means of flusible solder. This holds a glass valve in position. The metal pieces are sealed in such a way that at the occurrence of fire, due to increased temperature solder is softened and strut falls apart, with this the glass valve opens and the water starts rushing out (Fig. 10/A).

5.10.2.2 THE DURA SPEED SOLDERED SPRINKLER

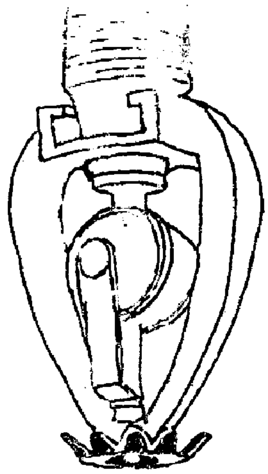
Efficiency of the sprinklers are generally effected due to the atmospheric corrosion. In this type of sprinkler all due precaution have been taken, here the solder which secures the key to the heat collector is almost completely enclosed by the metal of those two parts. There is a thin film applied to the thin edge of the solder. This of course doest not affect the sensitivity of sprinkler (Fig. 10/B).

5.10.2.3 THE QUARTZOID BULB SPRINKLER

This is one of the most improved and advanced type of sprinkler. In this type the operating element is free from corrosion. The other advantage over the soldered type is there no limitation of ratings.

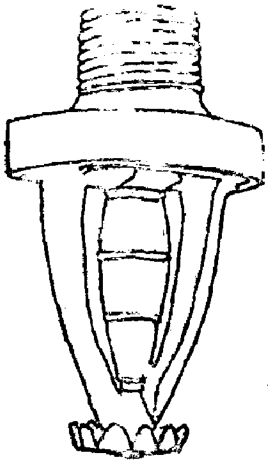


SPRINKER



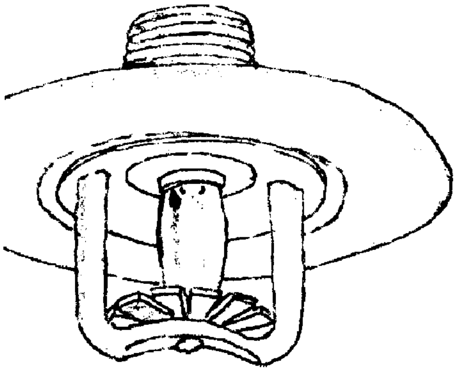
THE "ULRASPEED" SOLDERED SPRINKER

FIG 10/B

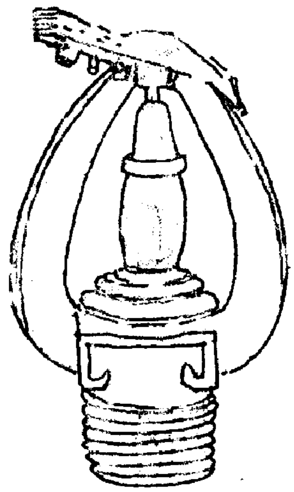


THE GRINNELE QUARTZOID SPRINKLER

FIG 10/C

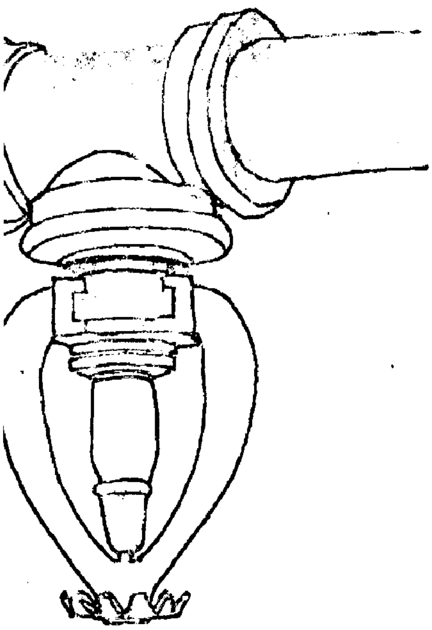


NELL TYPE 'E' QUARTZOID
LB SPRINKLER

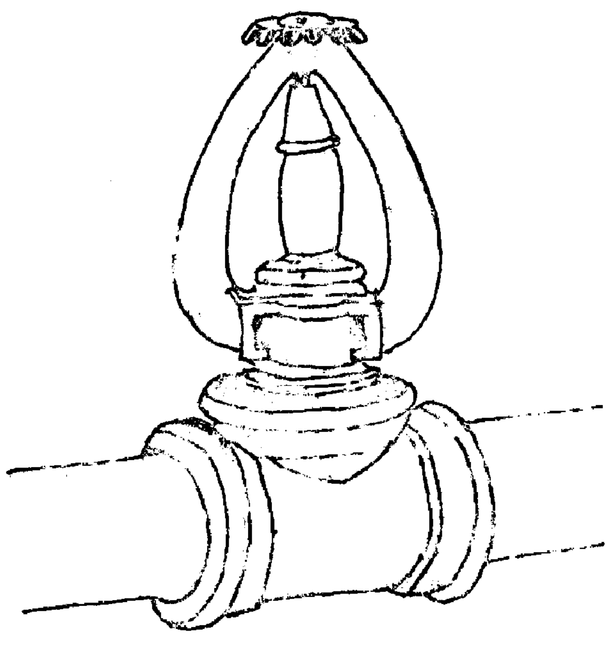


THE GRINNELL TYPE 'C' SIDE WALL SPRINKLER

FIG 10/E



RINKLER FITTED PENDENT
N THE PIPE WORK.



TYPE 'C' SPRINKLE FITTED
ABOVE THE PIPE WORK

FIG 10/G

TEMPERATURE RATINGS FOR SPRINKLERS TABLE - 8

The temperature rating is engraved on the deflector of every coloured as indicated in the following table[49]:

of Sprinkler	Rating of Sprinkler Recommended.		Temperature Not to be Exceeded where Sprinkler is Located.		Colour of the Bulb Filling
	Temp. in cent.	Temp. in Farn.	Temp. in cent.	Temp. in Farn.	
	72°C	162°F	38°C	100°F	
	93°C	200°C	60°C	140°F	
	141°C	286°F	107°C	225°F	
	182°C	360°F	149°C	300°F	
	227°C	440°F	191°C	375°F	
	68°C	155°F	49°C	120°F	RED.
	79°C	175°F.	60°C	140°F	YELLOW,
PRIC' ULD S	93°C	200°F	74°C	165°F	GREEN.
	141°C	286°F	121°C	250°F	BLUE.
	182°C	360°F	160°C	320°F	VOILET.
	227°C	440°F	204°C	400°F	BLACK.
	260°C	500°F	233°C.	460°F	BLACK.
	68°C	155°F	49°C	120°F	RED
L TYPE ID BULB	79°C	175°F	60°C	140°F	YELLOW,
	93°C	200°F	74°C	165°F	GREEN.

The three popular type of sprinklers which are widely in use are as following.

(a) THE GRINNEL 'C' TYPE QUARTZOID BULB SPRINKLER

In this type of sprinkler the Quartzoid bulb and its filling are of a permanent and unchanging nature with the latest scientific advance to counter the corrosion effects. From the rating of temperature (Table 8) it can be observed that it covers quite high range of temprature which generally encountered in industrial type of set up (Fig. 10/E).

(b) THE GRINNEL TYPE 'E' QUARTZOID BULB SPRINKLER

This particular type of sprinkler is specially designe to suit the interiors, with pleasing look. In this pipe work can be concealed above a false ceiling (Fig. 10/D).

(c) SIDE WALL SPRINKLERS

Where possibility of condense vapour dripping from sprinklers and pipe work above and spoilling the contents belo there side wall sprinklers are good, for the use in offices, entrance halls, lobbies and corridors, for shop windows displa areas etc. The other advantage is, it can be very convenientl installed without much affecting the interior decoration. Th sprinklers give effective uniform coverage upto 12 feet from the wall (Fig. 10/E).

5.10.3 SPACING AND POSITIONING OF SPRINKLERS[50]

As per the recommendations of the insurance companies should be at least one sprinkler for every 100 sft. of floor area. The deflectors should be placed such that there should be clear space of 12 inches below the level of each deflector with a radius of 2 ft. from each sprinkler. Therefore, in the store goods should not be kept within 12 inches of the level of the deflectors and above them. Sprinklers must not be placed withi 2 ft. of columns or beams. Care must be taken while placing the sprinkler, so that the deflectors are not more than 12 inches from nonfire resisting ceilings and not more than 18 inches from fire proof ceilings. In a building where ceiling is not fire resisting, sprinklers must not be more than 11 ft. apart and the sprinklers nearest to the wall must not be more than 6 ft. from them. Where ceiling or roofs are constructed of approved fire-resisting materials, sprinklers must not be placed 12 feet apart and not more than 6 feet apart from the walls.

5.10.4 CONTROL SYSTEM FOR SPRINKLER

For better control over sprinklers, they are generally divided into different sections in a protected building. Ther may be several such ~~installation will~~ have sections of units in one building. Each such installation will have its separate fire alarm and set of controlling valves. In a la-rg premises or building such division of sprinklers have definite advantages. With ten such installations an outbreak of fire in any one section would involve only equipment in that section without effecting the other nine. At the time of any extension or alternations to the sprinkler equipments can be carried out without shutting water from the remaining installations. Also the seggregation of control points on the entire area makes local control easier and quicker than it would be if only one control valve have been employed. The other advantage is as each installation gives the alarm bolt it is easier to locate as where the actual fire occurs.

There are three types of sprinkler systems

(i) The wet system

(ii) The dry system

(iii) The alternate wet and dry system.

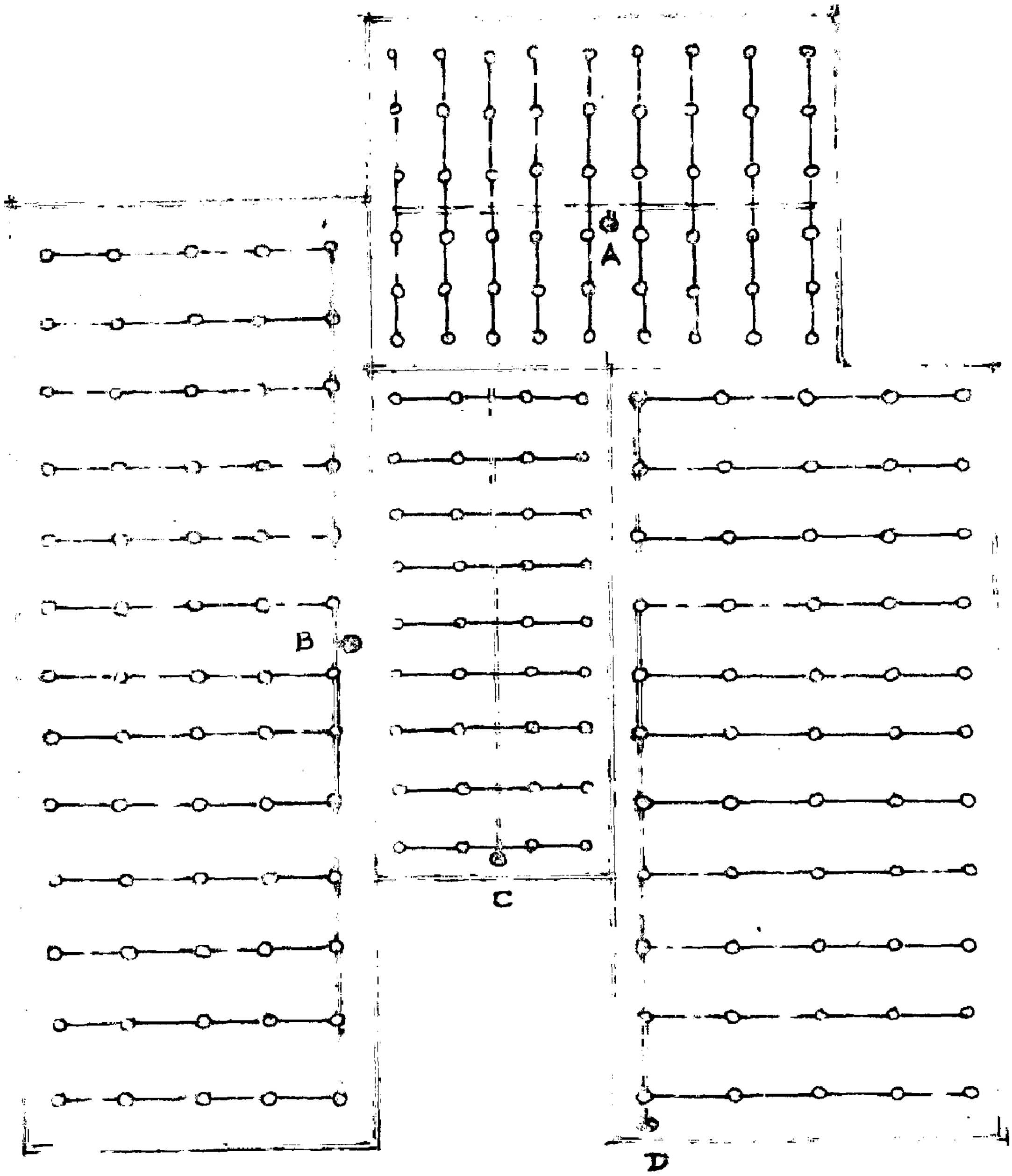
(i) Wet system is the one where the sprinkler pipes are constantly charged with water under pressure. This system is employed when there is no possibility of frost or freezing sprinklers on wet systems are normally fitted pendent below the sprinkler pipe work as shown in the Fig. 10/F

(ii) Places where the possibility of frost or freezin is there, the dry type of system is used. In dry system all installation pipe work is charged with air at a moderate pressure and the water is held back by a differential valve which when a sprinkler opens and releases the air in the pipes, lifts and allows water to entre the pipe work.

(iii) Places where there is possibility of frost only in winter there alternate wet and dry system is adopted when winter comes the water from all installation pipe line is drained out and charged with air under pressure. Sprinklers on dry and alternate system are normally fitted up right above the pipe work as shown in Fig.

5.10.5 WATER SUPPLIES FOR SPRINKLER SYSTEM

Water supply for the sprinkler system is one of the most important consideration. Sufficient amount of water should always be readily available for the installations. Any supply which may be good but could not be relied under all conditions can not be termed as good or effective for fire protection. For claiming the maximum rebate of insurance premium the installation should have two independent water supplies, one of which must be unlimited, may be from public water supply or from elevated water reservoir. It is also necessary to maintai minimum running pressure of water to 23 lb/sq. in at the highes sprinkler at all times. For the lowest class of sprinkler the water pressure from the reservoir should not be less than 5 lb/ in. at the highest sprinkler.



A - CENTER CENTRAL FEED   C - CENTRAL END FEED
B - SIDE CENTRAL FEED   D - SIDE END FEED

FIG 11 · LOCATION OF CROSS MAINS AND RISERS [52.]

SOURCE: TIME SAVER STANDARDS

5.10.6 PIPE SIZES

Although installation of the sprinkler system is a job of specialised engineer, it is very essential for a designe to know, some of the thumb rules regarding the pipe size and the maximum length of distribution pipes with sprinkler head on one side or both sides of it. Number of sprinkler on any one floor, undivided by fire wall and supplied through given sizes of pipe should not exceed the sizes as given in Table___ for ordinary hazard occupancy. When the piping arrangement provides long risers or feed mains an increase in pipe sizes may be needed to offset friction losses.

RISERS

There should be one or more riser in each building and each section of building divided by fire walls. Where conditions demand, the sprinklers in adjoinings or sections cut off by fire walls, may be fed from a system riser in another section of building. Each system riser should be of sufficien size to supply all sprinkler on riser of any one floor of one fire section.

LOCATION OF RISER

There are four standard locations of the risers (i) Central central feed, (ii) Side central feed, (iii) Cen ral End feed, (iv) Side end feed. These locations are clearl illustrated in the Fig. 11

TABLE - 9

PIPE SIZE Vs. NUMBER OF - Table (   ) SPRINKLERS.

(a) When both the distance between sprinklers on branch lines and the distance between branch lines is 12 feet or less.				(b) When either the distance sprinklers on branch lines or the distance between branch lines ex... 12 ft.			
...ze Pipe ...	Max No. spklrs	Size Pipe in.	Max No. spklrs	Size Pipe in.	Max No. spklrs	Size Pipe in	Max No. spklrs
	2	2½	65	1	2	3	30
	3	4	100	1¼	3	3½	60
	5	5	160	1½	5	4	100
	10	6	275	2	10	5	160
	20	8	400	2½	15	6	275
	40					8	400

Branch line for the sprinkler system should ordinarily be limited to 8 sprinkler. Not more than 14 branch lines should be allowed on either side of cross main.

5.11 THE DRENCHER SYSTEM

The drenchers are most effective installations for preventing the transmission of fire through radiation from the nearby building. This is done by the discharge of water through the nozzles over the external openings of a building. These discharge nozzles are fitted at suitable place and intervals to the drencher water pipe line. The drencher pipe work is fitted on the outside of the building under the roof projection on the windows and door ways. Automatic drenchers are very much similar to the Quartzoid Bulb sprinklers and operates individually on same principle. None automatic drenchers are mannually operated. It has open nozzles and when operated valves are opened to bring them all into operation simultaneously. It should be noted that the stop valve of the drenchers is to be placed at a prominent position where access during fire should not be obstructed.

5.12 FIRE RESISTING DOORS

Primary aim of fire protection is to confine fire to t smallest possible area of the building, to prevent the fire spread. Normally the usual source of fire spread are through door ways, windows, ventilators which connect room with each other or through passage ways and staircases and lift wells

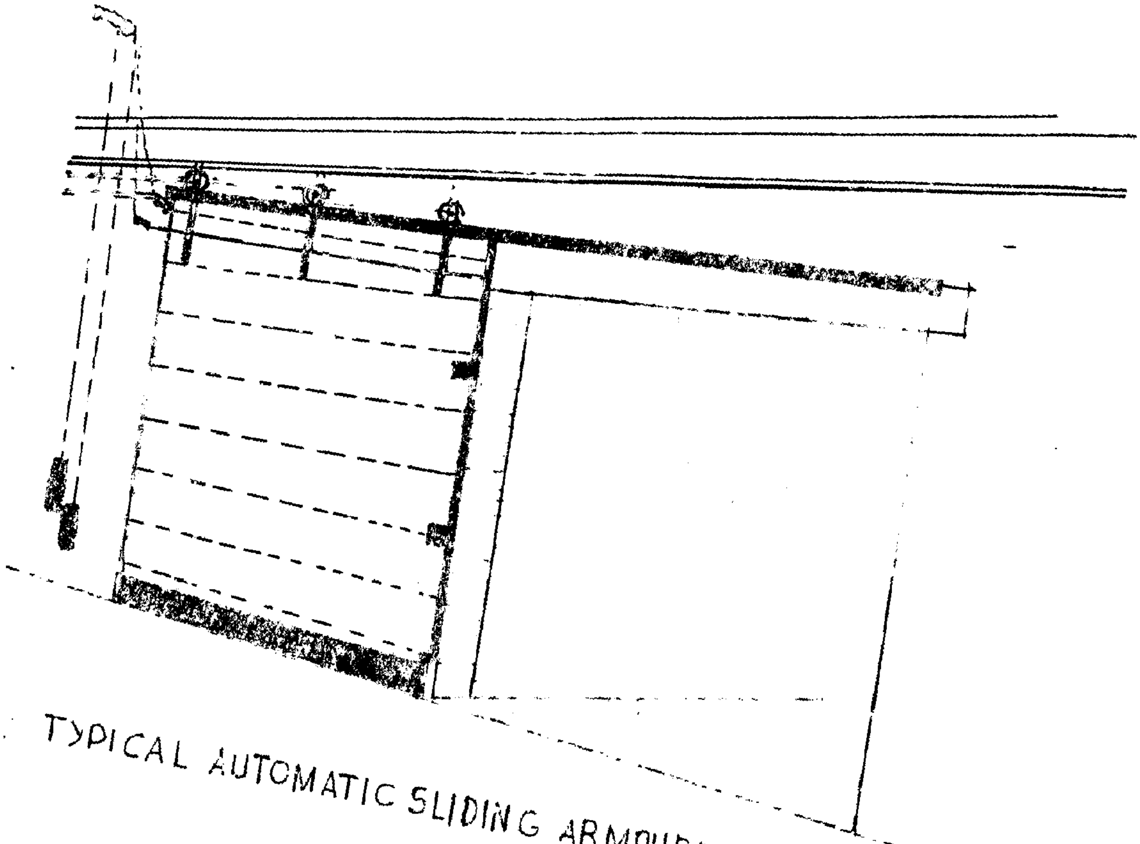


FIG 12/A. TYPICAL AUTOMATIC SLIDING ARMOURED FIRE DOOR

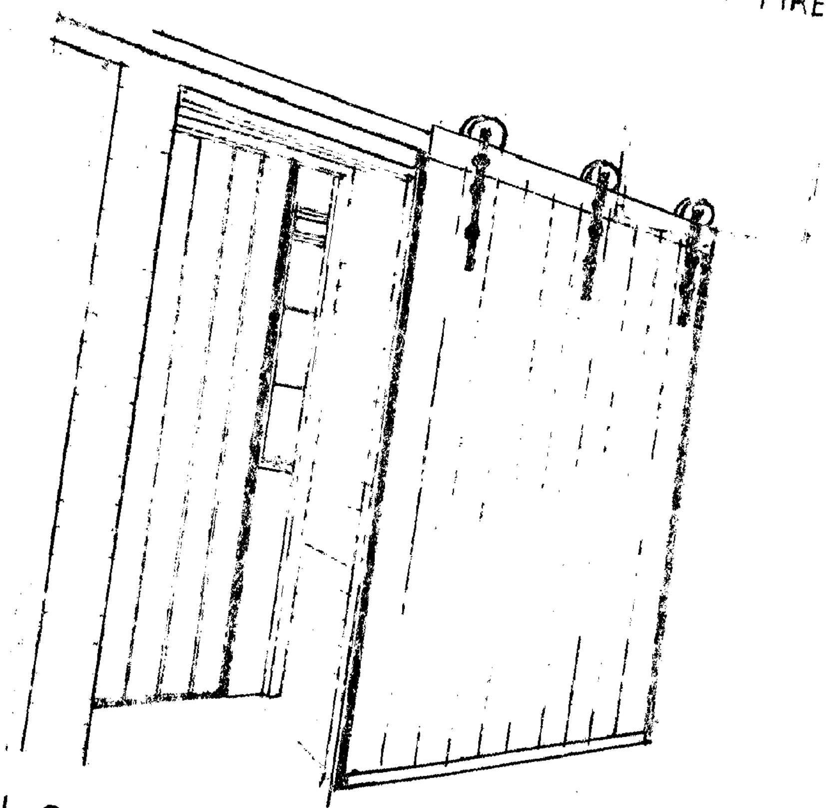


FIG 12/B TYPICAL COMPOSITE FIRE DOOR.

FIG No 12 TYPE OF FIRE RESISTANT DOORS

which connect different floors. If fire resisting doors or shutters are installed at such places, the fire can be confined to the part of a building and prevent further fire spread.

Some of the typical fire resisting doors are as following.

5.12.1 ARMOURED FIRE DOORS

These doors are made of three or four layers of thoroughly seasoned tongued and grooved pine boards, treated with a special preservative against dry rot. The boards are fastened together with nails driven flushed and then incased in tinned steel sheets designed to exclude air. The special construction with laminated boards also ensures that the door will not warp. Being deprived of air, the wooden core cannot burn and even when doors have been exposed to a fierce fire for several hours the side core remained very much unaffected (Fig. 12/A).

COMPOSITE FIRE DOORS

This type of door is developed to meet the need for a door with the same high fire resisting qualities as the armoured door but more suitable for installation in decorative surrounding. The composite door has a cellular core formed from angular steel strips with asbestos mill board facing on both sides. The core is enclosed in a channel-section frame and the outer cover of the door is of steel sheets. This type of construction gives the door the necessary qualities of low heat condentivity and high fire resistance (Fig.12/8).

These doors can be folding, hinged or sliding form and can be designed to close automatically if required.

5.12.2 STEEL ROLLING SHUTTERS

This type of fire resisting doors are good for sealing important internal spaces to prevent the spread of fire. The important advantage is that it requires little space for installation, this can be installed on stair ways, in small passage ways and in such places where lack of space make it difficult or impossible to errect other type of fire resisting doors.

This type of fire resisting shutters are built from interlocking steel laths forming a curtain which coils around a steel barrel. The curtain slides in guides of channel secti let into the sides of the opening and deep enough to allow the curtain to expand laterally in the heat of a fire. This type o fire resoting shutters may be non-automatic in operation but c be fitted with a fusible link mechanism to close shutters automatically with generation of heat from the fire outbreaks.

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CHAPTER - VI

MEANS OF FIRESCAPES IN MULTISTOREY STRUCTURES

6.1 PROBLEMS RELATED TO FIRE ESCAPE

Normally all multistorey buildings are designed in accordance with the fire safety building codes, which provides a fair chance to every occupant to escape in open air by their own unaided efforts. However, it is not possible to design building so that under no circumstances any person be trapped by fire. This is not because adequate and suitable precautions cannot be provided but generally because of human failure to use and maintain these precautions and to do the right things in an emergency.

It is a moral duty of a designer, that right from the drawing board stages he should consider occupants safety from fire. For solving the problem he has to take care in analysing the occupancy characteristics, type of construction in relation to escape from fire.

Designing and planning of escape routes, can be sub-divided into three stages, the first, horizontal route, from any point on a floor to a staircase, the second one is the normal route down to staircase and third is the horizontal rout from foot of the staircase to the open air, away from the building (Fig. 13/A). It is however possible to simplify the stages of escape routes. The further analysis will show two fundamental risk categories. First the area in which the person escaping from the fire, is at some risk, because that area may be an unprotected zone, and second where risk is reduced to an acceptable minimum in the protected zone (Fig. 13/B). It is therefore very essential to have a clear concept of protected and unprotected areas and exit to make clear the acceptable route to safety.

6.2 FACTORS GOVERNING THE DESIGN OF FIRE ESCAPE

For designing the means of fire escape it is essential to study the occupancy characteristics and occupants capacity c a building as a whole. If building is compartmented or sub-divided by fire resisting construction and if all openings in each subdivision are fully protected as to the same standar of fire resistance of subdivision then in that case total evacuation from the building is not necessary when a fire break out in a multistorey building which is fully compartmented then fire should not penetrate either horizontally or vertically to adjacent compartments provided all communicating openings are properly protected. At the outbreak of fire, occupants in such case can escape through protected door ways of the compartment. At such situation it seems reasonable to assume that at worst, the floor of origin of fire, the floor above and possibily that

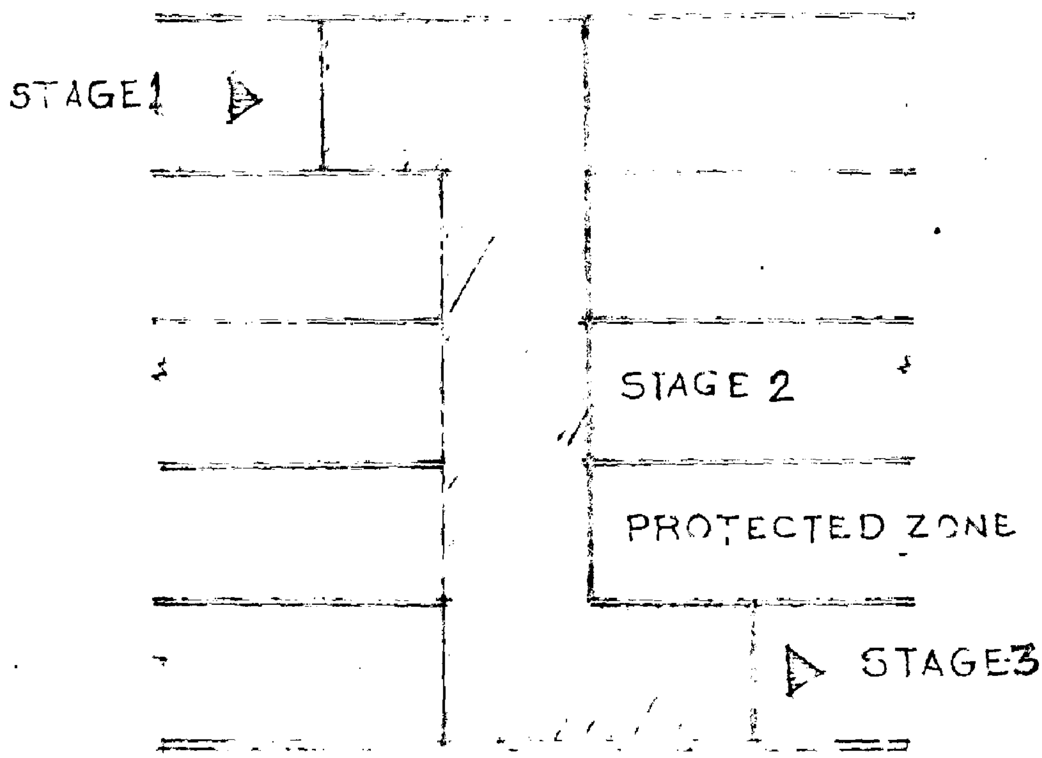


FIG. 13/A THE BASIC STAGES OF AN ESCAPE ROUTE IN BUILDING

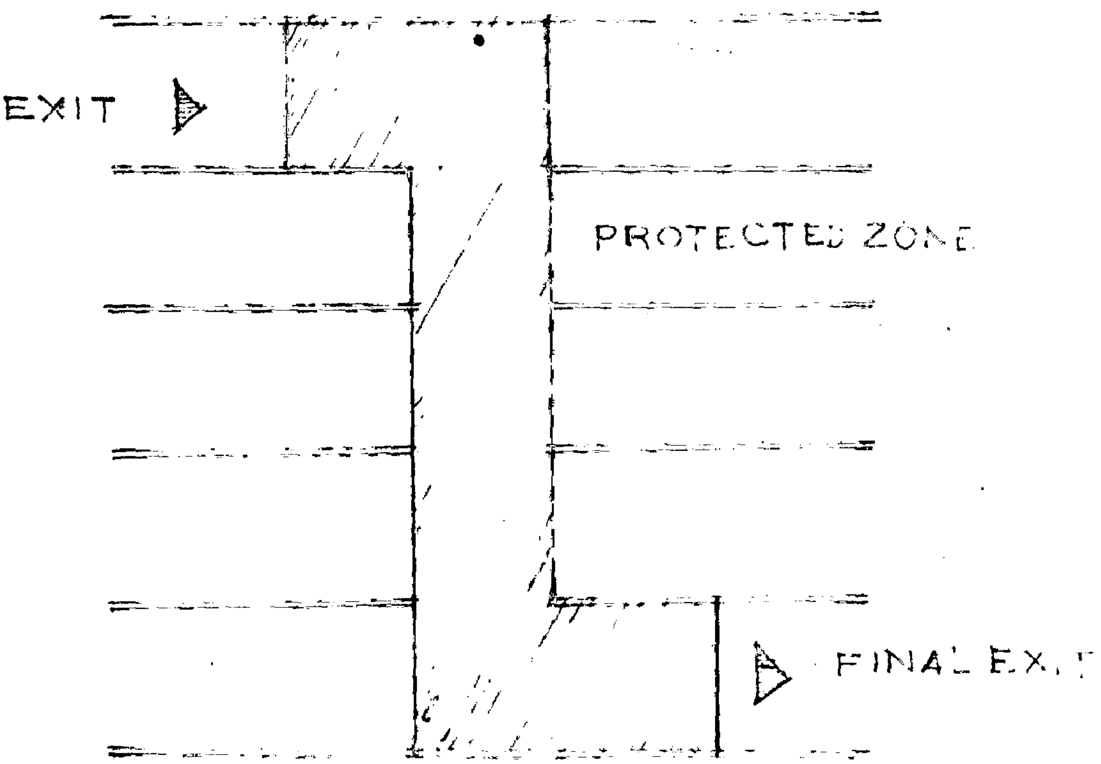


FIG. 13/B STAGES OF ESCAPE MAY BE CONSIDERED PROTECTED ZONE BOTH HORIZONTAL AND VER

13- STAGES FOR PROTECTION IN ESCAPE ROUTES below would be required to be evacuated. In many occupancies this may not be necessary, and building can be designed in such a way that only a compartment where fire occurs will only be effective and that alone should be evacuated. The smaller the compartment at risk, the greater is the chance of confining the fire to limited space. Recent developments in research into the problems of smoke movement in high buildings have shown that conditions can by virtue of smoke movement in vertical shaft produce dangerous conditions for escaping from the fire area[64].

It is, therefore, necessary that in tall buildings escape route capacity must be planned and designed to cater for a full evacuation when the emergency arises.

6.3 EXIT AND ESCAPE ROUTES

For quick evacuation and human safety adequate exit facilities and protected escape routes are very essential facto: to be considered. These should be provided to enable its occupants to reach to the open space or the street level without panic or confusion in case of fire. Some of the essential points which are very necessary for the design of exit and esca routes are given as following :

(i) Where the entire floor is to be kept open and used for office, the travel distance from the farthest point to any staircase or horizontal exit should not exceed 30 m.

(ii) Where the floor area is to be divided into cubicl the travel distance from the exit of each cubicle to any stairc or horizontal exit should not exceed 18 m.

(iii) Proper signs indicating the way to escape routes should be provided preferably near floor level but in any case at a height not exceeding 150 cms from the floor level. The exit sign should be designed in contrasting colours and should be electrically illuminated. The circuit for illuminating the exit signs should be independent of other circuits.

(iv) The occupant of each office should have available to them an alternative escape route besides a direct access to normal escape routes.

(v) Two enclosed staircases should be provided on the opposite ends of each floor.

If, in providing two staircases as indicated above the travel distance from the farthest point to the nearest stair case exceeds the specified limits the number of staircases should be increased to ensure that the travel distance would not exceed those limits.

(vi) The staircase enclosures should as far as possibl be on the external wall of the building. No staircase should b arranged around the lift shaft, unless the entire shaft is provided with an enclosure of 4 hour fire resistance.

In centrally located staircases not directly connected with the atmosphere, a positive pressure should be maintained in the enclosures by an electrically operated lever, so that th direction of flow of the air would always be away from the staircase.

An air-lock chamber is recommended between the lobby and the staircase. The air-lock chamber should be provided with arrangements for extracting smoke that may accumulate in it and should be fitted with self closing door.

The door of the air lock chamber and the staircase should open in the direction of escape.

The mechanism for pressurising the staircase shaft should be automatic and should be so arranged that it would be actuated by operation of the fire alarm/wet riser/sprinkler installation.

6.4 EXTERNAL STAIR CASE

This, of course, is an old practice to provide an external iron spiral staircase for fire escape. Most of the time these staricases are the result of after thought. These staircases are not as safe to use in an emergency as internal stairs. They can become more hazardous in wet weather, and if not well lighted at night time it may make the problem more complicated. It also creates an aesthetical disadvantage to the building but the designers can make them reasonably attractive, architectural feature. The other disadvantage of open external staircase is since they are exposed to weather their necessary maintenance may prove costly.

6.5 RAMPS

Ramps can be a good fire escape medium in the multi-storey structures as it will allow faster and safer movement than staircase . If it is bit detached from the building, it will have less problem of smoke during fire. The ramps should be provided with not more than 1:8 gradient, and should have non-slipery flooring. It should have hand rails etc. like that of stair cases.

Generally the ramps are neglected by the designer, because it occupies biggêr space for construction and in multi-stordy structures every inch of space is very costly and considered seriously.

6.6 TRAVEL DISTANCE

The maximum distance necessary for people to travel from the farthest point to reach the open air should be dependent on following considerations:

(i) type of occupancy and fire risk of the material

(ii) design and construction of the building, in particular whether fire and smoke could spread readily from storey to storey.

(iii) the type of occupants in the building, are they young, old, active or sick.

(iv) maximum number of people likely to be present and (v) how well the people in the building know the escape route.

In case the entire lettable floor space is undivided, the travel distance from the farthest point to the nearest staircase shall not exceed 30 meters[66].

In case the lettable floor space is divided by a room the travel distance from exit of the room to the nearest stair case shall not exceed 18 meter[66].

6.7 EVACUATION TIME

All the factors related to the design of means of esca are intended to make it possible to evacuate the building in minimum possible time. The period considered advisable is 2 minutes for complete evacuation of a storey. This time is related to type of occupancy, construction and fire risk. For the multistorey building with considerable height, it is advisable to make fire fight compartments as to allow evacuation of just the floor immediately affected by fire. It may not be necessary to evacuate the building completely within a specified time.

6.8 ESCAPE ROUTES : ITS WIDTH AND CAPACITY

The study of crowd movement and obstruction in exit is a subject of considerable complexity. It is at the escape rout person may find their speed restricted, unless adequate width is provided. The basic principle of all escape route planning must be such as to allow every one, to travel along and down it without risk of overcrowding or delay. On the way to the final exit no point of the escape route should diminish in width so a to form a battle neck.

"In theory a single unit passage way 533 mm (21 inches) wide would be able to discharge a single file of 100 people in 2½ minutes but such a width is not acceptable in practice as an obstruction however small can be fatal. The minimum width whic is acceptable is taken as 0.762 (2'-6") to provide a discharge rate of 100 persons in 2½ minutes. For more than 100 people two units are necessary i.e. 1 meter (3'-3") and above this wid each additional 150 mm of width may be provided for additional 30 persons. When there is a large number of persons involved this theory may not function efficiently. A scale of exit is evaluated on the basis of accumulated experience which recommends one exit for every 300 to 350 persons and this approach may be necessary irrespective of each one's actual discharge capacity"[67].

6.9 SIGNS AND LIGHT TO EXITS AND ESCAPE ROUTES

When a multistorey building catches fire, the spread of fire and smoke creates panic and confusion in the occupants. It will be of a very little value to provide sufficient exit, affording access to adequate means of escape, if they are not immediately located by the persons in an emergency. It is, therefore, very essential to ensure that a person any where on the particular floor of the building should be quickly aware that which direction he has to take for safety, "FIRE EXIT" or "EMERGENCY EXIT" signes should be placed above or close to the openings of such kind. The exit signs should be designed in contrasting colours and should be electrically illuminated, with an independent electrical circuit.

When natural light is inadequate in the escape routes o multistorey structure sufficient artificial lighting should be provided, so that the occupants are able to see their way out safely. Care must be taken to illuminate, corridors, stair cases and any other escape route, including any escape notice. In absence of daylight the electric arrangements should be maintained althrough the operation of fire extinguishment. In a building if there is an emergency lighting system is in addition to the normal lighting, it should preferably be the automatic system to start automatically upon the failure of normal electrical supply due to fire. These lights should preferably have independent circuit or standby power supply through diesel oil generator .

6.10 EVACUATION BY "SAUSAGE TUBE" OF SYNTHETIC MATERIAL

A French technician has invented a unique system for evacuation of people who are trapped in the upper floors of a burning building : A long "Sausage" like tube of synthetic material, approximately the wid th of a human body is made. This tube is hanged from a strong metal hoop attached to the building and can be lowered to the ground along the outside. In case of fire, trapped persons can ease themselves feet first into the tube and slide down. Their descent slowed by the tightly fitted material hugging their body. Maximum rate of fall is two meters per second. This system can evacuate up 35 persons a minute, regardless of their size and weight[68]. The drop can be controlled by pushing elbows outward against the tube.

CHAPTER - VII

DESIGN PARAMETERS FOR FIRE SAFETY PLANNING OF MULTI-STOREY STRUCTURES

7.1 FUNCTIONAL ASPECTS OF PLANNING

The main objective of fire safe design and construction of multistorey structure is to provide reasonable and adequate safety from the hazards of fire. This is one of the very important functions that a building as a whole has to perform. It is therefore necessary to maintain the balance between the various and often conflicting functional aspects.

It is necessary to examine the basic functions of a building and see how they may assist, detract or possibly conflict with fire safety and good fire planning. In any multistorey structure design a conflict of interests between financial, aesthetical and technical with fire safety function arises because it provides no apparent financial, aesthetic or amenity return for the money expended. This tends to reduce safety measure to the minimum level, sufficient to meet with the legal obligations. This is unfortunate but true and only by full understanding of the fundamental behaviour of fire and the measures to control it can help designers and ensure that the building is safe and comfortable place to live in.

On the basis of his study of the subject author has attempted to bring out the design parameters for various functional aspects of multistorey structures, which may be useful for the designers in reorienting the fire safety measures in their design.

7.2 OCCUPANCY

Only those occupancies which involves approximately the same combustible contents and similar fire hazards characteristics are classified in the same occupancy group. If any attempt is made to adjust improper grouping of occupancies the fundamental purpose of the classification is defeated.

If a designer tries to group two occupancy of widely different fire hazard, group regulation which provide high degree of fire protection adequate for more hazardoous occupanc will penalize building cost of the occupancy of lesser hazard. Thus building cost will be unduely increased. Further more type of construction and use of material suitable for lesser hazard occupancy will be restricted by more hazardoous occupancy.

Therefore under no circumstances hazardoous occupancies be mixed with residential educational, office or business occupancies.

No hazardous occupancy should be provided in any multistorey structure.

7.3 OPEN SPACE

In multistorey structures adequate open space on all sides are very essential for the following functions:

(a) For circulation of fresh air which is very essential for health and hygine of the occupants

(b) For parking of scooters, cars and other vehicles brought by the occupants and visitors to the building. This will also ensure, no obstruction to the fire service in case fire occurs.

(c) For speedy evacuation of the people without any traffic blocking or obstruction to fire brigade. For this location of exit should be properly considered

(d) For enabling the fire appliance to approach from all side of the building without any obstruction in the operation.

According to a revised rule for fire protection and fire fighting requirements for high rise buildings" Appendix D of Greater Bombay Corporation[54], the requirements for the open spaces are more practicable. The open space rule of Delhi Municipal Corporation suggest to the max. of open space as 50' on front, 20' on rear and 15' on side[55] which for the fire safety point of view is not sufficient for the access of heavy fire fighting appliances. Therefore author feels that the ope open space prescribed by Bombay Corporation is more practical.

It prescribes that for buildings of height upto 30 meters, at least two sides of the building must have courtyards of minimum width of 9.20 m. while the other two sides shall hav courtyards of minimum 6.10 m in width. In case of averaging of width 9.20 m, 6.10 m shall always be maintained free from car parking. The minimum widths of the aforesaid courtyards sh be clear of any structure and also of projection such as chajja and balconies, to a height of not less than 4 mts from ground level.

For buildings of height above 30 metres in addition to the minimum open space required for heights of 100 feet there shall be minimum open space at the rate of 1 foot for every 5 f or fraction thereof for heights above 100 ft subject to max. of 50 ft.

The fire protection rule further suggest that the courtyards must be hard surfaced so as to take the load of fire engine (about 12,000 kg.).

In case if a building where the depth exceeds the frontage by 10% or more the side courtyards along the depth sha be at least 9.20 m in width.

Author feels, while designing the open space for the multistorey building these parameters will help in producing more fire safe design.

7.4 PROTECTION OF OPENINGS IN EXTERNAL WALLS

Protection of wall openings is an important fire safety feature that often is given less attention in building codes than it deserves. Requirements in building code for exterior wall construction have been less justifiable for the severity of fire to which they are likely to be exposed.

In modern buildings a large percentage of the wall surface is generally made up of windows which if not of the fire resistive type (panes of wire glass set in steel frame) will permit ready access of fire to the contents of the building when the outside of the building is exposed to heat from an adjacent fire, irrespective of whether the wall itself is of fire-resistive construction of its degree of fire resistance.

According to fire records of foreign countries, the fire "drenchers" seems to provide the most effective window protection followed respectively by fire resistive windows having steel frames and wire glass and by steel shutters. Analysis of exposure of fire brings out that for protection against the severe exposure a combination of two or more protective measures are necessary.

However, it is standard Building Code Practice to specify only one required opening protective. The most common type of protective adopted for window openings is that afforded by wire glass in steel frames.

7.4.1 BUILDINGS WITHOUT WINDOWS

Modern buildings that have enclosing walls without window openings, sounds to be very safe against exposure hazard but this may create serious fire hazard to the lives of the occupants as well as difficult problems for fire fighters.

Such buildings present a problem to life safety from several stand points. The lighting system in a building can and usually does fail during a fire and when occurring in windowless building the unlighted interior increases the hazard due to serious panic amongst the occupants. Further more in a window less buildings the removal of smoke during and after fire which usually goes out through window openings presents and add to the problem and hazard, both to firemen and occupants. It is true that windowless buildings have air conditioning system but smoke and gas are likely to spread through the building unless an exhaust system is provided.

7.5 AREA AND HEIGHT LIMITATION

The limitation of area and height of buildings of different types of construction and occupancy class is achieved by specifying it in terms of F.A.R. which shall take into account the various aspects that govern in specifying F.A.R.

as given below :

(a) Occupancy class

(b) Type of Construction

(c) Width of the street fronting the building and traffic load.

(d) Density and locality where the building is proposed.

(e) Parking facilities

(f) Local fire fighting facilities

Purely from the fire safety angle the maximum height of buildings should be preferably be restricted so as to be within the effective range of the tallest ladder available with local fire service. If this is not done, then built in safety measures must be incorporated in the building design to ensure speedy and safe evacuation of the building, and at the time of the occurrence of fire, facilities for effective fire fighting for the five service men.

7.6 SPACE AND CIRCULATION WITHIN THE BUILDING

Space and circulation within a multistorey building is no less important than open space around it. Large areas and cubic capacities at risk can be so planned and constructed that life risk can be reduced to an acceptable level. Damage hazard on the other hand is directly related to the potential areas at risk. In other words larger the space, the greater the likely fire loss in case when fire occurs. For such risks as in commercial, space between display area should be sufficien provided for gangways which must be free from obstructions not only from the passage of persons in emergency but also for fire fighters. Height of the room is another factor which must not be overlooked. The effective response time of active fire fighting measurds, such as fire detection alarms, sprinklers etc. change in relation to the height of the floor where those devices are installed.

In the multistorey structure every square foot of floor space is highly valued. From the financial point of view circula tion spaces, corridors and fire escape staircases are features which very often shows no profit to the building owner. Howeve sufficient means of escape and safe access for the fire fighter must be provided, irrespective of how inconvenient and how rarely used.

There should be full and comprehensive understanding of the fundamental issue involved. If considered early enough in the planning stage, it will eliminate excessive and wasteful circulation space which will make building both functional and economical.

7.8 STATIC WATER STORAGE TANKS

Water is the cheapest and quickest medium of fire extinguishment where it can be used. Therefore, it should always be readily available. It cannot be so much relied on the municipal mains as much as on the water storage tanks which is provided for fighting fire. Water reserves in these tanks are exclusively used, only for fighting fire.

Static water storage tanks are provided on the ground level. The capacity of static water storage tank shall be as following[56].

(i) For residential apartments = 50,000 litres
(ii) For commercial buildings = 1,00,000 litres

To prevent stagnation of water in the static water storage tank and the domestic supply tankshall be connected to the tank of fire fighting storage through a baffle wall.

The static water storage tank shall be provided with fire brigade collecting breaching with 4 Nos. 63 mm dia. instantaneous male inlets arranged in a valve box at a suitable point at a street level and connected to the static tank by a suitable sized pipe not less than 15 cm dia. to discharge water into the tank when required at a rate of 2250 litres per minute[57].

7.9 WATER HYDRANT : WET RISERS

In multistorey building of more than 25 meter height water stored at ground level cannot be effectively utilised for fire fighting, therefore in taller structures water zoning of t reservoirs are done and hydrants installed at each floor on mains running down from the storage tanks.

For installation requirements of wet risers author has dealt these aspects at greater details in chapter 5.9.2 which may be referred. However, table No. 10 also gives the number of the standard requirements for fire fighting purpose in some of the occupancies.

7.10 WATER SPRINKLER SYSTEM

In buildings where very important documents are stored, or where articles of great importance are kept the sprinkler system is much desirable. At other place it is best left to th descretion of the owner. In buildings of hazardous occupancy however these units are to be made obligatory, not only from the point of view of safety of the building itself but also of the surrounding property. Although they are costly to instal but provides reliable protection to buildings as such in National Building Code, exit requirements is reduced by about 50% if the sprinkler system is adopted in any multistorey building.

The special installation requirements for sprinkler systems include

(i) at least 1 fire department connection on each frontage

		Residential and residential with shopping of less than 250 sq.m. area.	Residential with shopping above 250 sq.m. and commercial office.	Commercial offices with shopping	Hospitals
		I	II	III	IV
1.	Underground storage tank	50,000 litres	1,00,000 litres	Same as II	Same as II
2.	Over head storage tank	20,000 litres	-	Same as II	20,000 litres
3.	4" dia. wet riser with 2½ wall mounting type hydrant with single outlet 3/4" G.I. branch connection with 3/4" control valve for 3/4" dia. hose reel with nozle having 100 ft length on each floor.	One per 10000 sq.m. per floor.	One per 1000 sq.m. per floor	One per 1000 sq.m. per floor	One per 1000 sqlm. per floor.
4.	Alarm system	Manually operated	Same as I	Same as I	Same as I
5.	Fire escape external stair	Enclosed stair Minimum width 100 cm	Same as I	Same as I	Same as I
6.	Travel distance	22.5 m	30 m.	30 m.	22.5 m
7.	Extinguishers	Nil	Nil	for shopping area 9 lit. capacity per 600 mts.	-

(ii) a master alarm valve control for all water supplies other than fire department connections.

(iii) Special fire resisting walls between protected areas and unprotected areas; and

(iv) Sloping waterproof floors with drains to carry away the waste water.

When gravity tanks are used with sprinkler systems they should reserve at least 5000 gallons for this purpose and in any case enough to operate 25 per cent of sprinkler heads for about 20 minutes. As in case of stand pipe and hose system thi gives the fire company a chance to arrive and take over[59].

For other installation details and design aspects pleas refer Chapter (5.10).

7.11 STAIRCASES AND STAIRCASE ENCLOSURES

Staircases in multistorey structures are most vital part of the building for evacuation in case of fire it is therefore most important to design it most safe, for at least the fire resistance of 2 hrs following parameters will be useful for this purpose[60].

(i) All staircases shall be of enclosed type throughou their height and shall be fire resistance of not less than two hours.

(ii) Access to main stair cases shall be gained through at least half an hour fire resisting swing door placed in the enclosed walls of the stair cases. The swing type door open in the direction of the escape.

(iii) There should be no glazing or glass bricks in any internal enclosing wall of a staircase.

(iv) The staircase shall terminate at ground level and any staircase to a basement shall be entered from the open space.

(v) The enclosing walls of staircase shall be of brick or R.C.C. construction having fire resistance of not less than two hours.

(vi) The enclosed staircase shall be on an external wall of the building and shall be ventilated to atmosphere at each landing. No staircase shall be arranged around the lift shaft.

(vii) If the staircase is in the core of the building and cannot be ventilated at each landing, a positive pressure at 5 mm w.g. by an electrically operated blower shall be maintained. The mechanic shall also have facilities to be operated manually.

7.12 LIFTS AND LIFT ENCLOSURES[61]

(i) The walls enclosing lift shaft shall have a fire resistance of not less than two hours.

(ii) Landing doors of lift enclosures shall open in the ventilated lobby or pressurised corridor and shall have fire resistance not less than one hour.

(iii) Lift car doors shall have fire resistance of 1 hour.

(iv) If the lift shaft and lift lobby are in the core of the building, a positive pressure of 5 mm w.g. and not less than 2.5 mm. w.g. and not more than 3 mm. w.g. in the lift shaf and lift lobby vesper by an electrically operated blower shall be maintained. The mechanism shall also have facilities to operate manually.

7.13 SERVICE DUCTS

Service ducts shall be enclosed by walls having a fire resistance of not less than two hours. Doors for inspection or access shall also have fire resistance not less than two hours[6]

REFUSE CHUTES AND REFUSE CHAMBERS

Hoppers to refuse chutes shall be situated in well ventilated positions and the chutes shall be continued upwards with an outlet above roof level and with an enclosure wall of non-combustible material with fire resistance not less than two hours. The hoppers shall not be located within the staircase enclosure.

Refuse chutes air conditioning shafts and all service ducts shall not have any opening in the staircase walls[62].

7.14 AIR CONDITIONING[63]

(i) For air conditioning any multistorey building, there should be separate air conditioning system for each floor The fresh and return air duct for every floor should be distinct and separate and in no way interconnected with ducting of any other floor.

(ii) Staircases, lobbies corridors, lift lobbies and other escape routes should not be used as return air passage. In the residential buildings it is desirable that each flat should have its independent air conditioning system.

(iii) All ducts should be constructed of metal sheet or other non combustible material which will withstand the fire for not less than 2 hours.

(iv) Where ever the duct passes through opening in a wall or floor the recess between it and the wall floor should b sealed by a fire resisting material.

(v) Automatic fire dampers should be installed at intermediate stages for isolating sections of ducting when its length exceeds 25 m on any one floor.

(vi) The air handling unit room shall not be used for storage of any combustible materials.

(vii) Automatic fire dampers shall be so arranged as t close by gravity in the direction of the air movement and to remain tightly closed upon operation of a smoke detector/Fire Alarm.

7.15 FIRST AID EXTINGUISHING EQUIPMENTS

First-Aid Fire extinguishing equipment provides a ready and effective means of attacking and extinguishing fire if it i detected before it start spreading. Because these equipments does not suite in the surrounding, architect may be tempted to hide such equipment from immediate visibility, but such an act will defeat the purpose of first aid fire equipment on the contrary these equipments should be ready immediately to catch attraction and should be easily accessible. The ultimate sitting of the appliance must be closely linked with means of escape facility. Therefore appliance should be placed so that safe retreat is possible.

7.16 FIRE RATING

In order to estimate the fire hazard of building materials, tests corresponding to combustibility, flammability and flame spread have been developed by various fire research laboratories. These ratings are decided in terms of the time.

It indicates that the building material can withstand fire or resist without losing its physical qualities. The maximum rating for any material is generally 6 hrs and minimum permissible is 1/2 hr. This indicates the capacity of fire resistance of that material.

Any construction material specified by the designer for multistoreyed buildings should have a minimum fire resistance required for that type of construction and occupancy.

The minimum requirements of fire resistance of construction materials should be provided in consideration of the fact that in certain circumstances fire in a multistorey building may continue to burn for a longer time and that the structural members of the building should not disintegrate during that period or at least till all occupants of the building have been safely evacuated and fire services have had a fair chance of extinguishing the fire.

In National building Code Part IV the classification of the type of structure is done on the basis of fire resistance of the structure[63].

Type 1 has 4 hrs fire resistance

Type 2 has 3 hrs fire resistance

Type 3 has 2 hrs fire resistance

and Type 4 has 1 hr fire resistance

In the multistorey building there are numerous building components which has their different fire resistance ratings depending upon the specification of their composition and quali of materials. These fire resistance are illustrated in the Table No.11,11A,11B,11C. These tables may help the designer in understanding the right fire resisting qualities of materials to be used in the building.

7.17 METHOD TO IMPROVE FIRE RESISTING QUALITY OF BUILDING MATERIAL

The performance of many cumbustible building materials in fire can be improved by the use of flame retardent treatment Usually this consist of either surface coating or the incorpora ting of chemicals in the structure of the material which inhibit ignition and combustion.

When materials are used inside buildings in reasonably dry and constant temperature conditions, flame retardant treatment are likely to remain effective for long period. On the other hand when materials are used externally they are exposed to wide range of temperature and humidity and sunlight. All these factors can have an appreciable effect on the useful life of material.

MASONRY WALLS

Construction and Mat. Plaster not less than 1/2" including finish coat.	LOAD BEARING					NON LOAD BEARING				
	MINIMUM THICKNESS EXCLUDING PLASTER ( )									
	4	2	1½	1	1/2	4	2	1½	1	1/2
1	2	3	4	5	6	7	8	9	10	11
Bricks of fire clay Concrete or sand lime bricks unreinforced unplastered or with cement /sand or gypsum/sand plaster.	200 8	100 4	100 4	100 4	100 4	170 5½	170 6½	100 4	75 3	75 3
As (a) above with gypsum/vermiculite plaster. For clay bricks and other materials with a similar surface gypsum/perlite may be substituted.	100 4	100 4	100 4	100 4	100 4	100 4	100 4	100 4	75 3	75 3
Solid concrete blocks class I aggregate plastered as (a) (6 in. if unplastered.	150 6	100 4	100 4	100 4	100 4	100 4	75 3	75 3	75 3	75 3
As (c) with gypsum/vermiculite plaster	100 4	100 4	100 4	100 4	100 4	75 3	75 3	63 2½	50 2	50 2

(Contd.)

1	2	3	4	5	6	7	8	9	10	11	
Solid concrete blocks class 2 aggregate plastered as (a)	- -		100 4	100 4	100 4	100 4	150 6	100 4	100 4	75 3	75 2
As (e) with gypsum/vermiculite plaster.	100 4		100 4	100 4	100 4	100 4	100 4	75 3	75 3	75 3	50 2
Hollow concrete blocks class I aggregate as (a)	100 4		100 4	100 4	100 4	100 4	150 6	100 4	75 3	75 3	75 3
As (g) with gypsum/vermiculite plaster	- -		100 4	100 4	100 4	100 4	100 4	75 3	75 3	63 2½	63 2½
Hollow concrete blocks class 2 aggregate as (a)	- -		- -	- -	- -	- -	150 6	150 6	125 5	125 5	100 4
As (i) with gypsum/vermiculite plaster	- -		- -	- -	- -	- -	125 5	100 4	100 4	100 4	75 3
Solid autoclaved aerated concrete block unplastered	180 7		100 4	100 4	100 4	100 4	100 4	63 2½	63 2½	50 2	50 2
Cavity construction solid 2 inches air gap Bk of fire clay	100 4		100 4	100 4	100 4	100 4	75 3	75 3	75 3	75 3	75 3
External leaf and air gap as (1) inner leaf solid or hollow concrete bk.	100 4		100 4	100 4	100 4	100 4	75 3	75 3	75 3	75 3	50 2

CONCRETE WALLS

Construction and materials.	FIRE RESISTANCE IN Hr.				
	4	2	1½	1	1/2
	Minimum concrete cover to main reinforcement.				
	25 mm (1 in)			15 mm (1/2 in)	
	Min. thickness of concrete in mm and inches.				
(a) No plaster or with cement or gypsum/Vermiculite plaster to one or both sides.	180 7	100 4	100 4	75 3	75 3
(b) Gypsum/Vermiculite plaster 13 mm on both sides.	125 5	75 3	75 3	65 2½	65 2½
(c) Unreinforced concrete as (a)	- -	- -	175 7	150 6	- -

Source: G.J. Langdon Thomas Fire Safety in Buildings

The above table indicates the fire resistance rating for the concrete walls. The thickness of the wall and the minimum thickness of the cover and quality and specif.

LOADBEARING TIMBER FRAMED INTERNAL WALLS

Construction and materials	Fire Resistance in hr.
Timber studs nominal size 75 x 50 mm (3"x2") faced on both sides.	
(a0 Plaster board 13 mm (1/2") thick with all joints made over the timber studs and joints filled.	1/2
(b) Plaster board 13 mm (1/2") thick finished with not less than 19 mm (3/4") vermiculite/ gypsum plaster	1
(c) Plaster board layers 36 mm 1$\frac{3}{8}$"	
(d) Plaster board layer 36 mm (1.3/8") with a mineral wool mat. .25 mm thick securely fixed between and to the sides of the studs.	1
(e) Asbestos insulation board 13 mm (1/2") fixed through 9.5 mm (3/8") asbestos insulation board fillets to the face of the studs.	1/2
(f) Asbestos insulation board 9.5 mm (3/8") fixed through 9.5 mm (5/8") as (e) above with mineral wood as (d)	1/2

Source: G.S. Langdon Thomas "Fire Safety in Buildings" Page 62.

TABLE 11/C

REINFORCED CONCRETE COLUMNS

Constraction and Materials.	Minimum dimension of concrete in mm and to provide fire resistance in hr. where faces of the cal. are exposed.				
	4	2	1½	1	½
Dense concrete:					
(a) Without plaster	450 18	300 12	250 10	200 8	150 6
(b) With concrete or gypsmn plaster 13 mm in (½") thick or hight mesh reinforcement.	300 12	225 9	150 6	150 6	150 6
(c) With vermiculite/gypsum plaster 13 mm (½")	275 11	200 8	150 6	120 5	120 5
Light wt. aggregate concrete.	300 12	225 9	200 8	150 6	150 6
	Min. dimension where the col. is bu to fire resisting vall or is embedde that the part is structurally adequa support the load i.e. exposed on one force only.				
s 1 (a)	180 7	100 4	100 4	75 3	75 3
s 1 (c)	125 5	75 3	75 3	65 2½	65 2½

Source- G.S. Langdon Thomas " Fire safety in buildings Page- 64)

Above tables indicate that for fire resistance of any structural lements, there, specification, section and proteetive coner are relati o their fire resistance rating. Biger the section of structural elemen nd thicker the protective corer higher will be the fire resistance pers

These tables may be useful in understanding the fire rating of var uilding matterials.

Fire resistance of any structural elements can be improved or increased by the following :

(i) By increasing the cross section of beam or column etc.

(ii) By decreasing the loads by using more effective designs

(iii) By using the light weight concrete or fire proof concrete

(iv) using the reinforcement with high critical temperature

(v) By increasing the prâtective layer of concrete etc.

CHAPTER - VIII

A CASE STUDY OF FIRE SAFETY MEASURES IN MULTISTOREY STRUCTURES

8.1 FIRE SAFETY REGULATIONS AND PRESENT PRACTICE

With the general awareness and two major multistorey fires one at State Bank of India building at Bombay on March, 1972 and the other one at L.I.C. building at Madras on 12th July 1975. Building authorities all over the country realised that in order to stimulate better, safer and more fire protecte building construction, fire safety regulations and building bye-laws may be revised on a rational and uniform basis.

In this respect Bombay Municipal Corporation for Greater Bombay has taken a lead in revising its fire safety bye laws. This new bye-laws on "Fire Precautions and Provision of Fire Fighting installations in highrise buildings" are recommended unanimously by the group of officers, appointed by Maharashtra Government. These new rules have come in force since 7th February 1975[69]. After publication of the bye-law, it has been felt and realised by different State Governments and city corporations, that fire safety bye-laws and regulations of their respective corporation is not adequately safe for the multistorey structures. Very recently Delhi Municipal Corporation has also revised its Building Bye-laws[70] and enforced more fire safety measures. The recommended reports are finalised but

it is not yet made public, but it may be very soon that they wi
be enforced as revised building bye-laws.

At present almost all multistorey structures which have come up are not in the true accordance of fire safety building code, and the safety bye-laws. While doing the survey of multistorey building author has come across many such points which are conflicting with fire safety aspects.

8.2 OBJECTIVE OF CASE STUDY

Main objective of author in doing a survey and case study of the multistorey buildings at Delhi is to bring out all possible conflicting aspects existing in the buildings already constructed. These aspects could prove hazardous in case fire occurs in them. Author has studied the building bye-laws of municipal corporations and development authorities of different cities; Nagpur, Hyderabad, Madras, Bombay and Delhi and observed that except the revised fire precaution rules and bye-laws of corporation of Greater Bombay, which has come in force from 7.2.1975 rest of building bye-laws do not adequately cover most of the fire safety aspects.

Revised fire safety bye-law of Union Territory of Delhi is much similar to the Revised fire safety bye-laws of Greater Bombay Corporation. Since the revised bye-laws of Delhi Municipal Corporation is not yet published author may be referi to the Greater Bombay Corporation Bye-laws in his case studies.

On the basis of these bye-laws and the studies involved in the previ-ous chapters of this dissertation author has done the case study of multistorey structures at New Delhi. Most of those buildings are at or around Connaught Place.

Author has distributed this study in two parts (i) Study of External Fire Safety Aspects, and (ii) Study of Internal Fire Safety Measures.

8.3 STUDY OF EXTERNAL FIRE SAFETY ASPECTS

Lacunae in external planning of the multistorey structures are illustrated under following heads :

8.3.1 (i) BUILDING SEPARATIONS :

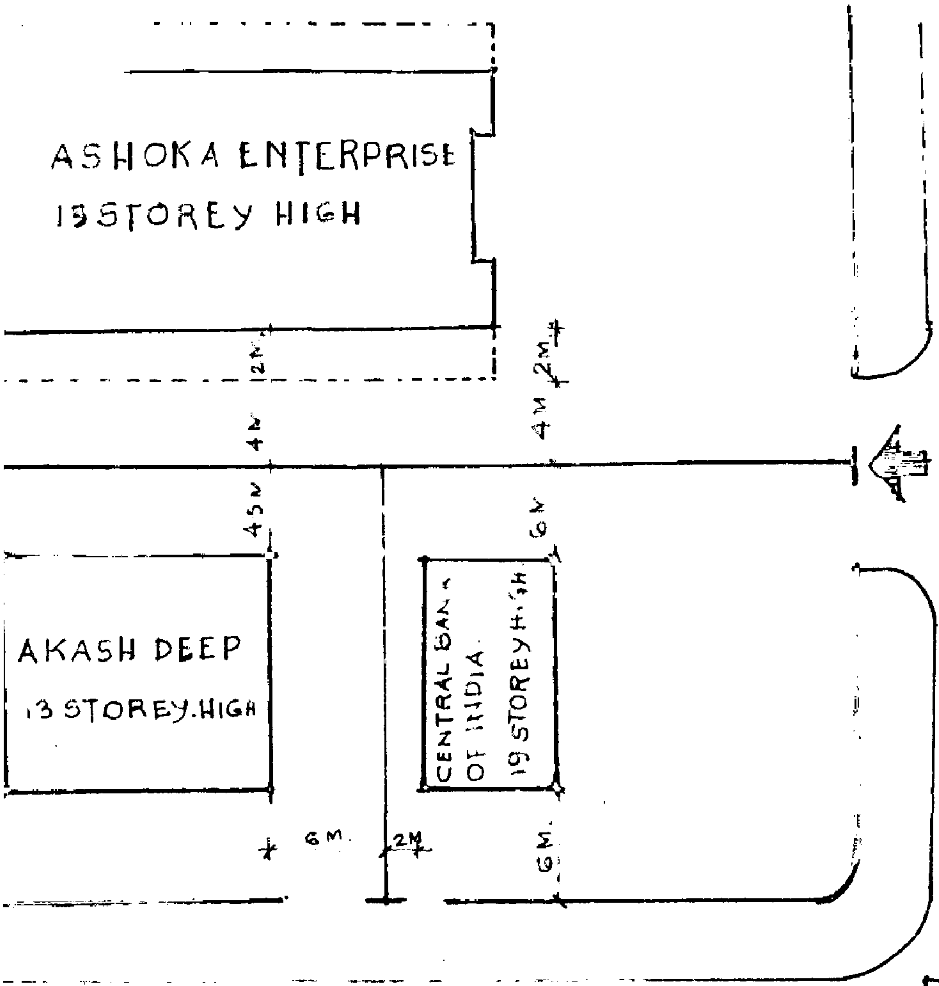
While surveying the multistorey buildings at and around Connaught Place, author has noticed that the building separation distance between the two tall buildings have been mostly not considered by the building authorities before giving permission for erection. This is one of the vital points which may encourage outbreak of fire through radiation from the adjoining building, if it is on fire. Lesser building separation may be permissible only if external walls of the building is well protected by drenchers pipe line which will reduce the intensity of radiation until such time that the fire brigade may reach the spot and controls the fire but at present there is no such installation of drenchers in any of the building.

Photograph (No. 1/A) shows two multistorey buildings on Barakhamba road. On the right is "ASHOKA ESTATE", a 13 storey (39 m) high building and on the left is 19 storeyed (57 m) central bank of India Building (behind C.B.I. building) in the same line is "AKASH DEEP"). The separation distance between these two buildings is the sum of their side marginal open space (See Fig. 14) i.e. (8 + 6) = 14 meter, which is very much inadequate, as per the revised building bye-laws. As per the unrevised building bye-laws of New Delhi which recommends the open spaces around multistorey building as a fixed distances inspite of their different heights which is 50 ft. from the front, 20 ft. from rear and 15 ft from the sides, but the Delhi Teritory and the Greater Bombay Corporation Bye-laws which are revised take into account the proportionate height of the building for the open spaces around. Open space around increases or decreases proportionately in relation to height of the building. (See Table 12).

According to the table the actual safe distance in accordance to their respective heights should have been (12 + 16) = 28 m.

PHOTOGRAPH (No. 1/B)

This photograph is of "Hansalaya" on the right (behind the free foliages) a 23 storey tall (69 m) structure



PHOTNo 1/A

FIGNo 14

OTO 1/B

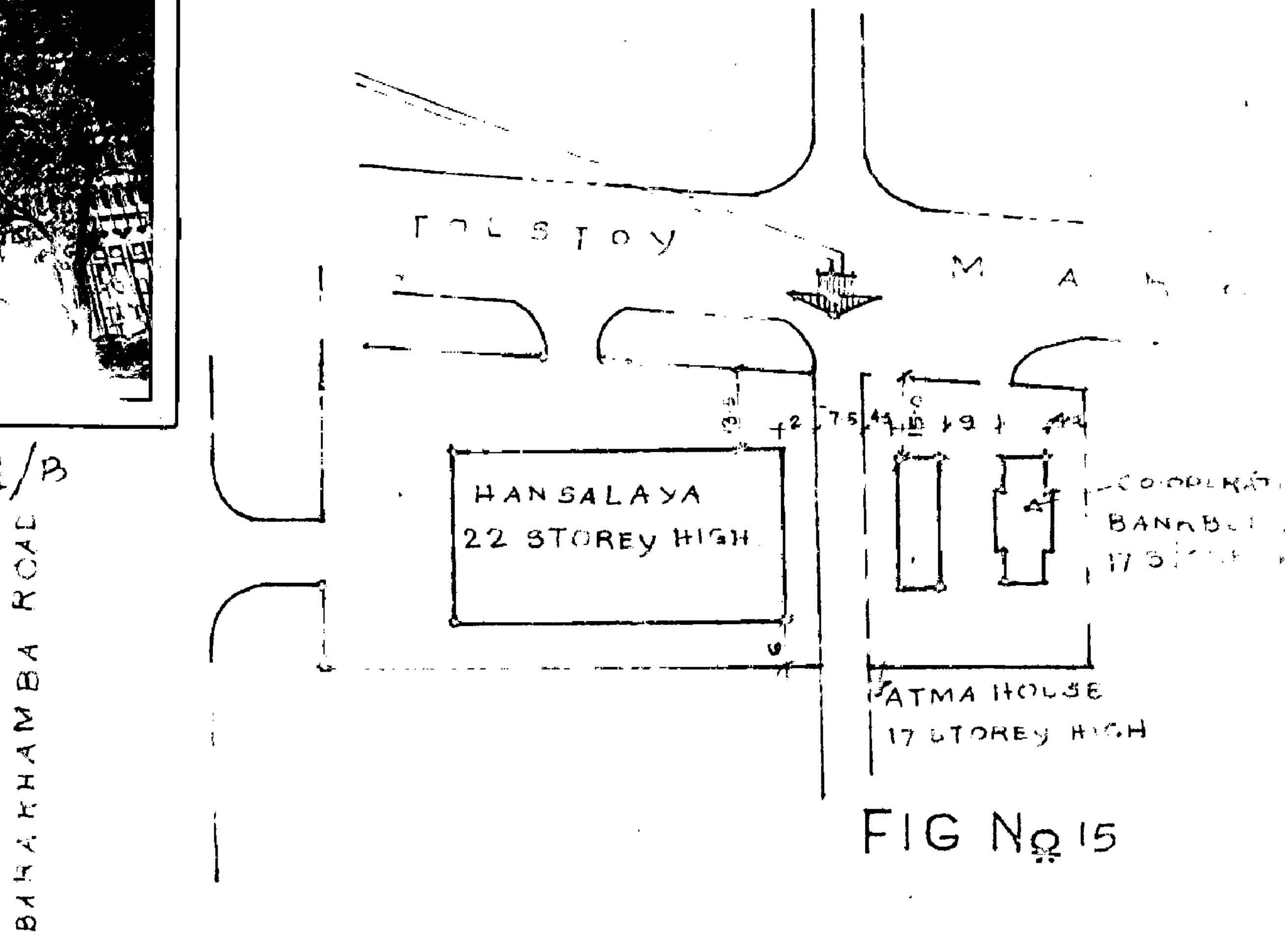


FIG No 15

TABLE - 12

REQUIRED OPEN SPACES FOR THE DIFFERENT HEIGHTS OF THE BUILDING

According to Bombay[72] Revised Building Bye-laws.		According to Union Territory of Delhi[73] Revised Building Bye-laws	
Height of building above ground level.	Required open spaces	Height of Building above ground level.	Required open spaces
ft.	ft.	Meters	Meters
Upto 30	12	10	3
39	15	15	5
45	17	18	6
51	19	21	7
54	20	24	8
60	22	27	9
69	25	30	10
78	28	35	11
80	30	40	12
90	30	45	13
100	30	50	14
120	34	55 and above	16
130	36		
140	38		
150	40		
160	42		
170	44		
180	46		
190	48		
200	50		

on Barakhamba road and on the left is "ATMA HOUSE" a 17 storeyed (51 m) building. As shown in the Fig. 15 the separation distance between the two building (approximately) is (6 + 7 + 5) = 18 m. which actually should have been, according to table (16 + 7 + 14) = 47 meters.

PHOTOGRAPH (No. 1/C)

This photograph shows, two tall buildings on Barakhamba road. These buildings could not be photographed more clearly because of thick trees surrounding the premises (SEE Fig. 16). On the right of the photograph is "Central bank of India building" 19 storeyed (57 m) high and on the left is "AKASH DE building 13 floor high (39 m). It is very surprising to note that the rear set back open space for Central Bank building is only about 2 mt. and thus total separation between these buildings is (2 + 6) = 8 mt. which according to the (Table No. 12) should have been (16 + 12) = 28 meters.

These three examples out of many others indicate that at present these buildings are facing serious possibility of fire spread due to radiation hazards, if fire occurs in any of the adjoining buildings. It is, therefore, suggested that Corporation or Municiple bye-laws should also include and impose, the installation of fire drenchers on the external surface of buildings where possibility of radiation hazard prevails due to nearness of adjoining buildings.

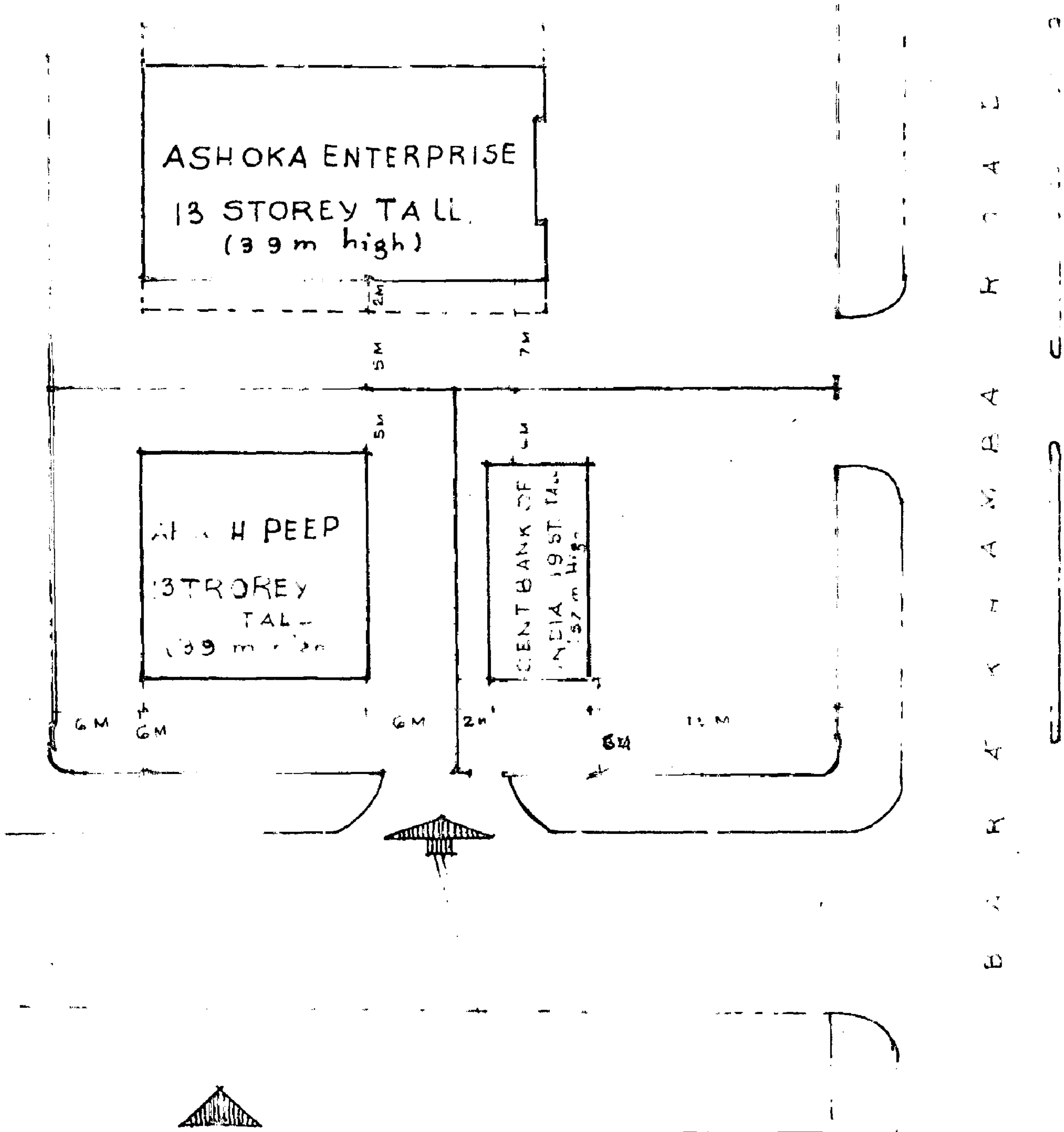


FIG No 16

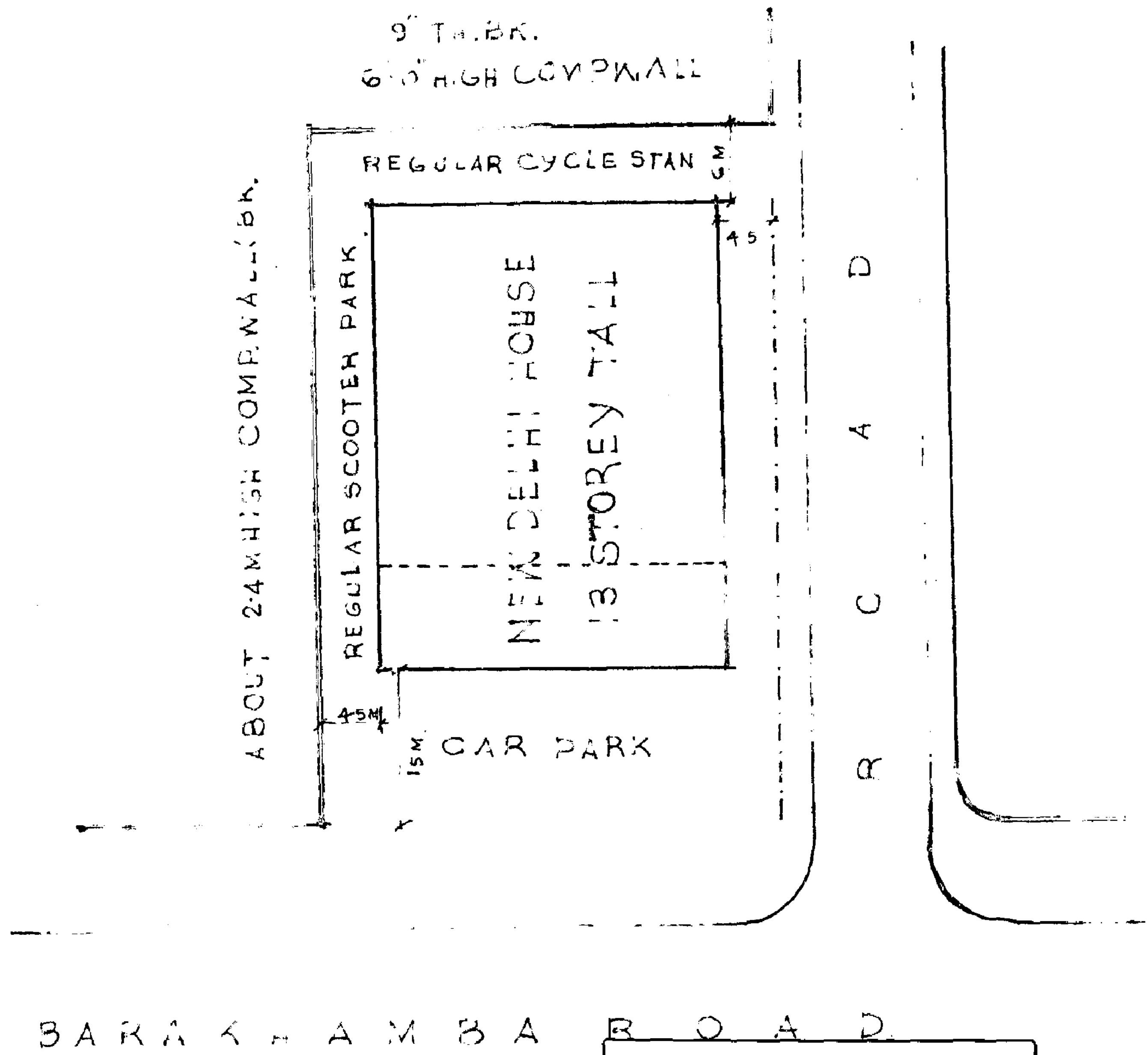
PHOTOG No 1/C

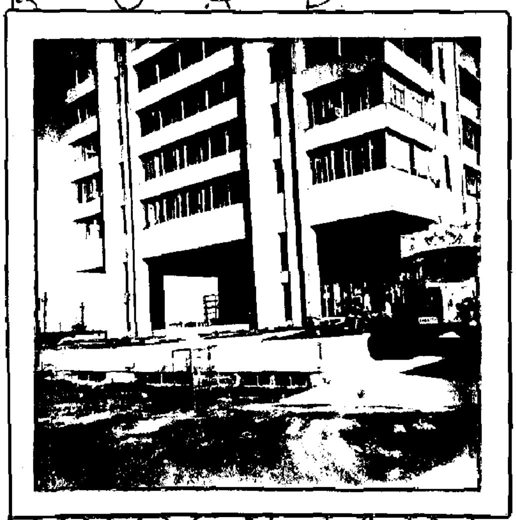
8.3.2 ACCESSIBILITY OF FIRE FIGHTING EQUIPMENTS

The accessibility problem of fire fighting equipments i multistorey buildings is already considered while prescribing t revised open space rules. In Delhi Municipal Building Bye-laws published in 1969, the set back marginal open spaces for Connaught place extension is given as 50 ft. on front, 20 ft. a rear, and 15 ft. on the side of buildings. With compound walls around the building open space of 15 ft. is not adequate enough to permit heavy fire "turn table engine" pumps and water tanker etc. to operate and move to back area or sides of the multistor building.

Over and above these side and rear open spaces of an office complex are fully utilised as scooter and cycle parking during the office hours (See Fig. 17) which will prove hazard for fire fighting and evacuation operation. It is, therefore, suggested that parking rules should be strickctly enforced, in the multistorey structures.

In some of the buildings though there is adequate open space available around the building yet the factor of accessibility is not considered seriously D.D.A's "VIKAS MINAR is one such example. Inspite of the advantage of being in isolation and no building separation problems, this factor of accessibility has been overlooked while providing clear height to the basement floor. In the premises; access to fire engine





PHOTOG No (4/A)

PHOTOG No 4/B

is possible only from the two sides, in the front of the buildi[ng] where there is a provision for open car parking, and to the lef[t] side of building from where, the exit to the vehicles are provided. But on the rear side and side towards school of planning, is not approachable by the fire engine, because of about 3 ft. increased height of basement floors, as shown in th[e] photograph (No. 4/A) and (4/B). This may create serious obstruction in smooth operation of fire extinguishment in case of fire in the building.

8.3.3 ARCHITECTURAL TREATMENTS AND FIRE HAZARDS

In some of the buildings the architectural treatment to emphasise the elevations are such that it may create an obstruction for fire safety and protection activities. Photograph (No. 2/4) is of "NEW DELHI HOUSE" a 13 storey tall structure on Barakhamba road. This building is almost a square plan with about 100 ft. width (approximately) with a central chowk in between. To emphasise the elevational treatment of the building vertical alluminium fins are provided which cover the window openings on all the four facades of the building. These alluminium strips on the first place will be heated very quickl[y] in case of fire and then radiate extra heat, and prevent fire extinguishing and evacuation operation through the windows, in case of emergencies.

"HIMALAYA HOUSE"

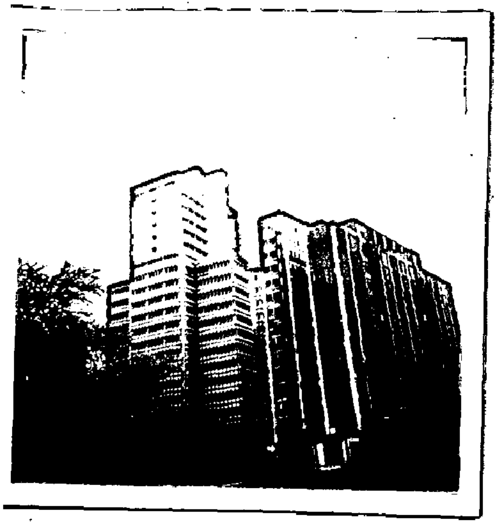
This building is also 13 storey tall on Kasturba Gandh: Road. As shown in the photograph the front facade of this multistorey building is treated with composition out of R.C.C grill work. This may be good enough to improve the architectural appearance of the building, but it also creates an obstruction in the emergency operation of fire extinguishing and evacuation of the occupants through the window openings of front facade, in case of fire in the building (Photograph No.(:

"IRAQI AIR WAYS BUILDING"

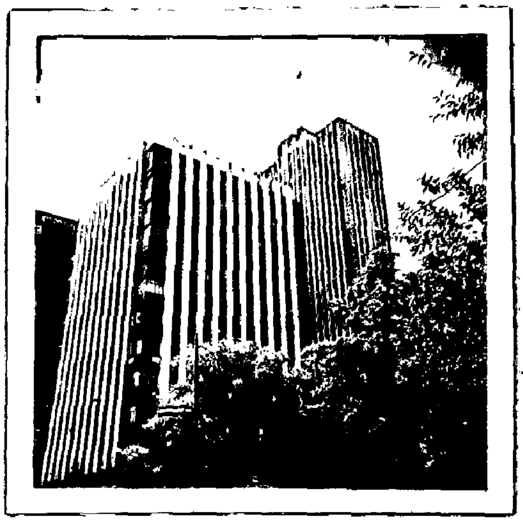
This building is also on Kasturba Gandhi Road and is 13 storeyed tall. In this building as shown in photograph(2/C top three floors are projecting beyond the other on the front facade. In case of fire on the 10th floor; due to the nature of fire spread from floor to floor through windows these projections on 11, 12 and 13 floor will catch up the flames quickly than other floors. There will be additional heat produced in the floor above due to conduction as the projected portion of the floor will be heated with more severity, from the bottom by the flames.

"VIKAS MINAR"

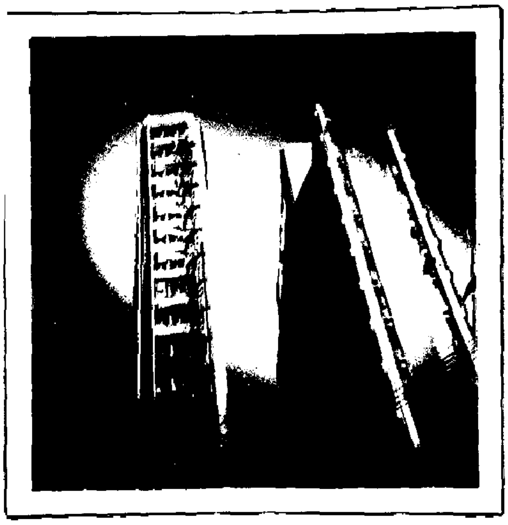
This building is opposite to school of planning and Architecture, New Delhi. This is 22 storey tall structure.



PHOTOG NO 3/A.



PHOTOG NO 3/B.



PHOTOG NO 3/C

PHOTOG NO 3/D

Firo fighting operation will be further affected duo to closo proximity of buildings on both sides, due to insufficient accessible/ space. It is therefore suggested that such factors should also be considered by the municiple authority while giving permission for the construction in any multistorey building.

Another example of the proximity of more than two tall structures is shown in the photograph (No. 3/B) and (Fig. which shows "Central Bank building (19 storeyed) on the right and to the left is 'AKASH DEEP' only at about 8 mt. apart from Central Bank. The third building (which could not be photograp except for a small black strip of corner) is the 'ASHOKA ESTATES' (See Fig.) which again is only about 16 meter away from both of those buildings. Under this situation 'AKASH DEEP' building is fully covered on two sides by Central Bank building on the right and "ASHOKA ESTATES" on the rear side. In case of outbreak of fire in "AKASH DEEP" there will be potential danger of radiation hazard to both of those buildings. Furthermore there will be accessibility problem for fire engines and fire extinguishing due to inadequate open space around.

In contrast to the close proximity and congestion here D.D.A's Vikas Minar presents a feeling of isolation and free environment photo (No. 3/C).

8.3.5 EXTERNAL FIRE ESCAPE STAIR CASE

As shown in the photograph (No. 5/A) the external spiral fire escape stair-case is provided in both the buildings the one on the right is the "ATMA HOUSE" and the other next to it is the "Co-operative Bank" building.

Author is of the view that such type of fire escape staircase is not a very safe practice in a building which is 17 storey tall:-

In case of fire, as it is, people are in panic and confusion, and over and above due to the spread of smoke, occupants may not be able to adjust their visibility immediatel as soon as they come over such staircases, and in a rush of escaping earlier the casulties due to falling down may be possible.

Because these staircases are open type the feeling of t great height from the 17th floor may make some of the occupants nervous. Moreover during the rainy season the staircase is liable to become more slipery and lastly in the night time, in case of electrical failure due to fire, the staircase will remain unlighted and the darkness will further add to the risk of using such type of fire escape stair cases for such a height of building.

8.4 STUDY OF INTERNAL FIRE SAFETY MEASURES

For the purpose of the case study of the Internal fire safety measures in multistorey structures, author has prepared a questionnaire and collected information from the practising architects who have designed, some prominent multistorey struc at Delhi. Out of these questionnaires author has selected abo seven questionnaires and compiled them in a consolidated form in a Table No.   to get an overall idea of the internal fire safety measure adopted in current practices of multistorey structures.

8.4.1 ANALYSIS OF THE STUDY

It has been observed from the Table (No.   ) that for fire safety measures in multistorey structures the only measur adopted is "Fire Hydrant" wet risers system, and some of other very important aspects of fire safety like, fire detector, fir alarms and fire dampers, etc. are totally neglected. Only in the 'Vikas Minar' building there is a provision of installatio of fire detectors and fire alarms on each floor. Author strongly feels that all these measures should have been provid in a building which is of considerable height.

Another fire safety measure which has been not serious considered is fire escape staircase. Kanchalaya inspite of being tallest building of New Delhi has no fire escape stairca

D.D.A's Vikas Minar which is next taller has forced a fire escape in its plan as an after thought, this fire escape has no natural light and ventilation, and probably would prove more fatal than the usual staircase.

In none of the buildings which author has surveyed, has provision of fir e lifts, for the use of firemen to reach the effected floor immediately without introption.

Most of the buildings under study are air conditioned, but none of them has a provision of fire damper which automatically stops the smoke entering the air conditioning ducts in case of the fire.

Water supply from the corporation main is not satisfactory, that is why many of the multistorey structures have their own tubewell, which certainly more reliable source of water supply. For "Dead Water Storage" many structures have combined this storage with domestic water storage. The water discharge ~~pipe~~ pipe for domestic use is fitted at half the height of the tank, which discharges maximum 50% of water and keeps the remaining 50% as dead storage for fire fighting purpose. This prevents stagnancy of the "Dead Storage" water.

Sprinkler system or fire drenchers are not adopted in any of the buildings including "Nehru House" which has an

"International Doll Museum. Author has deliberately included this building in his study apart from its not being a very tall structure. Sprinkler system is probably not adopted because of the economical considerations, unless the controlling authorities make it compulsory for specific occupancies.

For the communication of fire to the nearest fire station all buildings under study have adopted telephone system. This is no doubt very economical, but only when city telephone service is very reliable and efficient and no time is wasted in communication because of the "engaged number or line".

"Service Core", except in "Vikas Minar" in all other buildings under study are taken at the periphery which is good for preventing the additional smoke hazard through service core due to bad ventilation if it is in the centre. However, for "Vikas Minar" a pressurised system is adopted in the central core to prevent smoke entering into it.

Table 13 gives a compiled information about the interna fire protection in the seven prominent building of New Delhi. These informations are gathered on the basis of questionnaire prepared by the author and these were filled up by the respectiv architects or their representatives.

For quantifying the table author has adopted the grade system. Therefore, there are four grades, as following:

At what distance is motor main from the building	Is there sprinkler system is used on any floor	Is drencher fixed any where in the building.	Any special water supply for drencher or sprinkler	Is there fire detector fitted on every fl. if yes at what location	Is there public alarm system if yes at what location.	What is the system of communication of fire to nearest fire station	Approximate distance from nearest fire station	Any visual guidance envisaged for occupant in case of fire	If yes at what ht.	In what colour	their location.	Is building divided in vertical fire zone	How these zones are separated.	Is there any fire compartmentation in the building	If yes whether compartments are vertical/ horizontal or both	Type of Construction of building and fire rating.
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
4	5	6	7	8	*9	10	11	12				13		14		15
Own tube-well at about 20'-0" from plot line	No	No	No	Yes at the ceiling of every fl.	Yes every floor	By telephone	About two furlongs	No	No	Nil	No	Yes	By means of res-[illegible] floors	Yes No	Horizontal within the rooms	R.C.C. frame with cent. core 4 hrs.
(A)	-	-	-	(A)	(A)	(C)	(B)					(B)		(C)		(B)
About [illegible]00'-0"	No	No	No	No	No	By telephone (C)	1/4 mile (B)	Yes (C)	4'-0"	Red colour	every fl. at strategic location	-	-	No	-	R.C.C. frame struct. 4 hrs. (D)
(F)	-	-	-	-	-											
About 15' from plot line (A)	No	No	No	No	No	By telephone (C)	About 600 yds (B)	No	-	-	-	No	-	No	-	R.C.C. frame struct. 2 hr. (C)
	No	No	No	No	No	By telephone	will be located shortly at 1/4 mile (C)	No.	-	-	-	No	-	No	-	R.C.C. frame structure 2 hrs.
(A)						(C)										(C)
Own tube-well	No	No	No	No	No	By telephone	1 furlong	Yes	7 ft. ht.	Red colour	Near at all exits	Yes	By service floor at 16th floor	Yes	Horizontally in room only	R.C.C. frame with service core 4 hrs.
(A)						(C)	(B)	(C)				(B)		(C)		(B)
About ~~6[illegible]~~ 60 ft.	No	No	No	No	No	By telephone	About 0.5 kmt.	No	-	-	-	No	-	No	-	R.C.C. frame struct. 2 hr.
Own tube well 15 ft. from plot line (A)	No	No	No	No	No	By telephone	About one furlong	Yes	7 ft.	Red colour	On all exit doors & stairs	No	-	Yes within the office blocks	Horizontally within the [illegible]	R.C.C. frame struct. 2 hr
						(C)	(B)	(C)						(C)		(B)

Fire hour rating of the				Fire escape stair-case provided.	If yes its location	What is fire rating for stairs	What is maximum distance from stair to any room or place	Fire lift is provided	Is it powered with special power supply	Type of electrical fittings	Is there any generator for fire emergency	Does generator has separate power connection	Is it obligatory to obtain permission from fire authority	What are general remarks of fire authority	Location of service core in the centre or periphery	If in the centr... any provision for safe...
...ame ...ruc-...re	floors	Load-bearing wall	For partition wall.													
29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
				16				17		18	19				20	20
...3.	4 hrs.	4 hrs.	1 hr.	Yes (C)	Within centre	Two hrs.	About 30 ft.		-	Concealed conduite type (B)	Yes (B)	Have separate	They are the guiding authority.	Nil	In the centre core (B)	The C... tral ... is pr... souri...
...3.	4 hrs.	8 hrs.	1 hr.	Yes (B)	Rear side	Two hrs.	About 60 ft.	Nil	-	Concealed wiring (B)	Yes (B)	Yes	Yes	-	At periphery in the entrance oby	- nat... vent... tion...
...1.	2 hrs	2 hrs.	1 hr.	Only one t.case	-	Two hrs.	About 70 ft.	nil	-	Concealed wiring (B)	Yes (B)	-	Yes	--	At periphery (B)	Natur... ve ti...
...	2 hrs.	2 hrs.	1 hr.	Only one t.case	-	One hr.	About 50 ft.	nil	no	Concealed conduit type (B)	No	-	Yes	-	At periphery (B)	Natur... ve ti...
...a	4 hrs.	2 hrs	1 hr.	Only one t.case.	on the extreme end of Bldg.	Two hrs.	About 100 ft.	No	-	Concealed conduit type (B)	Yes (B)	Have separate ...	yes	-	At periphery (B)	Natur... vent... tion...
...	2 hrs.	2 hrs.	1 hr.	One st. case.	-	Two hrs.	70 ft.	No	-	Concealed conduit type (B)	No	-	Not then	-	At periphery (B)	Natur... venti...
...	4 hrs.	4 hrs.	1 hr.	Yes (B)	On rear side	Two hrs	About [illegible] ft.	No	-	Concealed conduit (B)	Yes ([illegible])	Yes	Yes	-	At the periphery (B)	Natural ventila...

Is there any provision of air conditioning dampers	No. of pumps for water supply for fire fighting and supply to hydrant. No. of standby pump for emergency.	What are the provisions for first-aid fire fighting.	Where it is located and what type of extinguishers.	Grading of building according to average marks.	
				Marks for Grading. Excellent = A = 4; Very good = B = 3; Good = C = 2; Poor = D = 1	
47	48	49	50		
	22	23			
No	One pump for supply one standby (A)	Three types of fire extinguishers portable hose reel (B)	Near staircase lobby portable type	A - 6 x 4 = 24 B - 8 x 3 = 24 C - D - 4 x 2 = 8 Total 56	Total heads for rating = 24 ∴ Average = 56/23 = 2.43 ∴ Building is graded B for [illegible]
No	One pump for supply (B)	Portable fire guns and hose reels (C)	Near the exit on every floor portable type	A - 1 x 4 = 4 B - 10 x 3 = 30 C - 4 x 2 = 8 D - Total = 42	∴ Average = 42/23 = 1.82 ∴ Building is graded "C" for fire protection
No	One pump for supply One as standby (A)	~~Average~~ Hose reels and fire extinguishing guns (B)	Near staircase lobby	A - 3 x 4 = 12 B - 5 x 3 = 15 C - 3 x 2 = 6 D - Total = 33	∴ Average = 33/23 = 1.43 ∴ Building is graded for fire protection.
No	One pump for supply only (C)	Fire extinguishing guns and hose reels (B)	Near staircase lobby	A - 2 x 4 = 8 B - 7 x 3 = 21 C - 3 x 2 = 6 Total 35	∴ Average = 35/23 = 1.52 ∴ Building is graded 'D' for fire protection
~~[illegible]~~ No	One pump for supply (C)	Fire extinguishing guns and hose reels	On each floor at staircase lobby.	A - 3 x 4 = 12 B - 8 x 3 = 24 C - 4 x 2 = 8 Total = 44	∴ Average 44/23 = 1.91 ∴ Building is graded 'D' for fire protection
No	One pump only for supply of drinking water (C)	Portable fire extinguishers on every floor near staircase	One each floor with hose reel at staircase lobby	A - 1 x 4 = 4 B - 6 x 3 = 18 C - 4 x 2 = 8 D Total = 30	∴ [illegible] = 30/23 = 1.30 ∴ Building is graded 'D' for fire protection.
No	One pump for supply	Portable fire fire extinguishing [illegible]	One each floor near staircase lobby	A - 2 x 4 = 8 B - 10 x 3 = 30 C - 3 x 2 = 6	∴ Average = 44/23 = 1.91 ∴ Building is graded "D" for fire protection

Excellent	-	A	=	4	marks
Very good	-	B	=	3	marks
good	-	C	=	2	marks
poor	-	D	=	1	marks

The total heads which are considered for marking are 23, which are marked separately on the table. Author has given grade to individual heads on the basis of its efficiency and reliability. At the end of the table, total value is worked out. From these total average grade points are worked out and thus the building can be put ~~in~~ to that particular category so far as the fire protection measures are concerned.

From the compiled value and the grading it can be noted that except the D.D.A. Vikas Minar all other Buildings in the table falls in the poor category and grade D.

On the basis of this table author conclude that fire protection and safety measures in most of the buildings at New Delhi are very poor and these need serious attention of building authorities. With such safety measures the life of occupants are in great danger in case fire breaks in any of these buildings.

8.5 STUDY OF SOME OF THE FIRE SAFETY ASPECTS OF "HANSALAYA" AND ITS VERIFICATION IN ACCORDANCE TO NATIONAL BUILDING CODE.

Author feels that the case study of multistorey structures will not be complete without having a complete idea about checking or verifying the fire safety aspects of a building in accordance to National Building Code. For this purpose author has selected "Hansalaya" being the tallest structure of New Delhi. Due to limitation of time it is not possible to take more number of examples and verify. However, the method adopted will hold good for all multistorey structur and thus it will be a matter of exercise. The aspects which are considered for the study are, occupancy and type of construction, Max. F.A.R. permissible according to N.B.C. trav distance, capacity of Exits and exit width.

"Hansalaya is a twenty three storeyed structure designed by M/s Kothari & Associates Architects on Barakhamba road, New Delhi. This study basically is meant to give an ide for verification of the safety measure in accordance to the Na National Building Code regulations on fire protections which a listed in the Appendix. C.

8.5.1 OCCUPANCY

(TABLE 14)

Sl. No.	Group	Occupancy	Floor Details
1	H	Storage	Basement & Ground floor (Parkin
2	F	Mercantile	1st floor (Shopping) Minor occupancy to be grouped wi
3	D	Assembly	2nd floor & top floor (23rd Fl.) (Restaurant) Minor occupancy to be grouped As 2nd Fl. with E and top Fl. with A-5.
4	E	Business	3rd floor to 15th floor (12 floors) (Office)
5	A-5	Residential	17th to 22nd floor (5 floors) (Hotel)

Note: 16th floor is the service floor

8.5.2 PREDOMINANT OCCUPANCIES

(TABLE No. 15)

Sl. No.	Group	Type of Occupancy	Floor details
1	H	Storage	Basement & Ground
2	E	Business	1st to 15th floor
3	A-5	Residential	17th to 23rd floor

8.5.3 TYPE OF CONSTRUCTION

The building is of R.C.C. structural frame which has fire resistance of 6 to 2 hours, depending upon other structural components. Taking the average of 4 hrs. as composite fire resistance for the whole building the type of construction will be classified as Type 1.

A brief of parking and floor areas of the building as obtained from the architects office has been given in Appendix A

MAXIMUM F.A.R. permitted as per N.B.C.
(Refer Table 1 N.B.C.

GARAGE ARE NOT INCLUDED IN F.A.R.

(TABLE NO. 16)

Predominant Occupancy	Total floor area (ft^2)
E - 1st to 15th floor	175485.56
A-5 17th to 23rd floor	22532.00

Area of Plot after road widening = 49954.8 ft^2

∴ F.A.R. for group E = $\frac{175485}{49954} \times 100$

= 351

& F.A.R. for group A-5 = $\frac{22532}{49954} \times 100$

= 50

F.A.R. 351 is permissible for group E since the construction is Type 1.

F.A.R. 50 for group (A-5) is allowed in all types of constructions will be the same throughout the building.

Total F.A.R. of 496 is also permissible

(Predominant occupancy group E) since the construction is of type 1.

8.5.4 MAXIMUM TRAVEL DISTANCE ALLOWED
TYPE OF CONSTRUCTION

(TABLE NO.-16)

Occupancy type	Permissible	In Hansalaya (Appendix A)
E	45 m	44 m
A-5	22.5 m	22 m

Special exit requirements for both types of occupancies.

(i) There should be minimum 2 exits accessible from each floor as remote from each other as possible.

But Hansalaya provides only one exit (one stair-case) throughout its 23 floors although the maximum travel distance from any quarter to this stair-case is well within the permissible limits.

8.5.5 CAPACITY OF EXITS

Stairways N.B.C. specifies the following :

(TABLE NO. 17)

Occupancy	Occupants per unit width (50 cm.)	Min. Occupant load m^2/p
A-5	25	12.6
E	50	10.0

EXIT WIDTH CALCULATION FOR HANSALAYA

(TABLE 18)

Occupancy		Area/fl.
A-5	5593 ft^2	514.5 m^2
E	10665.53	981.2 m^2

Occupant load for (A - 5) = 514.5/12.5
= 40

Occupant load for (E) = 981.2/10
= 98

.˙. Exit width for (A-5) = 50/25 x 40
= 80 cm

Exit width for (E) = 50/25 x 98
= 100 cm.

Hence the min. stair width

In Hansalaya, the stair width is 150 cm which is well above the minimum permissible.

8.5.6 FIRE LIFT

One fire lift with a lobby approach and with self-closing fire doors should be kept reserved for the fire fighting personnel to enable them to reach the required floor immediately and take charge of the operations.

But no such lift is provided in Hansalaya.

C H A P T E R IX

CONCLUSION AND RECOMMENDATIONS

9.1 The composite picture, that emerges from the study carried out in the proceeding chapter indicate that objective of any fire oriented design is to benefit and safeguard the interest of the occupants. Irrespective of its type of construction, when a multistorey building is used for an occupancy which involves a fire hazard higher than the degree of fire safety provided by its type of construction, it becomes necessary to impose supplimentary fire safety precaution upon its use. Such precautions may consist of limiting that building in size, requiring greater seperation from adjacent buildings, requiring smooth protected exit route and fire escape, requiring compartmentation for confinement of fire, requiring automatic fire extinguishing equipment, such erection in certain congested area of the city where danger of spread of fire is great. These limitation necessarily depend upon the amount of disparity between the degree of fire safety afforded and degree of fire hazard that exists in that occupancy and building under consideration.

9.2 "The statistical report of Bombay Fire Brigade reveals that in 1907 and 8 fire calls were only 115 involving property worth 33 lakhs was destroyed or damaged as against 3,590 fire calls in 1960-69 involving property worth over 499 crores 76 lakhs. of this property worth one crore 4 lakhs were damaged

490 crores 72 lakhs"[74]. Though these figures reflects the efficiency of the fire protective methods and safety measures adopted in recent years. Yet ~~much~~ author strongly feels that so far the multistoreys stru-ctures are concerned, these aspects are miserably neglected by the owner, because these measures do not provide any financial returns.

9.3 First, and foremost requirement for fire safety is well designed, properly located exit routes and fire escape staircases, but unfortunately these are not provided in most of the buildings. Fire on one of the multistorey building at New Delhi on Barakhamba Road on July 22nd reveals the fact that our buildings are very much unprotected and unsafe, author wishes to quote the statement made by the senior fire officials on the 22nd July 1976 fire on Barakhamba Road, it says"the casualties could have been avoided, if the people had not panicked. There were no fire escape routes, provision for water or ventilation to let out the fumes.

Multistoreyed buildings in the connaught place area are virtual death traps in case of fire. Alternative stair-cases are not provided and there is no provision for fire fighting aids.

If a major fire was to break out in any of these buildings, fire official would only be able to watch the fire spread and take its toll, without being able to do any thing"[75].

Author therefore feels that the fire regulations and bye-laws of all major cities should be revised and strictly enforced on the construction of multistorey buildings.

9.4 The study of the national building code of 1970 Chapter IV suggest that though the main purpose of the code is to provide healthy and safe living in the building, it has cared more for the building and less for the people who lives in it. Code suggests of coating an exposed steel work with fire proof paints, but not show concern for the building which is filled with highly combustible furnishings and equipments of the people.

9.5 Building by laws of most of the city corporations, do not provide adequate open spaces around the multistorey building. These bye-laws suggest fixed open spaces for the front, rear and sides, for without considering the height of the building. As the building grows higher it needs more open space, for the fire fighting operation and evacuation with insufficient open spaces, accessibility of fire engine becomes difficult. It is only in the Development Control Rules of Greater Bombay" has rightly revised the the open spaced requirements, this in consideration of above mentioned problems, this rule is on page 6, Table XXVII and suggest the open space around the building to their proportionate height; beyond 100 feet height 1 foot of open space is added for addition 5 feet in height to the maximum of 50'-0". This bye-law apart from accessibility, also solves the building separation or exposure hazard problems during fire in the adjoining building. Author, therefore recommends that the open space requirements of the multistorey buildings should not only be considered for light and ventilation, but also, for accessibility of fire engines and appliances, and the building separations to prevent exposure hazards. Therefore present byelaws of all major city corporations which do not satisfy above condition need revision.

9.6 External walls of the modern multistorey building are full of windows, which are having less fire resistance time, when building is under fire, these windows create a weaker link and thus create a puncture, which encourages to configuration hazards, and give way to smoke. Present National Building Code do not have restrictions on the maximum area limits for window opening. As the number and area of the openings are more building may react more factor to the configuration hazards. Therefore author suggests that along with the present window opening rules there should also be limitation on the percentage of the maximum openings, with required fire resistance ratings of the windows on external wall.

9.7 The reusability of the building after the fire within a shortest time is an important factor to be considered. This will be possible only when there is provision of quick and easy repairs of any possible damage to the structural parts of the building. These aspects are therefore to be considered at an earlier stages of design. The solution may be material dependent and may also require a study of structural system.

9.8 In multistorey buildings the staircase and lift enclosures are designed, both at the periphery of the building or in the central core. With fire safety point of view at least one side of the staircase enclosure should remain ventilated from atmosphere directly. This helps in venting the smoke out. On the contrary in the central core ty pe of planning of st,ir and lift enclosor, the central core area is blocked from all sides, a nd in case of fire, smoke which can not go out creates hazard and to avoid this the mechanical pressurised system is to be adopted, which ultimately means an additional cost of installation and maintenance of pressurised system. It is, therefore, suggested that peripherial location of staircase and lift enclosure will be more functional and economical under Indian conditions.

9.9 "First-aid" fire fighting appliances are most important equipments to fight fire at the ~~critical~~ initial stages. It is, therefore, very essential to keep these equipments at a place from where it can be immediately located. Designers should therefore be very careful as not to hide these equipments to ensure better interior. During fire maximum safety is centred at the escape routes and staircases to see that every occupant should escape out before the fire has gone out of control. It is, therefore, very essential to keep these "first aid" equipment near the stair case.

9.10 Inspite of being most dependable and efficient fire extinguishing system, sprinkler system is not very popularly used in our country, mainly because of the eco nomical considerations. Places where important documents are kept, banks and places of any precious and rare collections, etc., should be provided with automatic sprinkler equipments for fire safety. The excessive cost of sprinkler installations can be compensated to some extent by the permissible increase of 50% in travel distance of exit routes. The installation of sprinklers may also attract people to pay more rent, but be secured and safe from the fire.

9.11 In the Municipal Corporation and from planning bye-laws F.A.R. have been specified only in terms of the occupancy group. The type of construction used for the building for the same occupancy goup group. The type of construction used for the building for the same occupancy group is not given any differential treatment, and only one value of F.A.R. is given for one occupancy. This aspect need a review taking fire safety measures in account.

9.12 It has been observed that many of the extinguishing agents are corrosive in nature. Therefore, all fire appliances coming in their contact should be taken care off and should have periodical check up, otherwise it may prove dangerous at the time when emergency demand them.

9.13 If partial occupancy can occur before completion of the building, special attention to fire safety again during this period is needed.

9.14 During the fire all occupants are warned and guided through the landspeakers which are fixed on each floor for quick escape and neccessary instructions are given to them through these landspeakers, while signalling/warning/guidance methods should be adopted taking Indian conditions in account, like literacy, multiplicity of languages spoken, read and understood.

9.15 It is necessary to place the multistorey buildings not only according to the occupancy or building classifications, but also taking into account the distance of the nearest fire-station, approach roads, size of water main and its pressure etc.

9.16 Multistorey structures for mixed occupancy should be discouraged.

9.17 Such ~~architecter~~ architectural features which add to the fire risk or hinder fire fighting operations sh ould be avoided.

9.18 Normally it has been observed that after the fire extinguishing operation a large amount of water remains collected in and around the premises, which is due to poor drainage system. This may be suitably provided at all levels

9.19 Water is the cheapest and the best fire extinguishing agent, where it can be used. Still in some of the places the water sup ly through the corporation main do not have sufficient pressure to fulfil emergency requirement of multistorey structures during fire. In such places it is advisable to provide a "tube well" within the premises. This will be more reliable source of water supply during any

9.20 Apart from all possible efforts to avoid fire by preventive and curative measures, an occasional visit by the fire brigade inspector to all multistorey building will make considerable difference. This may help in finding out the type and the nature of the cumbustible materials or furnishings the occupants brings with them.

The fire brigade inspector will also inspect and check the emer ency fire fighting equipments and its maintenance. In addition to this he should also check up the general building condition and the equipments used in the building, like A.C. system, water supply, electrical installations, lifts etc.

These precautions and periodical checkups will further reduce the possibility of fire in multistorey structure considerably.

Author, in this dissertation has tried to assimulate and analyse the standard trends, researches and prevailing practices pertaining to fire safety and fire protection in multistorey structure, and hopes that the information of this dissertation may serve as a hand book for fire protection and safety measures in the multistorey structures design.

This dissertation to state modestly gives a broad guideline for fire safety and protection. Each of the chapters needs detail investigation and could be a dissertation by itself.

—

APPENDIX - A

s of Human Life		Loss of Animal Lives			No. of special service and resane calls.		
1971	1972	1970	1971	1972	1970	1971	1972
8	4	-	1	-	-	-	-
53	50	94	41	33	474	635	697
2	4	-	-	-	14	2	16
-	-	-	-	-	93	125	131
40	41	-	-	-	602	790	802
10	12	10	12	10	10	7	15
20	16	2	2	1	91	91	89
8	21	19	17	109	54	32	35
1	-	-	-	-	-	-	-
-	1	4	-	10	1	1	5
6	4	90	31	81	-	2	1
4	5	4	23	2	56	58	41
1	3	1	2	--	-	-	-
-	-	-	-	-	-	-	-
25	127	-	-	-	718	800	709

APPENDIX- B

" HANSALAYA "

OFFICE BUILDING
15, BARAKHAMBA, NEW DELHI.
For SHRI HANS RAJ WADHRA

KOTHARI & ASSO., 65-G CONNOUGHT CIRCUS

AREA & PARKING PLAN
Drawing dated 16 Aug., 1970

vered area (basement)	=	30,966.45	ft^2
vered area (G.F.)	=	24,467.05	ft^2
closed area (G.F.)	=	5,225.08	ft^2
rmissible area	=	5,366.	ft^2
vered area (First Fl.)	=	21,463.75	ft^2
a of lifts on (First Fl.)	=	353.00	ft^2
vered area (Second fl.)	=	10,144.56	ft^2
vered area (Typical fl.)	=	10,665.54	ft^2
vered area (for 16,17, 18, 19th fls.)	=	5,653.00	ft^2
hine room	=	733.62	ft^2

Height. ft.)	No. of Floors.
Basement	1
G.F. (Parking)	1
1st (shopping)	1
2nd & Top Floor (Restaurant)	2
Typical Floor (Office)	12
Service Fl.	1
Hotel Floor	5
	23 Floors.

APPENDIX - A

Name of the states Fire services.	No. of the stations.	No. of Fire calls received.			Loss of property			Loss of Human Life			Loss of Animal Lives			No. of special service and resque calls.		
		1970	1971	1972	1970	1971	1972	1970	1971	1972	1970	1971	1972	1970	1971	1972
1. Kerala fire force.	17	575	708	718	24.3	36.2	50	9	8	4	-	1	-	-	-	-
2. Tamil Nadu Fire service.	63	4490	4935	5412	70.28	137.2	123.0	40	53	50	94	41	33	474	635	697
3. Poundichery	3	124	131	184	1.074	2.149	5.545	13	2	4	-	-	-	14	2	16
4. Mysore state.	16	910	962	1166	66.067	83.963	66.173	-	-	-	-	-	-	93	125	131
5. Bombay.	14	2004	1792	2346	2.22	5.71	3.05	.50	40	41	-	-	-	602	790	802
6. Thana Mumiciple.	2	210	138	154	22.31	11.2	15.11	7	10	12	10	12	10	10	7	15
7. Indore	8	338	387	464	1.14	0.70	2.91	37	20	16	2	2	1	91	91	89
8. Bihar	21	685	598	812	1.111	1.242	1.121	24	8	21	19	17	109	54	32	36
9. Central Railway.	16	211	242	360	4.00	5.85	7.85	-	1	-	-	-	-	-	-	-
10. West Railways.	20	293	240	273	7.97	5.85	8.87	1	-	1	4	-	10	1	1	5
11. Jammu & Kashmir.	27	691	508	444	101.69	83	75.01	9	6	4	90	31	81	-	2	1
12. Tirpura.	6	264	325	253	8.62	9.59	6.5	-	4	5	4	23	2	56	58	41
13. Andaman/ Nikobar.	3	42	33	36	2.03	0.11	0.38	-	1	3	1	2	--	-	-	-
14. Kandla Port Tust.	-	8	11	21	1.05	0.85	2.7	-	-	-	-	-	-	-	-	-
15. Delhi.	-	3027	2723	2903	53.59	5234	79.16	41	25	127	-	-	-	718	800	709

APPENDIX- B

" HANSALAYA "

OFFICE BUILDING
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Height. (ft.)	No. of Floors.
Basement	1
G.F. (Parking)	1
1st (shopping)	1
2nd & Top Floor (Restaurant)	2
Typical Floor (Office)	12
Service Fl.	1
Hotel Floor	5
	23 Floors.

Original Size of plot	=	56365.5	ft^2
Size of plot after road widening	=	49954.8	ft^2
Permissible F A R	=	4.	
Area on F A R	=	199819.2	ft^2

FLOOR	AREA IN FAR	AREA NOT IN FAR
Basement	Nil	23803.0
Ground	--	22467.0
Ground (enclosed)	5225.10	
First Floor	21465.75	
Loft	--	3532.0
Second floor	10144.56	
Typical floors (13x10665.53)	138652.15	
Service floor	--	5993
Hotel floor 4 x 5593	22532.00	
Machine room floor	--	733.62
	198017.00 ft^2	

F A R used = 3.96

PARKING

Open parking	=	54 cars
Area available	=	13743.87 ft^2
Area required	=	13500.00 ft^2
Covered parking (G.F.)	=	52 cars
Area vailable	=	15515.8 ft^2
required	=	13000 ft^2
Basement parking	=	
A Cars = 34	..	8500
Scooters = 70	..	2100
Cycles= 770	..	11550
Area required	=	22150
available	=	25182.45 ft^2

APPENDIX - C

FIRE PROTECTION PART IV NBC 1970

Scope: 1.1 covers requirements of fire protection of buildings through the classification of buildings based on occupancy and type of construction, and their requirements.

1.2 also covers the exit requirements of all occupanc

3. Classification of buildings based on occupancies

A- Residential --	1. Lodging or rooming houses.
	2. One or two family private dwellings.
	3. Dormitories.
	4. Apartment houses (flats)
	5. Hotels.
B- Educational --	School college, etc.,
C- Institutional	1. Hospitals & Sanitaria
	2. Custodial institutions - homes for aged and infirm, convalescent homes orphanges.
	3. Penal institutions - jails, prisons, mental hospitals, reformatories.
D- Assembly	1. Theatrical stage + fixed seats for over 1000 persons.
	2. Theatrical stage + " " for less than 1000
	3. Without stage - capacity : 300 or more
	4. Without stage. Less than 300
	5. Rest.

E - Business	Used for transaction of business, doctors dentists, news stands, lunch counters serv less than 100 p. Barbershop, beauty parlo city hall, town hall, court houses, librar
F - Mercantile	Shops, stores, market for display & sale o merchandise, wholesale or retail, office, storage & service facilities incidental to sale of merchandise.
G - Industrial	1. Low hazard industries 2. Moderate hazard 3. High hazard
H - Storage	Ware houses, cold storages, freight dept. transit shdds, store houses, truck and marine terminals, garrages, hangers, grain elevators, barns, stables.
Note:	Storage properties are characterised by the presence of relatively small number of person in proportion to the area.
J - Hazardous	Storage & manufacture of natural gases inflammable liquids etc. amunition, explosives etc.
Note :	A cert. of occupancy shall be necessary, before any change is effected in the charactor of occupancy of any building.

4. <u>Types of construction</u>

Type 1 -	Structural components with F.R. $\frac{3}{4}$ 4 hrs.
2 -	F.R. 3 $\frac{1}{2}$ HRS.
3 -	F.R. 2 - hrs.

5.2.2 City divided into Fire Zones:-

1 - Comprising of A + B + C + D + SMALL E & F

2 - E + G1 + G2

3- G3 + H + J

overlapping fire zones - major portion of bldg. to decide.

5.6 <u>Restrictions on type of const.</u>

F.Z. 1 to conform to Type 1,2,3, or 4

F Z 2 1 , 2 , or 3

F Z 3 1 or 2

6. General requirements

6.1.2 Max. floor area to conform to Table:

<u>Table 1</u> . F A R for bldgs. facing one public street of 9 m. width.

UL - Unlimited

NP - Not permitted.

OCCUPANCY	TYPE 1	2	OF 3	CONSTRUCTION 4
A	UL	200	140	100
B	UL	200	140	100
C	UL	150	100	80
D	UL	100	70	50
E	UL	290	230	160
F	800	180	140	100
G	750	190	160	130
H	600	150	130	100
J	280	110	90	NP

6.1.2.1 Each portion of a bldg. separated by 1 or more contin ous fire resisting walls, having a fire of not less than 4 hrs. extending from the foundation to 1 m abov the roof at all points at all points may be conside to be a separate bldg. for the calculation of max. p missible ht. and floor area provided that openings in separating wall are also protected by fire assemblies

Open spaces & max. height shall conform to the req irement of part III General Bldg. requirements.

6.1.5 Fire stop or enclosure of all openings.

6.1.6 Fire detecting & extinguishing system in buildings of such size, arrangement or occupancy that a fire may n itself provide adequate warning to occupants, automat fire det. and alarm facilities shall be provided.

6.1.6.2 Water supply for fire fighting.

(a) Hydrants installed in all bldgs. over 24 m. in and in all bldgs. over 60 m. in ht. andspecial pump arrangements shall be made.

(b) All the arrangement to be in accordance with (I

(c) Source of water - upto 60 m ht.

each hydrant fed by a pump rated to deliver 2275 1/mm. pump shall draw its water from a storage of not less than 200,000 lt. in addition to (d) (e) below.

- above 60 m in ht.

to ensure that there is pressure of 3 kg/cm^2 at each of the top most hyrants. -- PRV to the provided at lower points to avo underirably high pressures.

) Emergency water supply to tank :-

Storage tank provided with 150 mm fire brigade pumping in connection to discharge at least 2275 l/m into the tank.

1.7 Lighting & Ventilation to conform to Part VIII Sect.1.

1.7.1 A /c & V. systems installed to minimise danger or spread of fire, smoke or fumes.

1.7.2 A/c syst. circulating air to more than one floor or fire area shall be provided with dampers or designed to close automatically (done through heat sensitive dvices) and to stop fans in case of fire unless fans are designed to remove smoke.

7.3 A/c serving large assembly (over 1000 p.) hotels (over 500 ro photo-electic control established.

7.4 Smoke venting facilities in windowless bldgs. underground structures large area factories shall be automatic in action.

7.5 Natural draft smoke venting shall utilize roof vents or wall vents near ceiling-- normally to be open- if closed to be provided with automatic opening in case of fire-- such as fusible links etc., (h. s. devices).

6.1.7.6 Smoke venting facilities for exit safety to have exhaust equipment for a 5 min. air charge.

6.1.8 Installation of Chimney & heating apparatus to conform to IV(9)

6.1.11.2 <u>Surface finishes</u> :

Class 1 - Surfaces of very low flame spread :- on which not more than 19 cm effective spread of flame occurs.

Class 2 - Low fl. spr. 30 cm. first 1½ unit 60 cm fl. value.

Class 3 - Medium fl, spr. cm. first 1½ unit 85 cm. first 10 min.

Class 4 - Rapid fl. spr. 30 cm. first 1½ unit 85 cm. first 10 min. exceeding these two limits.

6.1.11.3 <u>Use</u>

Class 1 - Any situation.

Class 2 - Except on walls & ceilings of stair-cases and passages.

Class 3 - Only in living room and bed rooms (not in rooms in the roof). and only as lining to sold walls and part: tions. Not on stair-cases and corridors.

Class 4 - used as ceiling lining if the ceiling is : from the upper surface of floor below and walls conform to class 1.

- not used in kitchens, passages, staircase: (excluding materials containing bitumen) Ref. (IV 4)

6.1.12 <u>Glazing</u>- Refer N B C

6.1.14 Fire lifts :- To be provided for bldgs. over 24 m to have 6 passenger capacity min. fully automated with emergency swit ground level.

7. Exit Requirements

7.2 Types : Doorway corridor passageways to an internal or external staircase or t verandah or terrace which have acc to the street or to the roof -- als link with another building. Lifts & tors are not considered exists.

7.3 Arrangement: Max. travl dis. to an exit (in meter

<u>Table 2</u>

OCCUPANCY	A	B	C	D	E	F	G	H	I
Types 1&2	22.5	22.5	22.5	30	45	30	30	30	22
Types 3&4	22.5	22.5	22.5	30	30	30	30	30	22

If provided with sprinklers -- where this is not p requirement the dist. increased by 50%

The T.D. to an exit from dead end of a corridor sh be ½ the dist. specified (max) except in B.C.D.

7.4 Capacity 50 cm. = 1 unit 25 - 50 = ½ unit
(width) Less than 25 not considered

Table 8. OCCUPANTS PER UNIT EXIT WIDTH

OCCUPANCY	A	B	C	D	E	F	G	H
Stairways	25	25	25	60	50	50	50	50
Doors	75	75	75	90	75	75	75	75

If sprinklers provided when not required by code, capacity/storey/unit width of exit of stair ways increased by 50%.

If horizontal exit provided, capacity/storey/unitwidth exit of stairways increased by 50% in F,H,G,D.E. type of occupancy & in C by 100%

When both provided, capacity, to be doubled.

7.5 Mimimum occupant load ta ken for calculations:-

OCCUPANCY	OCCUPANT LOAD (m^2/P)
A	12.5
B	4
C	15
D (a) with fixed seats	.6
(b) without fixed seats including dining rooms	1.5
F (a) St. floor & sales basement	3
(b) Upper sale floors	6
E & G	10

load of mezanine to be added to main floor

7.6 Number of exits :- Min. 2 exits serving every floor area above and below floor 1 (G.F.) at least one of them internal enclosed stairway.

7.7 Exit Doorways - Min. 100 x 200 (ht)..
Overhead or sliding doors not allowed revolving door allowed only in some occupancies, exit door way to open outward.

7.8 Corridors & Passageways - Min. equal to width of exit doorway throughout where stairways discharge in corridor the height of corridor (min.) = 2.4 m.

7.9 Interior staircase as a self contained unit with one side external wall.

Staircase round a lift not allowed

Min. width 100 cm.

Min. tread = 25 cm. Max. rise = 19 cm

Max. No. = 12 per flight.

Head rails ht. (min.) 100 cm.

7.10 Fire escapes or External Staircase :-

not taken to account while calculating evacuation time of a building.

all fire escapes directly connected to the ground.

Min. width - 75 cm.

tread - 15 cm. riser max. = 19 cm.
max. No. of risers = 16 per flight

hand rails - 100 cm.

spiral fire escape - low occupant load, & bldg. ht.=9mt.
min∅ 150 cm. with adequate headroom.

Roof exit : in all bldgs above 3 storeys and sloping roofs less than 20^{o} access to be provided rontinuous from the street.

Horizontal Exit: width equal to that of exit doorway. to be equipped with at least one fie door of self-closing type.

7.12.3 Fl. area on the refuge side to serve fully the danger si allowing min. 0.3 m^2/P.

of the refuge portion at laast one door to lead directly to exterior or street.

links not to be provided with steps - but ramps in case difference in levels max. 1 in 8 slope.

7.13 Fire Tower : must for multi-storyed bldgs. (over 6 store or 25 m. in ht.)

at least one means of egress shall be fire tower walls w 4 hr. F.R.

Ramps - greater than 1 in 8 not allowed

bet. 1 in & 1 in 8 - non - slipping material to be used.

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