UNIT 24
FIRE PROTECTION

Structure

24.0 INTRODUCTION

"Ignore safety and the problem won't go away. But you will."

This appeared in Graffiti, which is a boxed item usually in the penultimate page, *The Times of India*, Delhi Edition, June 12, 1998. We do not know the name of the Commentator, the item is from Asia Features, but we felt his pity observation is an appropriate beginning for this unit, presumably, the comment relates to all aspects of safety, of which safety from fire forms a most important part. In the previous unit on principles of tire safety, we have discussed the chemistry and physics of fire and then went on to consider the phenomena of combustion and explosion. We elaborated on the concepts of exposure and hazard and then ended with the hazards of electrical heating and lighting.

We will begin this unit with life safety, the most important objective in a tire situation. A stairs and it's in buildings are vital fix safe evacuation of the occupants; our discussion? on this aspect would be quite detailed. Next, we would study how fires spread in a building, and then dealt with in the fire-fighting operations. This would lead us to the various fire detection and extinguishing methods like sprinklers, hydrants. extinguishers, buckets and so on, as also fire watchers, who can help a great deal by discovering the fire at the inciting stages. We would then consider some specific fire situation like tires in tall buildings, assemblies, etc. Finally, we take up the matter of testing and maintenance because the first would enable us to know whether or not our systems satisfy the design criteria while the second would ensure its response when it is needed at the time of an emergency and then include a review of fire-damaged buildings along with measures for rectification.

24.1 Objectives

After studying this unit, you should be able to

- determine the number and features of the exits and stairs,
- understand the manner of fire spread and the need to isolate and separate exits
- Know the methods of detection and extinguishment of fires, learn the tire characteristic in specific tire situations like tall buildings, assemblies, etc. and the protection measures needed there, and
- Know the Methods of testing and maintenance of the systems.

24.2 LIFE SAFETY-EXITS AND STAIRS

Life safety is the main purpose, to fulfill which other facets of tire safety work of course, there is the need to save property as well; but, if lives are lost, the other measures of fire safety are of no avail. Thus, in the event of a fire, life safety would mean adequate arrangements in a building to enable people to set out safely. The aim is to ensure that the occupants of the building move to a place of safety, which is ultimately outside the building.

It is therefore necessary to have escape routes. which are adequate for the number of people involved, are easily found out, and are clear of any kind of obstruction at all times. it is also necessary to know the problems faced in this regard so as to overcome them with suitable measures, and thereby ensuring reliable means of escape. Moreover, there are instances. both in India and abroad, in which deficiencies escape routes gave rise to very heavy loss of lives. The codes, good practices and standards that have been formulated out of these tragic disasters are largely piecemeal and arc the only guidelines to follow. We briefly review these incidents noting the effects of their short comings on life safety in particular and tire safety in general.

24.2.1 Notable Fires in Delhi Region in 1990-99

We have limited our discussion to Delhi: not because it is the capital city, but the details of the fire are well known. As for the incidents which resulted in laws in England and elsewhere, we mention two along with the legislation's they brought forth. We mention these incidents in order to understand better the issues related to life safety and not as an exercise in finger pointing.

Lal Kuan, Delhi, 31st May 1999: The locality is a busy trading area an old Delhi, near the famous Chadni Chowk. The narrow and are full of traffic, which delayed the fire brigade. The fire down containing extremely flammable chemicals. Eyewitnesses say that I a ball of fire rolled down the street striking down everyone on its path. The immediate death toll was 16, which rose to 57 subsequently. On press report says that the chemical 1 was MEW, was yellow in color and could not be dislodged by the jet of water from a fireman's hose from the surfaces it stuck on.

Uphar Cinema, 13 June 1997: Transformer in the car-park smoked in the morning. Inspection revealed nothing, though the Bucholtz relay was stated to be apparently defective. The transformer burst into flames when the film Border was shown. Smoke entered, trapped people in the balcony, I the fire exit of which was apparently locked. 59 dead due to asphyxiation and stampede.

Dabwali, 23 December 1995: A pandal was erected in a plot enclosed by brick walls where a school function was in progress. The fire, presumable due to a short circuit, engulfed the pandal quickly, and in the resulting stampede for the only exit over 450 died, mostly school children. The person who was the pandal contractor lost 6 members of his family.

Vigyan Bhavan, July 1990: Though no lives were lost, this fire knocked out of service the country's premier venue for international conferences and the like for a time. There was no sprinkler protection and apparently quite a lot of wind panels. Although the National Building codes, 1970 say that only materials with the lowest flame-spread ratings are to be used in such assemblies, apparently the recommendation was not followed.

24.2.2 Fire which Brought Forth Legislation

Theatre Royal, Exeter, 1887

This fire resulting in the death of 186 persons brought forth the law on safe exits in public places.

Paris Charity Bazaar, 1897

121 died in this fire as the exits were not marked. The provision relating to marking of exits in licensing rules was the result.

24.2.3 Specifying the Requirement

Initially, the laws stated that there should be adequate means of escape without specifying what is considered adequate. Because providing a means of escape in a building at the design stage is not difficult. It is however, not possible to know what would be the conditions during a fire. The exit routes could be blocked, outsiders unfamiliar with the building may go round and actually stumble into the fire and exit signs could be obstructed from vision. All these constitute the first of the three fire control problems, the answer to which is the creation of fire safety awareness. The second problem is people-oriented and thus hard to resolve. Inspire of being alerted about the fire, people would still delay their departure, to finish the work they were doing. Even though clear instructions are there, they should still go to the wrong places. Here the need is for education, telling that a small fire could grow big in a short time and kill people, the third control problem illustrate the as advantages of being very specific. If this is done rigidly, then there is at the basic problem may still remain unsolved. Anyway, probably taking a cue fireman eighteenth century law which stipulated that ail inns and hostels in England should have one, two, or three-story high ladders to enable residents to escape from a fire, provision ~f means of escape was made a condition of license for cinemas, because the films in use at that time were highly flammable. There after the unit of exit width was decide by observations in public places and fixed at 22 inches or 50 cm as at present.

In explosions or after the' first shock of earth quake, there is not much time for people tap take evasive action, while in hurricanes forest fires, volcanic activity people get some time to flee. Building fires fall between these two, just time enough to get out in most of the incidents. Also, death in fire is due to the inhalation of the toxic products of combustion, notably carbon monoxide. The exposure could be prolonged due to lack of mobility or poor visibility due to smoke-logging. Delays could also be due to lack of information on the state of the fire, that is, how serious it is. Also, could be due to sleepiness, drunkenness disability, etc. Again, researches have shown that people are neither of unpredictable behavior pattern, nor do they always act as role models. Taking all this into consideration, the objective of the means of escape provision has been set as to:

1. provide sufficient number and adequate safety routes from all parts of the building so that people can move away from the source of danger in a direction which take them away from it, ultimately taking them to a place away from the building.
2. make the exit routes sufficient in number and width, so that there is no possibility of congestion;
3. ensure that the exit route from the farthest point does not extend beyond a certain limit, say, 30 in or 100 feet;
4. protect the exit routes inside the buildings from the effects of fire in the building; and
5. make the routes clearly recognizable by prodigal illuminated signs.

Moreover, there are two features (though they are not expressly regarded as design criteria) Witch are taken into consideration while devising safety routes. There are people characteristics and building characteristics. The people characteristics consists of awareness familiarity and ability, while building characteristics relate to height and shape. Thus, awareness means whether the people are fully awake or not. If aroused from sleep, then better safety provisions are needed than when they are fully awake. Similarly, familiarity means whether they are familiar with the building layout and are able to find the escape1 route on their own. If not, then good directional signs showing the escape routes are necessary. Ability means whether they can escape unaided, that is without the help children, elderly and physically disadvantaged people so often need. In building characteristics, the height of the building, the shape and size of its floors and their compartmentation or fire separation are considered. The height affects the degree of protection needed for the vertical escape route. The greater the height of the building, the more will be the need to keep its vertical escape route clear of flames and smoke. The shape of d e floors is important in the sense that in an uncomplicated floor, where free circulation if possible, the horizontal escape route will also be uncomplicated. If, however, circulation is tortuous, so will be the escape route, compartmentation of division of a large area into relatively smaller sizes, has not much effect on the horizontal routes excepting that if the divisions are tire-resistive, then a low rating of fire resistance may be provided to the route walls.

24.2.4 Horizontal Routes

The cardink1 principle of selection of escape route is that the person must have the option to choose one from two available routes. If there is only one route, there is the chance that it right lead directly into the fire (Figure 24.1). However, the general principle is that the numbed of routes must be decided after taking into consideration the number of people in the room, and that a large number of small exits are preferable than a small number of large exits. This brings us to the concept of travel distance, which is regarded as the distance a person has to traverse to the nearest point of safety. The "nearest point of safety" could be a place outside the building where the staircase is not fire-separated from the corridors and lobbies on the floors of the building. Where such a separation exits, the point of safety is the staircase core, just beyond the fire-resistive door.

This brings us to consider travel speed, which varies depending on the density of the people on the floor experiments involving a number of disabled persons, speeds ranging from 100 meters per minute to 20m/min have been have served in corridors. About 70 m/min is therefore considered normal, but in such instances the population density was 0.5 per sq. meter of floor area. As the density rises, the speed decreases, and all movement comes to a standstill nearly when the population density reaches $4/m^2$. The exit widths of a door and an exit route have to be sufficiently wide allowing the people to escape without congestion. Anyway, the basis for exit width is number of experiments, which established that through an exit of 22 inches' width it is possible to attain a flow rate of 40 persons per minute.

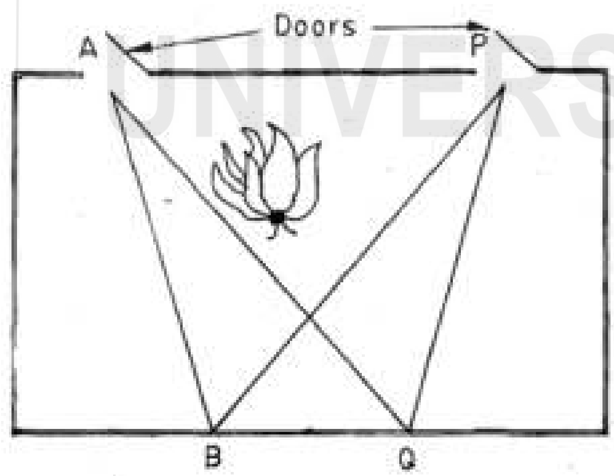

Figure 24.1: Shows Why Two Escape Routes are Necessary, Because One of the Routes From Q is almost through the Fire

24.2.5 Vertical Routes

In tail or high-rise buildings, a number of properly sized and fire-separated stairways ensure the residents exits to safety outside the building (Figure 24.2). They are specified in all codes and standards for multi-storey building in respect of escape routes, giving the details of location, the number, minimum width and the degree of protection. The last item is important considering the degree of hazard present in an unprotected stairway due to smoke and flames rising from lower levels through the openings (Figure 24.3). In fact, such stairways offer the flames and the hot gases of combustion are almost unimpeded passage from the ground level to the top of the building, In the protected stairway the travel speed of the person would be inevitably reduced. However, this is not regarded as of much consequence. Although, strictly speaking, safer usage is a location away from the building, the protected stairway is considered as one because on entering it the person is reasonably sure of going there. As the number of persons increase, there comes a stage when it is not possible for a person to reach the handrail. In such instances, it is necessary be provide a central handrail. It is also necessary for the floors to be at least two times more firing resistive than the walls in duration. Also, as more and more people will join the petson8 coming down from the upper levels, the population density in a protected staircase will be considerably large in the lower levels. This aspect has to he considered while designing the staircase. As regards smoke control and ventilation of %cape routes, we have discussed this aspect in detail in section 24.6.2 of this unit.

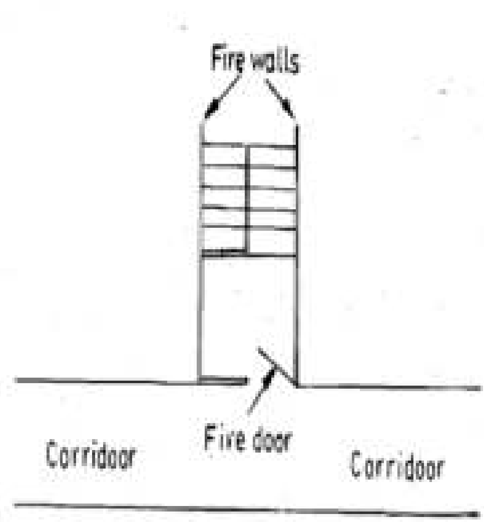

Figure 24.2: A Protected Staircase

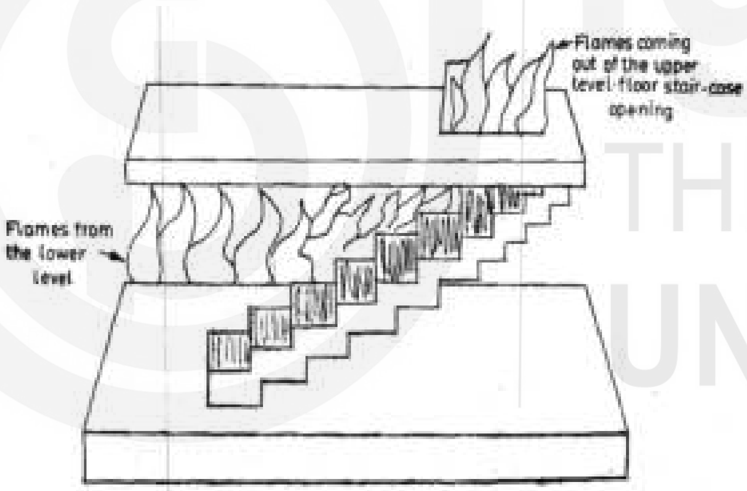

Figure 24.3 Fire Spreading to the Upper Level Unprotected Staircase Openings

24.2.6 Other Relevant Rules

There are a few features town and regional planning which have a bearing on fire safety in a general way. We now review those provisions, as they are given in the National Building Codes, 1970 of the Indian Standards Institution (now named Bureau of Indian Standards) in some details. With regard to zoning, the codes state:

> 'The city or area under the jurisdiction of the authority shall for the purpose of the codes, be demarcated into distinct zones, based on fire hazards inherent in the buildings and structures according to occupancy.'

Then follows the details of the occupancies to be located in the 3 zones:

Zone	Occupancy
Zone No. 1	Residential, educational institutional, assembly, small business and mercantile
Zone No. 2	Business and industrial but excluding high hazard
Zone No. 3	Storage, high hazard, and industrial, where buildings are for hazardous uses.

Next is the classification of occupancies and occupants per unit exit width through doors and stairs. The codes thereafter provide the occupant load for the occupancies along with their respective travel distances.

Sl. No.	Occupancy	No. of Occupants	
		Stairs	Doors
1	Educational	25	70
2	Residential	25	70
3	Institutional (Hospitals, etc.)	25	70
4	Assembly	60	90
5	Business	50	75
6	Mercantile	50	75
7	Industrial	50	75
8	Storage	50	75
9	Hazardous	25	40

It would be seen that in assembly, having regard to the number of people there, the occupant load (0.6 m^2 per person), the Travel Distance (30 m) and exit width (unit) discharge (60 per stairs and 90 for doors) are fairly high. Understandably, the corresponding figures for Hospitals are quite l0w, that is. 15, 25 and 22.5 respectively because quite a number of the residents there would need help from the attendants to move outside.

Occupancy	Occupant Load Gross Area per Person in m^2	Travel Distance in m
Educational	4	22.5
Residential	12.5	**22.5**
Institutional (Hospitals, etc.)	15	22.5
Assembly: Loose seats, Fixed seats	0.6 1.5	30
Business	10	45
Mercantile street level Upper level	3 6	30
Industrial	10	30
Storage	30	30
Hazardous	10	22.5

24.3 HOW FIRES SPREAD

Considerable research and investigation on how fires spread have been carried out under experimental conditions. The data so obtained relate to the growth and development (spread) of fire in those experimental rooms and compartments where mostly wood cribs are burnt to produce a fire (Figure 24.4) There is, however, not much information on a actual fires in buildings. It is also not clear how fires produced by various other fuels are Fire Protected by various other fuels are to be related to those fires in experimental wood cribs. Anyway, by comparing the experimental findings with fie observations in some actual fires in buildings, it has been found that data obtained are not too far from reality floor area involved, fire duration, structural damage due to nominal fire load, etc. are the parameters investigated.

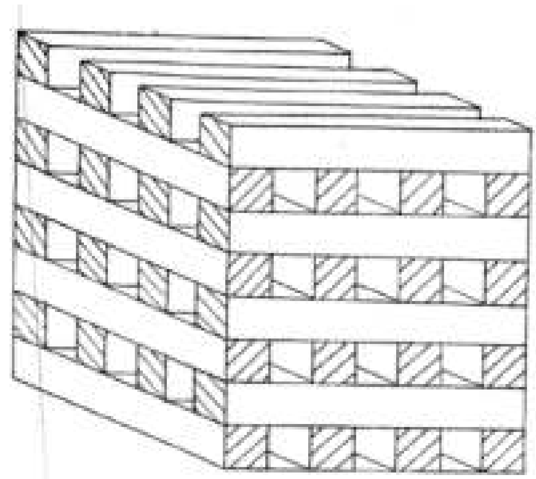

Figure 24.4: Wood Crib for Experimental Fires

24.3.1 Growth and Development

It has been observed that once the flames reach the ceiling and extend horizontally beneath it, the transition from a developing fire to a fully developed fire occurs. It is found to be a critic stage of the fire process. when an increase of 1 m in the height of the vertical flame leads to a 5-7 m extension of the horizontal flames spreading all over the ceiling. As we have discussed already discussed, these horizontally spread out flames in the ceiling radiate a lot of heat on the contents below raising their temperature to ignition level, and they start burning even though they are quite far from the actual seat of fire. Thus, once this happens, a small area of fire can quickly become very large. In an actual fire, when such a state is reached, the chances of fighting the fire from inside the building and saving be contents are remote; while preserving the building by firefighting operations from outside, the chances are slender.

24.3.2 Building Contents

In any building fire situation, it is the contents such as wood, paper, textiles. etc. along with structural elements like wooden beams and rafters, doors and windows, etc., which acts as the fuel. In residences it may not be as significant as in offices, while in industrial premises, it is considerably more because of the presence of combustible materials which might be in process, from a tire point of view, the most important property of the fuel (contents) is the rate of burning or heat output per unit plan area of fuel, in an experimental set-up it is relatively easy to find out that, while in an actual fire incident the rate of burning is rather more difficult to obtain. In any event, it can he found out by considering the amount of the fuel remaining after the fire and the till between detection and extinction. Computing on this basis, it has been found that the rate of burning in the experimental crib tires correspond to that in an actual tire situation where the contents, tightly-packed cardboard boxes, crates, clipboards, etc. represented a moderately severe hazard.

Once the fire has reached the fully developed stage, that is, after it has attained the maximum rate of burning, experiments have shown that the fire will then behave in one of two ways, these two modes of burning depend on whether the rate of burling is controlled by the nature and quantity of the fuel or is limited by the supply of air for combustion. The first is called a fuel-enrolled fire, and the second, a ventilation controlled fire. Firefighting cooperation's in a ventilation-controlled tire is considered more difficult. Because on opening closed areas and rooms, where the contents have been, heated to ignition level but have not yet started burling due to lack of oxygen (air), there would be more air now for combustion, and the whole contents would flash-over, start burning all together, making the fire uncontrollable.

24.3.3 Fire Effects

We now know from experiments that when fire breaks out in a building the rapidity of spread and development will primarily depend on the height of the flame produced, the temperature inside the building, and the intensity of radiation falling on the unburnt fuel near the seat of the fire. As regard? the height of the flame, we are aware that it is directly linked Lo the rate of burning, that is, the more fuel burning per unit plan of area, the more the height. Now, we go back to the hazard classification of industries stated earlier in this unit, and find that (from experimental data) low hazard corresponds to a fire load of below 20 kg of wood per square meter; medium to 20-40 kg/m^2 and high to 40 and above kg/m^2. Our wood-crib experiments show that the transition from developing to developed state occurs in low hazard class after 10 minutes; in medium hazard, within 10 minutes: and in high, within 5 minutes. This is what we knew all along; that in order to be effective tire-fighting should start as soon as possible; that in situations where some quantities of combustibles are present, some in-house protection like hydrants is a necessity; and that where considerable quantities of flammable materials are present, sprinkler/water-spray/special extinguishing system is unavoidable, incidentally, our findings relating to structural damages in low and medium hazard classes show that these are generally limited to 2- 10 per cent. As regards high hazard, there are instances where the loss is nearly total. So, what have we learnt from these discussions?

- **Time:** The time taken to discover and notify or report a fire should be as short as possible. It is not always possible lo install costly protection systems, hut it is certainly possible to employ people and train them to watch out for fires, the details of which are discussed in subsection 24.4.1 of this unit.
- **Separation:** The wisdom in keeping not all the eggs in one basket is proved. The best way to prevent fires from spreading from one to the other building is to keep them separate physically, failing which they should be separated by fire- resistive barriers as already discussed.

24.4 DETECTION OF FIRES, ALARMS, FIRE WATCHING AND FIRE EXTINGUISHING SYSTEMS

24.4.1 Detection of Fires

The basic requirement in a fire fighting operation is to tackle the fire immediately or as soon as it breaks out. So, detection of the fire is necessary as also to know its exact location. Once this has been done, fire detected and location identified, we can launch the firefighting operation. Referring to the ideal time temperature curve (Figure 24.9, our efforts should be to detect and find out the source of the fire within the time T1-T2, As the time span is generally 5 to 10 minutes, it shows how important and crucial are the first few minutes in a growing fire. Once this time period is over, tire usually takes a hold, requiring more efforts to put it out. Ideally, the detection should be instantaneous, which is achieved by automatic detectors. If, however, the fire is seen by a person, there would be home loss of time (usually) before he shouts fire.

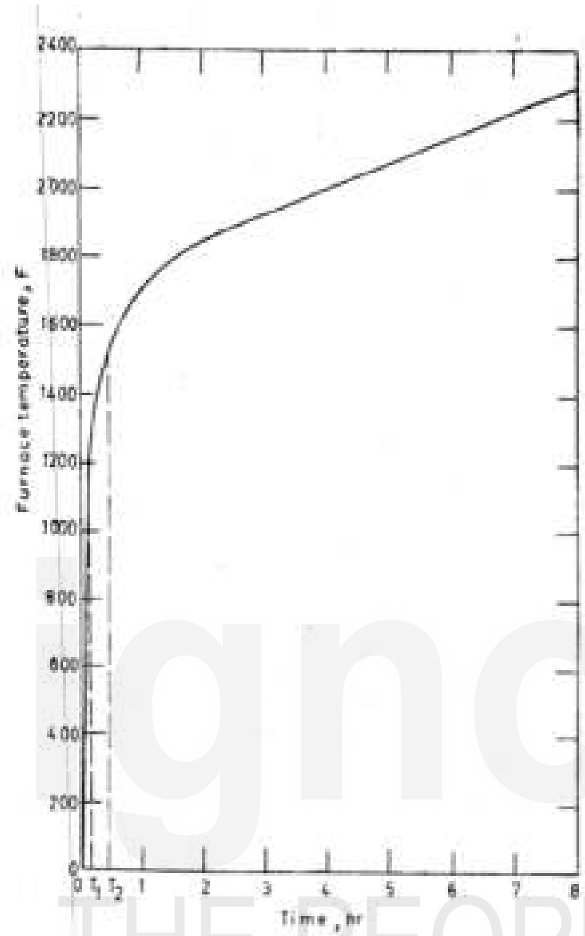

Figure 24.5: Ideal Time-Temperature Curve

i) Fire –watcher: A good pair of eyes, a sharp sense of smell and quick reflexes are the requirements of a fire-watcher, invaluable in locations without detectors. Ideally, he should be from security. watching accidental fires as he goes round the premises. Trained to lock out for incipient fires, smoldering rags raven an electric heater kept on, he would know how to tackle them and to call for help if the fire is big. His scheduled walk round the entire premises (for instance, in a factory) would take him to the process areas, the storage sections and the waste bins. In fact, it would be a good practice to assign fire-watching to a security person in all the shifts in factories or premises equipped with detectors and fire extinguishing equipment.

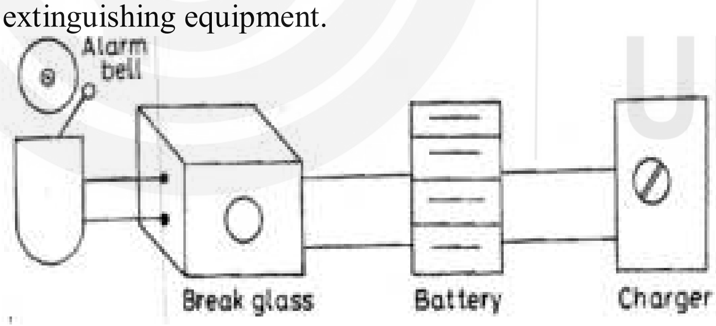

Figure 24.6: Manual Alarm Break Glass System

ii) Fire Alarm stems: Its purpose is to detect and locate fire, which is achieved by a number of call-points in suitable occasions in manually operated systems, and with a sufficient number of detectors placed in different zones to help pin-point the fire in automatic systems. The manual call-points in different **areas** and the detectors in each zone are connected to the indicator panel and control equipment. Consequently, when a call-point or detector is activated, the inductor panel shows its location.

a) Manual Operation: The preferred locations for manual call-points are areas where people are usually present during working hours. The call-points are switch, which are activated by breaking their glass fronts. Normally, such call-points are located near exits, to enable people to break the glass as they go out of the building on seeing a fire. Generally, these are so spaced that no area is beyond 100 ft (30m) of a call-point. Figure 24.6 shows the typical arrangements of a 24V DC battery operated system.

b) Automatic Operation: The eye of an automatically operated system is the detector, while the control equipment and indicator panel (presumably) forms the heart and the head. As we have seen earlier, each detector is placed in a separate zone, the location of which depends on:

- The number of detectors in a zone which the control equipment and the indicator panel can handle,
- The nature of work/processes carried out in the zone (it may be necessary to devote one zone to one room), and
- The dimensions of the rooms, compartment, of floors, their shapes, sizes and so on.

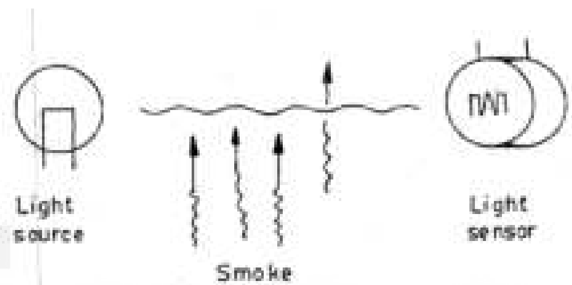

Figure 24.7: Obscuration-Type Detector

Types of Detectors: The detectors watch the zones in which they are installed round the clock for signs of fire, and therefore require no human presence. They belong usually to four broad categories such as:

i. heat-sensitive,
ii. smoke sensitive,
iii. obscuration-type, and
iv. back scattering type.

Heat Sensitive operates when the element inside is heated due to the fire outside to a pre-set temperature. Its other version is activated when the rate of rise in temperature of the zone exceeds a pre-set limit. The area of operation is around 35m^2 and the usual locations are boiler section, labs, kitchens, etc. The rate of rise is suitable for storages.

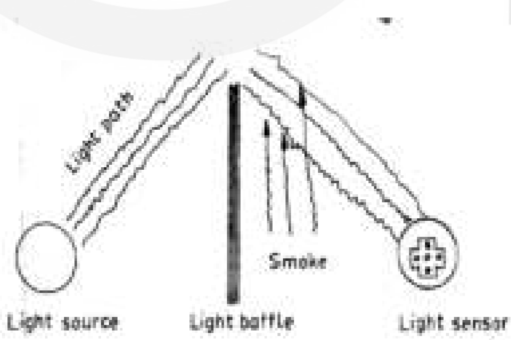

Figure 24.8: Backs Catering Type Detector

Smoke Sensitive operates when there is a minute change in an electrical circuit due to the incursion of very small particulate matter (smoke) in a chamber having an ionized field produced by a tiny radioactive source. The zone area could be as large as 90 m2 and beginning with dwellings and shops and premises it is widely used. However, it gives false alarms in humid conditions.

Obscuration Type: As the name implies, it operates when a light source is obscured or becomes faint. That is, smoke from the fire on entering the detector chamber causes a light beam to change the output of a photocell or photo resistor.

Backscattering Type: Its operating principle is to scatter a light beam by the smoke particles from a fire, thereby illuminating a photocell, which was hither to in the dark.

Figures 24.7 and 24.8 show the operating principles of these last two types in sketches.

The Bureau of Indian standards has publications in regard to automatic tire alarm systems. There IS 2189-1962, Indian Standard Code of Practice for Automatic Alarm System relates to the spacing of the detectors while IS: 2175-1962, is specification for heat motive fire detectors gives the details of the tests to which such detectors are to be subjected.

Table 24.1

Sl. No	Class of Fire	Equipment Needed
	A-Ordinary materials like wood, paper, cloth, etc.	Soda-acid extinguishers and water buckets
2)	B- Paints, oils and grease and such flammable liquids	Foam, carbon dioxide and dry powder extinguisher
3)	C-Gases and electrical equipment	Dry powder, carbon dioxide extinguishers
4)	D- Reactive materials	Special type of extinguishers

24.4.2 Fire Extinguishing Equipment and Systems

There exist a wide array of equipment's and systems to tight fires, beginning with the buckets and extinguishers kept indoors, which are often supplemented by hose reels. To protect the outside areas as also to throw a jet of water indoors, there could be a trailer pump a much more permanent and large water-throwing arrangement of which is found in a hydrant system with risers carrying water to the upper floors. Then there are special purpose water sprays to fight oil fires and the sprinklers for manufacturing areas and divisions with water sprays as gentle as rain.

However, before proceeding further with regard to equipment, we would briefly review the categorization of fires as also the classification of factories and premises according to hazards. The well-known categorization of fires is shown in Table 24.1, while the classification of factories and premises according to hazard depends on the fire load. The fire load as we have seen in the earlier unit, is the calorific value of the contends per unit floor area, Also, in order to regard a low fire load area as separate from a high fire load area, it is necessary to have fire-resistant barriers of 30 minutes, 1 hour, 2 hours and so on, a feature discussed in the previous unit. Accordingly, factories and remises with low, medium and high fire loads are graded as low, medium and high hazard classes.

i) Indoor Equipment: Buckets and extinguishers along with hose reels constitute equipment's kept indoors. so as to enable people to fight fires at initial stages. The buckets are usually of 9 liter capacity and are kept hanging in bunches near the exits. Columns and such other spots. To extinguish a fire with such a bucket of water, it is necessary to go round the fire powering water gently the base, and not throw at one go by inverting the bucker. In that event, the fire is likely to be carried to other areas by the spreading water. Likewise, the jet of the common 9 litre. capacity soda-acid extinguisher should he directed to the base of the fire. For a foam extinguisher used in a, say, burning pall of oil, the stream of foam is to be directed to a side of the pan. allowing foam to float on the surface and gradually covering it. The stream should never hit the burning surface of the directly, as that would cause the oil to splash, thereby spreading the fire.

ii) Small Diameter Hoses in Reels: These are used when the water requirement is more than a few buckets could hold. The installation consists of a spool (reel) mounted on a swivel bracket. About 120 ft. of ¾ to $1^1/4$" internal dia rubber hose is reeled on the spool with one end connected to a reliable water supply, while the other end is fitted will capable of delivering at least 22.5 liters per minute (5 g.p.nl). No portion of the area lo he protected should he more than 6m (20ft) from the nozzle when the hose is fully stretched. Small diameter hoses in reels are unsuitable for locations where electrical or oil fires are the predominant risks.

24.4.3 Installations with Fixed Piping

Factories and premises, where more water is needed than a small diameter hose reel could provide, are normally protected by fixed piping installations. For, say, a light hazard factory of 3 floors and of overall 50 ft (15m) height, fixed risers would be needed for the protection of the upper two floors only, while the ground floor would be protected by trailer pumps. For factories and premises of other grades of hazard, however a hydrant system with fixed piping network at all levels would be required.

Trailer Pumps and Fire Engines: As stated before, trailer pumps and fire engines are useful in low and medium hazard factories and premises with suitable please for keeping them in readiness. The trailer pump is to be towed lo the fire location by home vehicle. While the fire engine is itself mounted on a motor vehicle. There has to be a static lank of at least 45,000 liters capacity from which they would draw water by pumps (delivering 400 gpm at 80 psi in trailer and 700 gpm at 100 psi in fire engines) They carry a complement of 65 mm (2/12) 15 m long (50) hose lengths (12 to 18 mm nozzles ¾ dia) numbering from 6 to 9. Normally one trailer pump is needed for every 5000 m^2 (50,000 sq. ft.) of factory/premises floor area. For the purpose one fire engine is regarded as equivalent of two trailer pumps.

Hydrant System: A hydrant system is the second best among protection methods using water and a fixed piping network (the first is a sprinkler system). As we have discussed in the previous unit for purposes of firefighting water is the cheapest medium. It is plentifully available and with a specific head of 1 cal/^{o} C/gm and a latent heat of vaporization of 540 ecal/gm absorbs a lot of heat from the fire to cool and extinguish. However, to achieve this it has the be applied in the form of time droplets mist which creates problems. Then there is the disadvantage of material gelling wet as also the difficulty in getting rid of the run-off water. Even then a hydrant system has proved to be effective in numerous fires in the past as well a s in the present. Figure 24.9 show a Hogarth paining depiction firefighting in 18th century England. The equipments shown are rudimentary forms of what in today, a water tank pumps (has operated) and pipes and ladder to throw the water. The hose pipes in those days were made of leather. Incidentally, Hogarth used firefighting as metaphor to show the measures taken by the politicians to resolve a crisis.

So, that's what constitutes a hydrant system. A water reservoir of adequate capacity (say, One hour's requirement) a pump delivering the required volume of water (700 or 1000 or more in gpm.) at the desired pressure (generally 100 psi). As we have seen earlier the requirements in a low harzard factory /premises would be less stringent than those of a medium hazard me. Anyway, taking into account all that which constitutes a hydrant system would review them one after another.

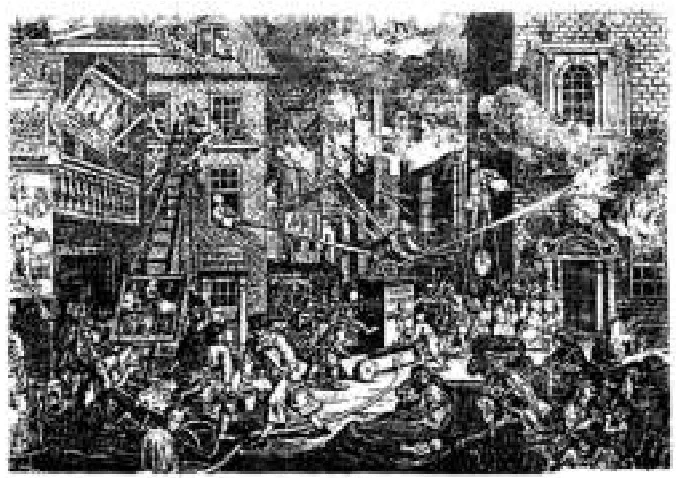

Figure 24.9 Hogarth's Satirical Painting Showing Fire Fighting in 18th Century England a Metaphor

a) **Reservoir:** The reservoir is required to hold the maximum quantity of water that might be required to Fight a tire. Considering the average fire load in a low-hazard factory or premises. it is, felt that in about all hours' time the fire should be under control, if not extinguished. However, no such thing is possible in, say, a petrochemical plant where the fire may continue to burn for hours. As such, in plants of this nature, the required water capacity is 6 hours duration. For medium hazard, the requirement varies between 2-3 hours duration, while high hazard factories require 4 hours pumping capacity. A petrochemical plant is of very high hazard category.

b) **Pumps:** Pumps are generally of centrifugal type, their impellers, wearing rings. etc. are to be of Non-corrosive metals like brass and bronze. Their discharge capacity and pressure vary depending on hazard category and number of hydrant outlets, for 20 such points in low hazard category, a 350 gpm pump delivering at 80 psi would suffice, but a 6.25gpm pump at 100 psi would be needed for about 120 points in a low hazard category for medium hazard, generally 1000 gpm at 100 psi is required, which is increased to 1500, gpm at 125 psi for high hazard. As very high hazard categories normally have more than 100 points, two or more pumps arc needed there. To ensure that the pumps are capable of taking overloads, they are required **to** deliver 1.50% of the of rated capacity at 65% of the rated discharge pressure and their shut-off pressure must not exceed 201L of the rated discharge pressure. In other words, a pump rated to deliver 1000 gpm at I00 psi should also be capable of delivering 1500 gpin at a discharge pressure not less than A5 psi. Furthermore, with its discharge valve shut, it should not develop a pressure exceeding 120 psi.

c) **Prime Movers:** The pumps are to be directly coupled to electric motors or diesel engines of appropriate power outputs. The motors are to be totally enclosed or drip-proof. with direct electrical supply, entirely free of other equipment's there. An alternative arrangement in the event of the failure of the main supply is preferred. The diesel engine has to take full load within 15 seconds after the start must be able to run continuously under full load for six hours. For this purpose, there has to fule enough in its tank to tank to enable it to run for the desired period. Two starting mechanisms, viz. battery-operated and electrical starter motor. are preferred.

d) **Piping:** The pipes are to be laid underground at a depth not less than lm (3 it) from the ground level and are to conform to any one of the following Bureau of Indian Standards:

- Horizontally cast iron pipes IS: 7181- 1974, or
- Vertically cast iron pipes IS: 1537-1976, or
- Spun cast iron pipes: IS 1536-1976.

The pipes are to be laid 2m (6ft) away from the buildings to be protected and are to be hydraulically tested for two hours at a pressure 3.5 kg/cm2 (50 psi) above the maximum working pressure. They are to be laid in rings. their sizes depending on the number of outlets in the network. For instance, in an installation of 100 outlets, the proportion of 100 (4"). 125 mm (5") and 150 mm (6") diameter pipes are to be 35%, 40% and 25% respectively of the total length, cut-off valves are to but provided for in the network to isolate sections for repair and maintenance work. The spacing of the outlets or hydrant points, which are to 1 m (3ft) above ground, depend oil the hard category. Thus light hazard building, there has to be a hydrant for each 60 m (200 ft.) length of its external wall. In medium hazard, the separating distance between two hydrants is 45m (150 ft.), while in high hazard, it is 30 m (100 ft). For the protection of the upper floors of storeyed buildings, two staircases outside are needed for each compartment. Hydrants on rises are to be provided in each floor landings of these stairs. The landing dimension is to be no less than 1.5 m x m (5'x3') which, as we have noted earlier in the section on life safety, is meant as a bridge head for tire fighters to help them to direct a jet of water inside. Likewise, in the staircase, the height of its riser not to exceed 200 mm (8") and the thread no less than 200 mm (8") as also the inclination no more than 60" to the horizontal, is also apparently made for the convenience of the fire fighters. Accessories like 15 mm long (50 ft) hose pipes of 65 mm dia, nozzles of 18 mm (3/4") dia, rubber rings for the coupling joints, etc. are to be provided in adequate numbers. Normally a 20% excess of the requirement is maintained. It is also necessary to maintain a properly trained and adequately manned firefighting squad. Generally, they also look after the routine maintenance of the system.

24.4.4 Sprinklers and Water Sprays

Sprinklers and water sprays belong to the group of protection systems which disc water from fixed points. The difference from the hydrants is thus quite apparent, where the point of delivery is the position of the fire tighter plying the hose-pipe. The two water spray systems (medium and high velocity) also belong to this category the difference is that unlike sprinklers, (heir sprays are ejected with some force. In sprinklers, the spray is more like rain. These systems are used to tight solid fuel fires, flammable liquid fires and combination of the two.

i) Characteristics of the Design: As we have seen in the hydrant system, each it been designed to serve a particular purpose. The water spray systems as also the sprinkler systems are designed likewise. The differenced in some of the items are meant to endow the system with some particularly desired feature. Even then, their overall design characteristics arc the same and may be regarded as made up of the following:

- A reservoir of adequate capacity, sufficient to meet the water requirement of the system
- An arrangement to pump the required volume of water from the storage to the system;
- A network of pipes feeding the distributors their requirement of water without much loss of head or pressure;
- A set of sprinklers/distributors through which flow the required quantity of water to sprinkled /distributed over the area to be protected: and

- A detector or detector system which riggers and activates the system in the event of a fire.

Generally speaking, we can therefore, regard the aforesaid as the components of sprinkler/fixed water spray systems. As in indoor equipments and in hydrants, the deployment varies with the nature of hazard in question. Accordingly, we have here also three broad groups of light, medium and high hazards, there being a further subdivision of high hazard into very high hazard.

a. **Discharge Density and Area:** Having compared the water discharge from a Sprinkler to rain, we can express the total quantity of water (rainfall) which has fallen on the ground as inches or millimeters. This is known as density of discharge and the minimum area over which this quantity of water has to fall per minute (design requirement) is known as area of discharge. Thus, for the protection of low hazard category 2.25 mm of water is lo fall per minute over an area of 84 m^2. The corresponding figures for medium, high and extra or very high hazard groups are 5 mm per minute and 72 to 360 sq. meters; 7.5 to 12.5 minimum and 200 sq. meter; and 7.5 to 30 mm. and 260 to 300 sq. meter respectively.

b. **Flow Rate and Running Pressure:** So, when we specify the density of discharge (rainfall) and the area (over which it falls), there has to be a corresponding minimum flow rate and a running pressure to achieve this. Incidentally, these figures have been obtained by carrying out various tests and the data so obtained have been published by the fire office committee of England and the National Fire Protection Association of USA under various rules and codes, we have, taken the figures from these rules and there is not much difference between them and the NFPA codes.

   Thus, for medium hazard under the FOC rules. We need a flow of 225 liters per minute under a running pressure of 2.2 bar (kg/cm^2) at the installation value plus the equivalent pressure of the water heat between the installation valve and highest sprinkler. For low hazard, the figures could be as low as 1 bar and 47 lit/m. Which in very high hazard, we have to calculate them from the area and density of discharge. Naturally, this leads us to consider the piping needed, which we discuss next.

c. **Sprinkler Piping:** Figure 24.10 shows the usual piping arrangement (of a sprinkler system with water from the supplies entering a self-starting pump and then to the installation stop value, which is to be kept open always excepting the time the system, is shut down for repair/maintenance. Above the stoop valve is the installation valve having two chambers with a flap in between. When the system is in readiness (operational but not operating) the upper chamber is kept at a higher pressure than the lower one which forces the flap to rest on its seat. As a sprinkler opens water from the upper chamber goes out, the flap lifts allowing water from below (and the pump) enters the piping from the upper chamber to the open sprinkler and is discharged as a spray. The

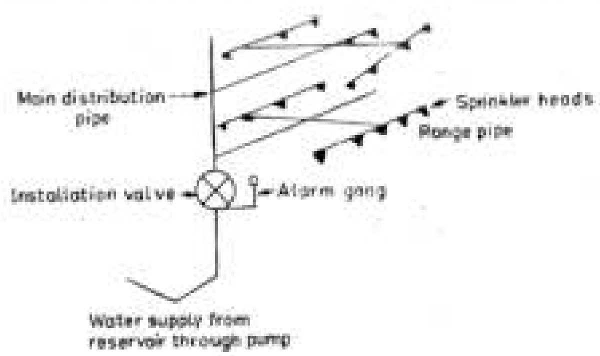

Figure 24.10: General Layout of Sprinkler Systems

flap on lifting uncovers a post on the seat, from which a small bore pipe leads to a water turbine. The turbine shaft has a striker, which hits a gong and thus sets an alarm. Water from the sprinkler falls in a spray on the fire below, while the bell rings indicating that a fire is detected and that the sprinkler system in the fire area is in operation.

d. **Sprinkler Head:** The sprinkler head (Figure 24.11) in effect if a heat-sensitive valve which opens on being activated by the heat (hot gases rising) from a fire, thereby working not (only as a fire detector but also as a distributor of water. Its tapered threaded base (G) is screwed into the range pipe. The discharge opening (o) is kept shut by a spring-loaded valve assembly, which in turn is held by a heat-sensitive glass bull/soldered link (BL) jammed against the yoke (Y). As the heat of the fire grows, the glass bull shatters/the soldered link melts, and the whole thing is thrown clear of the yoke. Water now comes out of the opening under pressure, hits the deflector (T) and then falls on the fire below as a spray. Through the serrations of the deflector (S), some water hits the ceiling, cools it, and then falls below as droplets.

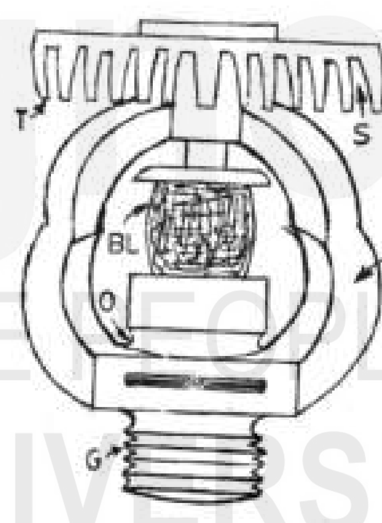

Figure 24.11: Sprinkler Hand

Soldered-strut or fusible link sprinklers are generally preferred in the U.S.A. in view of their low thermal capacity. Thermal capacity, as we have seen in Unit 8 is a product of the mass and specific heat, which for a metallic valve assembly is obviously lower than the one which has a glass bulb with a liquid inside. Consequently, the sprinkler with a low thermal capacity is activated quickly enough say the fusible link/soldered strut type users. The glass bulb users counter the argument that the weight (mass) of the valve assembly is not that great as to make any material difference in the response time. They, however, point out that over the years, there could be a cold flow of the solder/fusible matter due to corrosion, etc. which might result in the sprinkler not operating at all. India both glass bull and fusible link/soldered strut sprinkles are used. The point is that they may not be conforming to any standard and would offer namesake protection, thus inducing a sense of complacency. That complacency, would be costly/fatal depending on what, men or material, was under protection of such dangerously spurious products. So, wherever we see sprinklers, we should ask the standards it conforms to, Bureau of Indian Standards (it accepts both NFPA and FOC) or NFCA or FOC. It should also be necessary to find out whether or not the sprinklers carry any certification mark. Actually, in the National Building Code, 1970 of the Indian standards institution (earlier name of Bureau of Indian Standards) it is stated that sprinklers installed according to good practices would be required. Good practices here mean tried, tested and approved methods followed elsewhere. If there is no certification, it would be better to stay away from the premises protected by such dangerous sprinklers.

Sprinklers usually have nominal operating temperatures, and for a range of sprinklers such a temperature would begin at 57^0C or 1345^0 F. Generally, the highest nominal temperature available in such a range would be 200°C. In addition, there could be special purposes sprinklers with nominal temperature as high as 260^0C; Referring to the Time Temperature curve we find that when the fire is fully developed, its temperature is around 1200^0C (Figure 24.12) in the early stage considering, that this represents only a lapse of about 15 minute of time (T), it is quite apparent how heat-sensitive and quick the sprinkler head has lo $e in order to serve its purpose.

Placing and Spacing of Sprinkler Heads: The rules and codes referred to earlier also give details of placing and spacing of sprinkler heads. Thus, when p denotes the distance between two sprinkler heads in a row, and 01, the distance between the rows (Figure 24.13) then in low hazard class both p and q are equal to 4.6 m, while the area covered by one sprinkler is 21 m^2. This type of array is known as standard type, while (Figure 24.14) represents the staggered type. The staggered type is suitable for medium hazard class where the sprinkler heads are required to he placed within 4 m of each other. Naturally, the area covered by each sprinkler is low, 12 m^2 to 9 m^2 for chemical processing sections. One point of interest is that the placings in the range pipes has to be regular and no sprinkler head is less than distance of ½ p from the walls. Sprinkler heads are available in three opening sizes; 10, 16 and 20 mm.

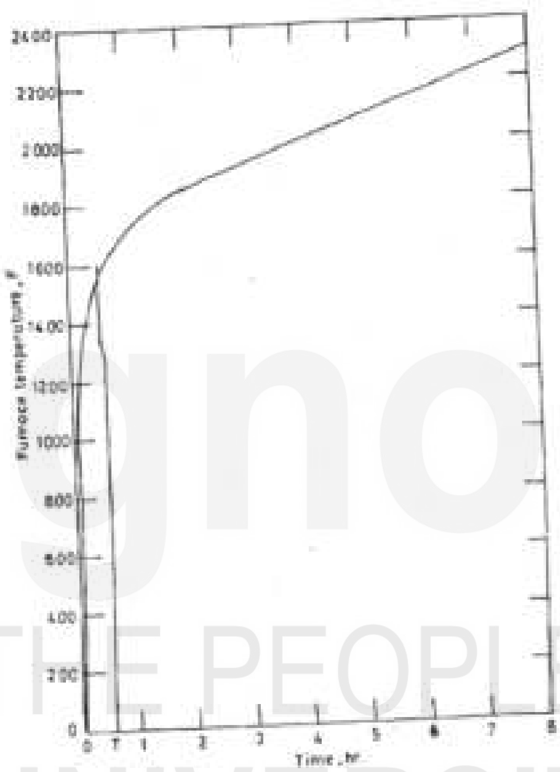

Figure 24.12: Standard Time Temperature Curve

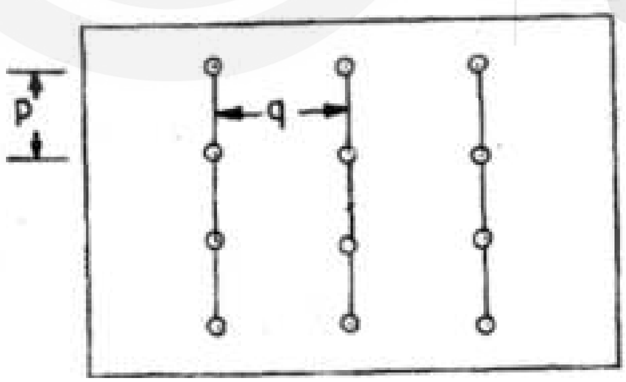

Figure 24.13: Show4ng Standard Arrangement

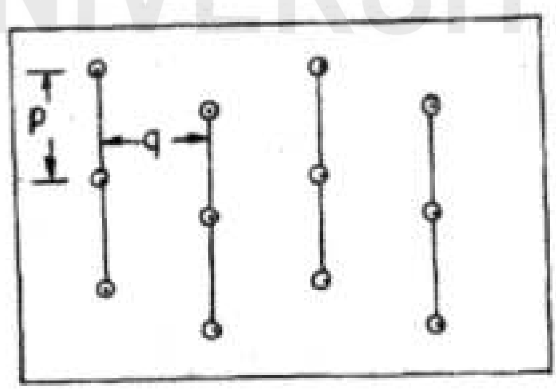

Figure 24.14: Showing Staggered Arrangement

The heads are fitted in the range pipes in two positions. In the upright position the deflector is above the range pipe, while in the pendent position it is below.

Water Sprays: The main characteristic of water spray is that the Water here hits the fire at a greater velocity than it does in sprinklers. AS such, water sprays are meant for use in flammable liquid fires as also fires of a mixed type like the one in an oil-filled transformer. They are also used to reduce exposure risks, that is, to keep cool a tank of liquefied petroleum gas facing the fire in a tank nearly. The principle behind is to release from the distributors water droplets of 0.4-0.8 mm size with enough force to overcome the up draft of the rising hot gases from the fire, pass through the flames and still left with some force to hit surface of the burning liquid so as to form a forth. This formation of froth is what extinguishes the fire because in so doing the water droplets bring down the temperature of the liquid to a level at which continuous combustion cannot be sustained. In other words, the water droplets bring down the temperature of the liquid below its fire point. Water droplets hitting the surface would be at once converted into steam, giving rise to a boil-over which would cause the burning oil to splash and spill, thus spreading the tire in all directions. To avoid such a possibility, the spray system has to be very quick in operation so as to serve its purpose effectively.

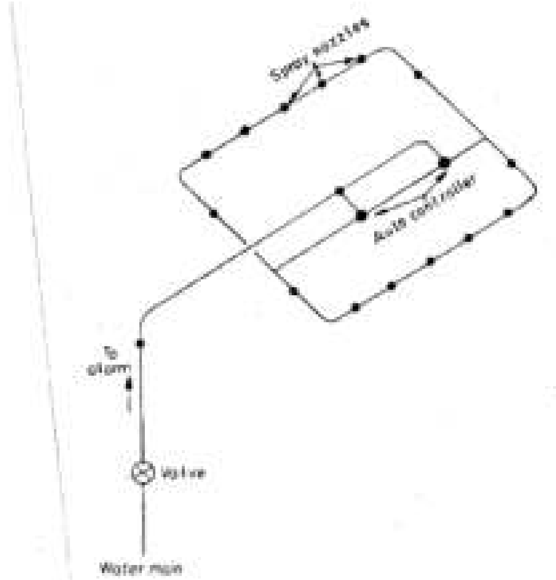

Figure 24.15: Water Spray (Small)

This is achieved by interconnect two networks of pipes though control value. The first containing detectors (sprinkler heads) at suitable points above and near the item under probation, charged with compressed air at a pressure higher than the design pressure of the water line. The compressed air holds back the water in the control valve, which on release flows into the spray nozzles and is discharged under pressure into the tire. As the detectors (sprinkler heads) open up on sensing a fire, the compressed air escapes bringing the control valve into action when the sequence mentioned in the last line follow. The discharge density depends on the nature and characteristics of the last to be protected and varies from I0 mm per minute to 70 mm per minute. For cooling purposes, where the direction of wind is a factor to be taken into consideration, a discharge density of 25 mm per minute is considered adequate. Figures 9,15,9,16 show the schematic arrangements of two high velocity water spray systems suitable for small and large areas.

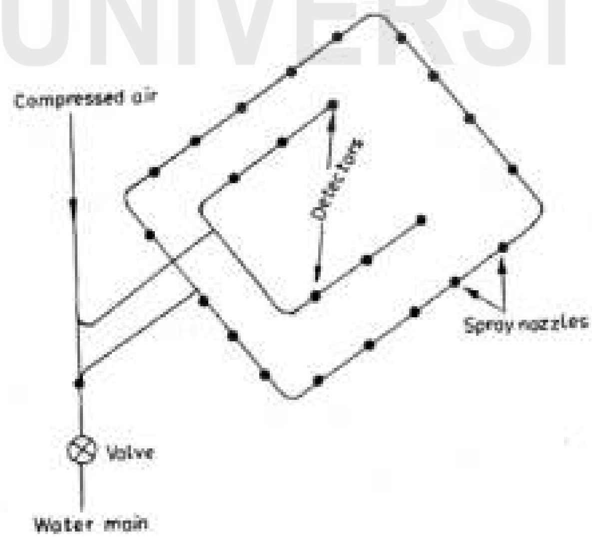

Figure 24.16: Water Spray (Large)

3) Special System: Foam, Dry Powder and Carbon Dioxide: Though we have stated earlier that water is the best and cheapest extinguishing medium available, we how quality our statement that here are situations where water cannot be used for its deficiencies like risk of electrocution, radioactive hazards, water drainage to sensitive equipments and so on. Be that is it may. the number of water-based installations to extinguish solid-fuel (class A) fires (hydrants, sprinklers, etc.) and flammable liquid (class B) fires (water sprays) for out strip the number of installations where special extinguishing used. Consequently, as the number of such installations are not many, there is a general lack of codes and rules relating to such systems. In view of this our as course on such systems would be of a very general nature.

i) Categories of special Systems

The special systems are usually categorized according to the extinguishing medium used foams, dry-powder and inserting gas (nitrogen and carbon dioxide). There is yet another agent, the inhibiting gases like chloro-fluoro-carbons. carbons. As, however, these gases on release attack the ozone in the atmosphere (thereby increasing the risk of cancer), they are no longer used.

These systems come in various forms and sizes like, say, a single cylinder protecting a quenching tank in a heat treatment department to a bank of cylinders protecting a computer room. Here, the initla1 release control the fire in a specific pint then diffuse throughout the area making the atmosphere unsuitable tor sustained combustion. These agents are also used in compunction with others as, for example, in a boiler of furnace section where the dry-powder system tackles, the running fires from a burst or broken (ruptured) fuel Line, while a water spray system extinguishes the oil-pool fires and keeps cool the hot metal surfaces.

Usually, a detector or detector system is employed to trigger the release of the special extinguishing agents. In a situation with a rapidly growing fire, as in flammable liquids, the director has to be sensitive enough while, at the Same time, must not give false alarms. Thus, in a single location arrangement (Figure 9-17) the detector itse1f may act as a stopper holding up the agent under pressure. On being heated by enveloped in the flames, it gives way releasing the extinguishing agent under pressure into the fire. For a multiple point arrangement, the detector or the detectors Stop the agent from being released through a control valve (figure 24.17). As the flames heat-up and actuate the detectors, the discharge heads in to the fire. Such systems could be of one-shot or multiple –shot operations.

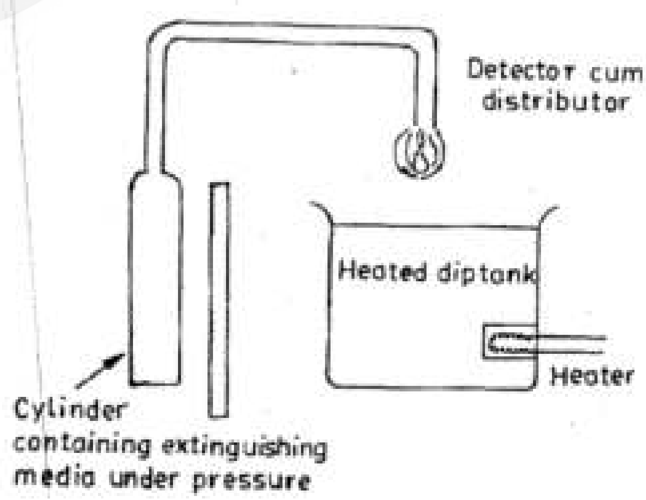

Figure 24.17: Foam System

i) Foam Systems: Foam usually consists of a solution of the foaming agent in water, which is aerated. The ratio of the volume of be bubble filled mixture to the volume of the aqueous solution is called its expansion ratio. Accordingly, a 5 to 30 expansion ratio gives a low-expansion foam; 30 to 250, medium expansion; and 250-1000, high-expansion. In a hand-held self-aspirating nozzle, and expansion ratio of 5-10 could be obtained. If air pressurization is used, an expansion ratio of 30 is possible, but this will have no effect on extinguishment. Foaling agents used ark generally protein based, fluoro-protein and AFFF type. The last is called aqueous film forming foam. and by reducing the surface tension of water helps in extinguishing the fire. Normally, the solution strength is 3 to 6 per cent depending on the foaming agent used. Low expansion foams are widely used to tight flammable liquid fires, where the fuel doc4 not mix with water. For water-miscible flammable liquid fires, a specially-stabilized foam is used (the loss of water due to absorption by the flammable liquid does not break them up the foam).

Foams extinguish fires by forming a coherent blanket over the free burning surface of the fuel. This blanket may not always be able to prevent fuel vapor from seeping through it, but even then it reduces substantially the evolution of vapor from the fuel surface by acting as a shield between the fire and the surface of the fuel. Thus, in addition to reducing radiated heat above the foam also acts as a vapor harrier. The radiant heat enough file1 to sustain the combustion is not (here due to the of fuel vapor required for combustion gets trapped in the foam vapor barrier. And, as a result, the fire is extinguished. Figure 24.17 shows a typical foam system, in which the foaming agent is stored in a suitable pressurized container or the foaming compounds inducted into the pressurized water line by a "propotioner", after which the solution stream enters the foam-making nozzle or branch-pipe, where the foam is a actually formed and then directed in the fire. Medium and high expansion foam installations serve very special requirements like aircraft hangers or off-shore oil rigs, each of them designed having regard to their particular needs. For instance, the conventional time-temperature curve has been found inadequate for oil-rig fires. the notified curve for such purposes, the temperature is required to rise to 1800 ^{0}F initially as compared to 1200^{0}F in the traditional likewise, for cooling purposes, off-shore installations need a discharge density of at least 25 mm/min, just about double of what is needed on-shore.

ii) Dry Powder Installation: Dry powder extinguishing mediums are used to put out fires in solid combustibles, flammable liquids and gases and flammable metals, each of them needing a different kind of dry powder. In general, there are four kinds, classified according to the class of tire which they are used. Thus, all-purpose ABE powders are used for all classes of fires excepting D. Normally; these are mono-ammonium-phosphate based with flow additives. The flow characteristics are further improved by reducing the particle size to a certain limited range. The B C powders, suitable for flammable liquid and gas fire, are sodium and potassium bicarbonate-based. The potassium bicarbonate-based powders are better than the soiumbicarbonate-based ones, but here also reduced article sizes improve performance. BC foam compatible powders, for flammable liquids and gases, can be used along with foam. The foam compatibility is obtained by mixing siliconnised additives with sodium or potassium bicarbonates. Anyway, among the BC powders, Monnex, a carbonic powder gives the best possible performance. It is a reaction product of urea and potassium bicarbonate; the carbonate is urea accounting for the improved performance. As stated in Unit 8, the powders breakdown into their anionic and cationic, components, which interfere with the flaming process, and the fire is extinguished. D class powders for flammable metals are of several kinds, some appropriate for radioactive metals and some for other combustible metals like magnesium. On being applied to the burning metal, they melt and disperse (fuse) into the burning surface forming a crust or skin. thus preventing further combustion.

Likewise, mono ammonium phosphate powders are effective in quelling flames and glowing embers in solid fuel fires were they breakdown and form a layer of phosphoric oxide on the surface, which prevents re-flash of the glowing embers. There is a critical rate of application below which the powders are not effective and an optimum rate at which the fire goes out. In this respect, they are similar to foams, which also have a critical and an optimum rate of application. All powders are to be of a certain particle size and must contain additives to improve flow and prevent cooking or formation of chips and granules, which grow into lumps. Although they are not toxic by nature, their presence in enclosed areas may lead to breathing trouble in people. It is therefore necessary to evacuate personnel from enclosed areas when they are in operation. One disadvantage of dry powders is that they do not protect after the extinguishment is over. On being released, they protect so long as the atmosphere is full of an extinguishing concentration. Once the powder settles down, the protection is over. An exception to this is the powder on the surface of the solid fuel, which is on fire. The layer of powder on the surface (formed during application), prevent a "reflash" though there could be some deep-seated smoldering embers.

Powder installations are not suitable for tightly-packed solid fuels like the stacks of paper in record rooms. Nor are they appropriate for electronics or relays and switchgears where 11ie residue may create problems. Small powder installations are used in hotel kitchen ranges and ducts and hoods; cotton mill blenders, openers and pickers and so on. A typical installation consists of the powder container, a cylinder of propellant gas, usually ' nitrogen, a control valve activated by sprinklers or detectors and the associated piping and discharge horns. Large installations would have capacities ranging from 50 to 1000 kg. The propellant gas pressure would be reduced to about 1500 kN/m^2 before it is led to the powder containers. The discharge pipes and work or nozzles would be properly sized and spaced so as to give a uniform discharge over the protected area at a rate and duration above the minimum requirement for complete extinguishment. Due care is to be exercised in laying the pipes and bends so as to ensure a constant solids/gas ratio in the pipes as far as possible.

iii) Carbon Dioxide Systems: A colorless, odorless, tasteless and somewhat inert gas, carbon dioxide is noncorrosive, electrically nonconductive and leaves no residue after it has been used to kill a fire. At normal temperature its vapor pressure is adequate for release through discharge pipes and horns. Its density is fifty per cent more than that of air, which enables it to spread easily at all areas of an enclosed space, excepting a few materials like cellulose nitrate, which has available oxygen for combustion, carbon dioxide extinguishes tires in almost all combustibles. Normally, carbon dioxide installations are employed for extinguishing fires in:

- Flammable liquids and gases;
- Electrical equipment like transformers, switchgears, rotating machines, etc.
- Engines running on flammable fuel;
- Ordinary combustibles such as paper, wood and textiles, while they are under process or in storage, including costly works of art which are susceptible to water damage; and
- Hazardous solids.

By reducing the level of oxygen in the air, carbon dioxide starves the fire of the required oxygen and extinguishes it. However, so does nitrogen, then what is the advantage in using carbon dioxide?

The advantage is its greater effectiveness because of its higher density than that of nitrogen. Compared to nitrogen, which needs introduction of 42% by volume, carbon dioxide needed is 34% by volume to extinguish fires in ordinary combustibles. Table 24.3 shows the reduction of oxygen when different volumes of carbon dioxide are introduced and their effects on combustion. Similarly, Table 24.4 gives the concentration of carbon dioxide necessary to extinguish fires in seine combustibles. However, for solid combustibles, it is difficult to find out the minimum concentration of carbon dioxide necessary to quench deep-seated fires. In Table 24.5 we see the recommendations given in the NFPA standard on carbon dioxide systems relating to this varies from 50 to 75 per cent by volume.

Table 24.3: Oxygen Reduction Effect

Oxygen in Air % by Volume	CO^2 Needed to Reduce O^2 Content by % Volume	Effect on Burning
23	0	None
17	19	Burning reduced by 50%
16	24	Small flames out
14	13	Large flames out
13	38	Smouldering at 25 mm depth
5	76	Smouldering only at 130 mm depth

Table 24.4: Minimum CO_2 Concentration needed f Extinguishment

Material	Theoretical Concentration % by Volume	Actual 1 Concentration % by Volume
Benzol	31	37
Coal gas	31	37
Ethyl alcohol	36	43
Kerosene	28	34
Petrol	28	34
Propane	30	36
Quench Oil	28	34

The main application of carbon dioxide is total flooding of the hazard or item to be protected. There is also a local application such as dip tank, etc. within suitable enclosures. Normally, carbon dioxide in cylinder under a pressure of 580 kN/d is used in total flooding systems, while design concentrations given in Table are considered adequate because they contain an extra 20 per cent by volume to compensate for leakage and imperfect diffusion of the gas throughout the entire enclosure. To extinguish the fire, the design concentration has to be maintained for a certain length of time, when additional quantity of carbon di-oxide is to be added for leakages and losses. Moreover, for total flooding to be effective, the discharge time is to be based on the nature of the hazard. For surface tires in the combustibles listed in Table 24.5, the NFPA code says that the design concentration must be attained within one minute. When there is a possibility of deep-seated fires, a concentration of 30 per cent by vc3lume is needed preferably with in one minute but certainly not beyond two minutes. Fm the combustible given in table 24.5 (deep-seated fires possible) the design concentration must be reached within seven minutes. As we have seen in this unit, early detection is vital for extinguishment to be effective.

Table 24.5: Effect of CO_2 on Deep-seated Fires

Effect	CO2 concentration % by Vol.
Dry electrical wiring ordinary material	50
Small electrical machinery, are under 57 m^2	50
Paper in stacks (record) Dust collectors	65
Dust, Trenches, Storage of Fires	75

Three problems are encountered in the operation of carbon dioxide total blooding systems. The first concerns people who might be within the enclosure to be protected. **As** a concentration of 30 per cent is needed tc3 extinguish a fire, we have to remember that people become unconscious within a few minutes in concentrations as little as 10 per cent, after which they die. It is therefore absolutely essential that there must be a "lock off' device, which would not allow activation of the system until, and unless all the people present in the enclosure have left and are safely accounted for in some place of assembly outside. The second problem relates to the inevitable increase in pressure when more gas is introduced in a closed and sealed enclosure. It is therefore imperative that arrangements must be there to avoid pressure surges because this can also damage the structure. Thirdly, situations where there are electronic instruments sensitive to drop in ambient temperatures, the introduction of carbon dioxide would create problems. Such injections will invariably cause the enclosure to fall, and hence electronic instruments sensitive to such drops in temperature iced to be properly insulated.

There is yet another problem faced in total flooding systems. As the gas is released through pipes and horns, static electricity is developed and from the horns /nozzles to the earth, there could be a static discharge. so, when used in an area where flammable vapors might be present, this hazard is to be mitigated /taken care of.

24.5. FIRES IN INDUSTRIES

Next to loss of life in fire, loss of material and property is of considerable importance, and in this regard, losses due to fire in industries constitute the bulk of such losses. Why fires in industries result in considerable hardships in economic terms'? Engaged, as they are in activities lading to, creation, wealth, industrial activity means more fire load in such premises than in, say, a residence. It also means that the intrinsic value of the there **is** such mare than, for instance in a office or a school. Having regard to the presence of hazards, which is substantially more than in other occupancies, in regional and city planning, area as separated and specially provided for with water, power and communication facilities are earmarked for industries, a point we discussed in section 3 of this unit relating to zoning. However, every rule has its exceptions; an example of which we see in mushrooming of industrial activity in residential areas. Of course, the activity there is in small scale, weaving and dying of textiles. manufacture of small engineering items, repairs of not too large inactions and so on. However, the smallness in size does not reduce the potential for losses in any manner. The smallness in the scale of activity gives rise to a relatively small loss. Before going into the discussion on fires in industries, it would be of help to us to know how the losses occur, the causal relationship between the loss and the activity, which contributed to it.

24.5.1 Causal Relationship

Every situation involving a loss can be analyzed into events with cause and effect relationships and from this a loss triangle similar to a fire triangle call be drawn as shown in Figure 24.18. For any loss to occur, there should be something which has a potential to cause a loss. \This could be a material process, an action or a circumstance, which has to potential to c use a personal or property damage or to interrupt normal activity. The capability to k sustain a loss usually exists in all situations in the form of property, person or values (profits) which can be damaged. The loss incident is a sudden event, which develops in the presence of the first two factors quickly and unexpectedly, but under statistically predictable conditions.

Figure 24.18: The Loss Triangle

Imagine, for instance, some flammable liquid inside a container. It has a proven capability to cause a loss. However, if it is stored outside with nothing nearby which can burn, then there is no capability to sustain, to increase the amount of loss. As compared to this, the same container, when stored inside plastic goods manufacturing unit, there will be an enormous increase in the capacity to sustain a loss. In other words, the container has now (he ability to trigger a loss amounting to a lot of money. The word 'trigger' is important, because that is how the loss would occur. It would be sudden, quick and totally unexpected, but using statistical tools can be predicted. However, the loss incident in itself is also important, because without it no losses can occur. However, not all incidents result to a loss. If our flammable liquid container, catches fire in a field with nothing to bur nearby, there would be a loss, no doubt, of some amount which perhaps we can bear Now that we have known the cause and effect relationship between a fire and the loss it 1 as given rise to, we can move on to the next phase of our discussion on fires in industries.

24.5.2 The Industrial Scenario

Like all other scenes, the industrial scene also begins with a site, a specific area where it is located. It could be being a planned zone, with industries grouped according to hazards, the least hazardous being placed for and away from the most, thus reducing the exposure risk (Unit 8) to the first to almost zero. Or it could be haphazardly grouped inside a zone, with a corresponding Increase in exposure risks depending on its neighbors. Or else, it could be the one in a residential, area where its own hazards would be a threat to the houses nearby. About exposure, the most important point to note is communication or its inverse separation. Thus, if a factory making items of cellulose nitrate is next to a residence with, say, a 8" brick wall between them, then for hazard purposes they are to be regarded as equal why? Because cellulose nitrate is perhaps the most hazardous material ever used in industry. It contains the oxygenic required for its combustion within its molecule and therefore can burn in an oxygen-deficient atmosphere fiercely, develops intense heat and generates acrid smoke. The separating wall evidently untested for fire resistance (unit 8) properties, will have hidden cracks and gaps, transmitting heat and the products of combustion to the residence, setting it ablaze in no time. That is why the residence has to be regarded as of equal hazard to the cellulose nitrate factory. Of course, this is an extreme example, but it illustrates all right the importance of separation in an Industrial setting as also elsewhere, less hazardous processor like, say, pottery manufacture will be under the shadow of a high hazard factory next door if they are not separated physically or are not separated by barriers with tested and proven fire resistance rating. Even a physical separation has to be of some minimum value, about 50 ft., (15 m) because radiation increases exponentially as the distance between the source and the receptor decreases.

24.5.3 Structural Details

Under this item, we look at the construction of walls, roofs, and floors; of separation between the floors, the departments and the passages and corridors leading from one to a the other; and of provisions relating to lightning protection, smoke dispersal and explosion venting (if needed). The last would comprise of a section of the wall, of a deliberately weak construction. which would give way if there is an explosion inside, thus venting the explosive force away from doing any harm.

So, what would constitute the perfect factory premises for our purpose'? It would be a framed structure of RCC with brick curtain walls. Its floors and roof would also be of RCC with fire resistive barriers protecting the staircases the lift-shafts and so on. The departments and divisions on various floors are likewise segregated by dividers of approved and tested fire resistance rating. And, if after all, it faces a more hazardous premises, then the openings on that wall face are protected by cut-off sprinklers and water sprays.

As, however, perfect things are very rarely found in this imperfect world, we would have to be satisfied with lesser things and what is more would have to 11ve and work among them. Thus, we would come across steel structural members such as beams, columns and roof-trusses, not necessarily protected from fires. There would be walls of corrugated iron sheets, cement-asbestos sheets and plain wood planks. The first offering no protection. even from a forceful impact by some external object. whole the third contributing its own hazard of combustibility. The only saving grace is that such structures would normally be of the shed type, of one storey construction generally.

24.5.4 Other Deficiencies, Other Woes

The shortcomings listed and discussed next are not imaginary, nor have they been found in organizations: with slackening discipline. These are found in otherwise normal, profitable concerns where n passive attitude appears to have been adopted towards such unquestionable vital issues. Using the terms of our loss triangle, we can therefore say that the deficiencies such as those discussed here, each has the capacity to cause a loss (the factory, in any event, has the capacity to sustain loss) appears to have been entirely forgotten. What saves us from all round catastrophe is the uncertainty of a chance, the unpredictability of the loss event. These are all instances of accident that is waiting to happen. The shortcomings we noted begin with the misuse of fire separating barriers, which, if kept open, will help an accidental fire to spread from one end of the factory to the other. Yet, we find fire doors, ordinarily self-closing, kept propped open by placing objects against it. The door itself has become damaged (reducing its efficiency) by goods in transit striking against it, by forklift trucks and by wheelbarrows. Heating and drying units, where naked flames are in evidence, have been duly kept separate for production areas, but the whole effort seems to have been wasted because of the storage of combustible materials like packing paper, card-board boxes and wooden crates surrounding the areas. The air-handling equipment, meant fix ventilation as also removal of dust has not been cleaned regularly, its dust collectors overflow, in which there are combustibles like saw-dust, making the situation extremely hazardous, (in unit 8, we discussed how a solid block of wood, very difficult to set on Are normally, will catch fire easily on being p-educed to shavings, and will explode on being changed to dust and dispersed in the air.)

Electricity, which is called the hidden-heat because faulty cable and improperly used equipment can generate heat to a dangerous extent, is not being put to use with due care. Temporary wirings abound; switches, cables, plugs and fuses are overloaded: and, in addition, power equipment, once installed properly, are no longer so due to lack of care and maintenance, Flammable quid, solvents, paints, etc., in the beginning kept in proper storages with due safety care and used in the production areas by only drawing the quantities require'$ now enjoy apparently the freedom to be everywhere. For the convenience of production, they are now kept in the shop-floor with no restriction on quantity. It is conveniently forgotten that while speeding up production, conditions for rapid spread of fire throughout the factory, are also being made. People smoke in corners not set aside for this purpose; emergency exits are blocked with discarded materials; and welding is carried out everywhere without due safety measures. Workers have only a dim idea about what to do in a tire; there are no clear instructions. The indoor lire fighting equipment lie in a neglected condition while the fixed installations like hydrants and sprinklers are not properly and regularly tested.

24.5.5 Safety Culture

Arriving amidst such chaos and disorder (from a safety point of view that is) as the newly appointed Building Services Manager with over all plant softy as an additional responsibility, what would you do? Well, your first priority will be to persuade your employers to regard safety as much a matter of concern as any other department or division and to commit in writing the required objectives. This has to be on paper, in the form of official directive, and requesting for full co-operation of everyone. The objective, for instance, may he along these lines:

- To make buildings and installations safe including those planned for the future;
- To ensure safe working of the plant;
- To spot hazards so as to eliminate, control or reduce them:
- To review, assess and improve continually upon rescue, safety and firefighting plans, and
- To instill among people a safely culture, to train and equip them with proper method and implements so that they are in a position to with unforeseen circumstances.

It is in respect of the last item of the objective, you will be needed to use your enthusiasm, persistence and knowledge to the fullest extent to create and appropriate safety culture in the organization. Now, what is culture? Culture is everything that we have learnt from family, friend and society. On touching a hot object. You withdraw your hand n reflex; you do it by instinct, nobody told you do so. But you had to learn how to sharpen a pencil; you saw someone doing it and picked up there from. Similarly writing greeting a friend are cultural trait. For instance, the Japanese learn about earthquake safety from their society, from the seismic features of their country. Similarly, people living in cold climates are usually aware of fire hazards, because the house they live in are usually of combustible materials (wood) to keep out cold and they light fires to keep worm. In the same way, for every industrial activity, there is an appropriate level of safety awareness, a safety culture which depends on the particular character of that industry. For instance, a person working in a fireworks manufacturer or in an explosives plant has to be somewhere obsessed with fire. The steel-worker, working in an environment also of fire, will, however, be more concerned about water accidentally coming in contact with molten steel, thereby causing a serious explosion.

In importing training, while telling do's and don'ts, it would be necessary to explain why particular features are hazardous and how for an electrical motor manufacturer, it will be the varnish making section as also the section where windings and rotors are dipped in varnish and baked. This has to be said to every one either by you or their superiors, who are in any event, committed to help you in the matter. The training process would have to be in painstaking details. After an overview of the working of the plant and its attendant hazards, more detailed discussions have to be held regarding the department's work. The tasks of the personnel and the unusual situations, malfunctions which may arise. What is to be done then and by whom is to be clearly spelt out? For instance, the older employee may fight the fire, it any, while the new one raises the alarm. About the indoor equipment for tire-fighting, such as buckets and extinguishers as also hose reels, all the employers have to be familiar with their operation. trying them out, one type or the other, during the training sessions. Hydrants and other special systems need trained personnel and are to be left to them for handling. And, if inspire of everything, the fire gets bigger, the plant personnel are to leave the extinguishing to the fire-squad and withdraw from the 'fire-affected premises or the department concerned after ensuring that the machines they were working on had been stopped.

24.5.6 Aftermath

Life, however, goes on and there will always be a day after when attempts will be made to restore normally. Actually, in our objectives, we have made provisions for that. Thus, while spotting probable hazards and reviewing safety plans, finished goods, raw materials and other stocks susceptible to water damage were identified and removed to dry locations. The review of the safety plans revealed machines and facilities likely to be affected by the spray from the fireman's water jets and suitable waterproof covers were obtained to protect them. The water run-off from the jets were diverted by creating appropriate blockages and pumped out after ensuring no toxic material IS involved. Not everything could, however, be thought of, not every condition visualized. Such matters were taken in hand after the fire and appropriate measures were taken by fresh contracts with suppliers, customers and so on.

24.5.7 The Worst Industrial Catastrophes

No discussion of fires (accidents) in industry is complete without reference to the two biggest and worst industrial accidents, which have been witnessed so far. They are known not only for the death and devastation they had caused, but also for the number of deaths expected to occur in future as a result of the long term effects of these tragedies.

These are the Bhopal and Chernobyl nuclear power plant disasters, which have found a place in the annals of man-made catastrophes for the sheer scale of their tragedies. In the Bhopal disaster, methyl isocyanate, a deadly pesticide, was kept in an abnormally large quantity in a storage system, which leaked. The most-affected people died in a large area, over which the leaking gas dispersed, the others are living a life of slow death. The principle apparently ignored is that the deadlier the hazard, the less is the quantity kept in storage. In Chernobyl, a tire occurred while a repair was in progress spewing. deadly radiation over a wide area, affecting a large number of people. The principle apparently ignored there is check safely systems protecting the plant before carrying out repairs.

24.6 FIRES IN TALL (HIGH-RISE) BUILDINGS -

The thumb-rule determining whether a building is tall (high-rise) or not says that it its top most floor is beyond the reach d the local fire brigade's rescue ladder, then it is so, otherwise not. Now, that creates another problem. As most of such ladders are 75 feet in height, about 15 feet of which is lost in placing the ladder at an angle (for stability), their effective height is therefore 60 ft. Thus, buildings over 60 ft. in height and containing more than five stories are to be regarded as high-rise or tall according to the thumb-rule.

Even so, we are left with problems while thus holds true for all the metros and the regional headquarters, there are still small towns and cities in the country where the effective tire brigade rescue ladder height do not exceed 30 feet. In view of this difficulty regarding heights, we would explain tall or high-rise building as the one in which the, topmost floors are beyond the local tire department's rescue ladder’s each thus requiring tackling and extinguishing of tires in these floors from inside The building.

If that one is regarded as the first problem, then the second problem is equally complex as it involves life safety and is therefore far more vital. It concerns the safe evacuation of the residents of the building, which, as we know from sections of this unit is a place of refuge away from the building. Now, the requirement of the above provision is somewhat difficult to fulfill in the sense that it takes an inordinately long time get all residents out of a really tall building by a devising to go out by using the stairs. In such cases lifts and elevators are not recommended because situations when the lift/elevator cabs instead of going down to the ground floor had actually stopped at the fire-affected floor, thereby exposing the passengers to great risks in some cases and killing them in others.

24.6.1 More Problems

The problems listed so far do not end, but are multiplied due to new trends in tall or high rise building design. In the earlier days such building was of masonry tor concrete construction. Presently, they are invariable of steel frames and RCC floors and walls. The glass windows on the floors are usually fixed as compared to the open windows of the buildings in the past. Moreover, the new buildings usually have glass panels in aluminum frames in the front or façade for better looks. The air-condition in such buildings is usually centralized, with ducts passing from cone floor to the other, almost unbroken from the topmost floors to the ones on the lower levels. Then there are the staircase openings, the lift shafts and other floor openings making the communication almost continuous throughout the floors.

As a consequence, while in earlier buildings an accidental tire in a floor remained usually confined there, in the new buildings the fires breading out in a floor spread rapidly through other floors and tend to engulf the whole building in no time. The fixed glass windows break issuing blaming which reach the windows above shattering them. The flames are sucked in, heating and setting alight the furniture, fixture there and the process is repeated. The air conditioning ducts carry smoke and the products of combustion to other floors, the helped by the chimney like effect of the lift-shaft and staircase openings. The glass panels on the facade now break up, cold air rushes in, driving the flames deep into the so far unaffected portions of the building. The fire has now spread all over the building.

That is the worst scenario; it does not happen all the time because remedial measures are there, though usually not implemented in entirely considering that the greatest number of tall buildings are to be found in the United States where 'sky-scrapers' were built early in the 20 century, a French group of insurance companies prepared a study-report after their visit, high-lighting hat they regarded as good features in a high-rise. We review those points for they represent the impressions of people like us, people with relatively less number of high rises.

24.6.2 Good Features

In high-rises, materials used inside are to be of least combustibility. These are interior finish materials, floor coverings, wall paneling's. partitions, etc., and these are to be of the, lowest flame s read rating while the smoke generated is to be the very minimum. Flammable fabrics, partitions made of combustible maters and wooden furniture is to be avoided far as possible. The same restriction is also applicable to drapery, furnishings, upholstery and such other office and household features. Structural members such as supports and bearing walls are to be of tested fire resistance of 2 to 3 hours, the purpose is to contain the fire in its point of origin till such time external help arrives the tire protection system lakes effect. hl fact, the aim is to restrict the fire in the floor where it started, even if it breaks out of the room or compartment of its origin. The roof and the floor of each storey thus are required to have a fire resistance of not less than two hours.

Ideally, the floor is to be divided into fire sections capable of holding fire within their boundaries. This, however, appears to be a difficult proposition considering the present &end of open plan offices very large areas with low-height partitions separating the desks and work stations. Glass panels on the facades perhaps cannot be entirely hut the tendency of the flames to jump the floors could be avoided by having concrete (incombustible) separating bands (which hold the panel frames) of at least a meter thickness on the outside between the floors. Lift shafts and staircases are to be inside a fire-resistive core of at least one hour, rising from the ground level to the top with the floor openings protected by fire doors of at least me hour's duration. Spread fire gases through ducts is to be limited by self-closing fire dampers in all locations where a duct penetrates a fire wall. Actuated by detectors, the dampers ate to be provided with manual controls as well.

With regard to lifts, two are to be set aside for the exclusive use of firemen during emergencies, and appropriate controls for this purpose are to be provided. Notices to this effect for the residents are also needed. To clear the exit passages, corridors. lobbies on all the floor as also other areas of smoke and hot gases, a captive ventilation shaft, to he used exclusively for this purpose, has to rise along the lift shaft from ground to top. Operated by smoke-defectors, the dampers on each floor of this shaft would open to suck the gases and thus remove hot gases/smoke from the exit passages, corridors and lobbies. As smoke and fire gases from the air-conditioning ducts may also have to be cleared, the exhaust system has to be necessarily of heavy-duty type, perhaps 100 per cent more then what is ordinarily required.

24.6.3 Alarm and Extinguishing Systems

Smoke/fire detectors in the corridors, passages, lobbies and other vulnerable areas on all the floors are to be provided with sirens sounding alarms on all the floors. The control room for the building services will have a telephone connection the local tire brigade direct as also a public address system with speakers on all floors to alert the resident. Meanwhile, if possible, the affected-floor residents will attack the fire with buckets, extinguishers and hose reels. The building security/fire-squad will start the fire attack with hoses connected to the floor hydrants, while waiting for the regular fire brigade to arrive. If the building is protected with a sprinkler installation, the most desired from of protection, then perhaps a lot of the foregoing activities will not be necessary. The sprinkler system, expectedly well maintained and regularly tested will respond to the nascent fire almost immediately. Raising an alarm and indicating its location (by the alarm on the floor, by indicator lamp in the control-room panel), it will start dousing the fire with its water spray. In that event, the security squad (should the building be non-sprinkled) would be spared of their very important task next, the safe evacuation of the building residents without any panic.

24.6.4 Safe Exit

Actually, we have to further qualify our last statement in the sense that unless the fire is completely extinguished, residents of the building (whether sprinkle or not) will have to he guided to a place of safety. In sprinkled buildings, it would perhaps be a place " inside the building. In non-sprinkled buildings, this has to be some place outside. which, as we have referred to earlier, give rise to problems.

A Canadian Research Council paper says that to get the people out of a fifty (50) floors high building, it took full sixty minutes or one hour. This was done in an orderly manner, without the jostling, pushing and showing that usually is found when a mass of people come out of a place. In fire situation, however, there could be some drawbacks such as some exits locked, some corridors smoky, etc. which would generate panic. Then there could be outsiders, people who are not familiar with the building and then behavior would add to the panic. So, there are other important things to consider along with the time taken for safe exit. The corollary to this requirement is that there is to be place of refuge for the resident of this floor-/those floors to some other floors of the same building. Because with the fire confined in one/two floors there is no need to guide all the residents to a safe exit. In high-rises with a heavy to moderate occupant density, every 5th floor is to be embarked for such purpose, that is safe refuge. In buildings with relatively low density, the refuge areas could be on every tenth floor. The un-spoken condition is that such buildings have to be necessarily sprinkled. In any event, we would regard as stupid if building of, say, more than six stories were not protected with sprinklers.

24.6.5 The Defiant

However, there are defiant in all walks of life. So, what would you do if you are to act as the property1 manager of a 10 storey high building where sprinklers were not provided as an act of defiance. Here, your first act on taking over charge will he to ensure that the fire-squad consists of people who can be trusted with responsibility. check that the fire pump and the building hydrants work all right, that the alarms, the detectors and the public-address system are in working order and familiarize yourself with the exit routes on all the floors personally walking down those routes. Now you would prepare an, evacuation plan, explaining the squad their duties, especially those assigned the duty of taking the residents out to safety. Next, you will get a number of floor plans printed, showing there in bold details the alarm points, the defectors and the exit route, that is designated stair, from the point farthest from. Convening a meeting of the residents of the building you hill explain (without getting unduly serious, but with a measure of firm intent) the plans for safe exit, give them copies if the floor plans (they are to be displayed prominent places, anyway) and ask for their advises in the matter. each of which you would ate and advise the commentator at you are doing about it after a time. You will arrange for a drill in which all residents would participate out of their own will at a date convenient to most. During the drill your squad would be particularly attentive to the needs of the children, the elderly and the physically disadvantaged (handicapped). Moreover, drills should be held frequently. During all this time you will use your best persuasive skills on the building owner so that a sprinkler system is installed.

24.7 FIRES IN ASSEMBLIES

Outsiders are people who are not aware of what is going on during an emergency situation and are not familiar with the safe way out. Such people are common in industrial, in tall buildings, in assemblies as also in business and shopping establishments, industry, he is a casual worker, not entirely a stranger to the premises, but an outsider after all. In tall buildings, they could be the visitors, visitor less in number than the regulars (office-staff) or the residents. So it is in business and shops, though in shops they could be more in number than the regulars. It is, however. in assemblies, that the outsider is exposed to danger. Apart from their numbers, which vastly outstrip the number of the people familiar with the place, there is blind panic which take little time to set in a crowd of people who are not known to each other. And even if they do, there is no certainty that; they would behave and act with reason. In the Dabwali disaster (Section 3), panic set in among the people in a small town. people who are most likely to be known to each other leaving over 450 dead, mostly school-children in a pandal fire. It could well be that in that crucial moment someone pushed down so that he knew - to get that extra breath of air to safety.

24.7.1 Codes and Legislations

The National Building de, 1970 of the Indian Standards Institution (now named Bureau of Indian Standards) places assemblies under class D, a classification meant for zoning (section 2 of this unit). This again is subdivided into 5 classes, having regard to the presence of a stage for the article performance the number of seats, fixed or loose and so on according the code such assemblies are to be located in zone 1, the area set apart for residences, schools, hospitals and small shops. The five subdivisions of class:

- D_l. which has stage for theatrical performances, and 1000 fixed seats;
- D_2, as above, but less than 1000 fixed seats;
- D_3, as above, but 300 or more seats of a temporary nature (not Axed to the floor);
- D_4, which is without a stage, and less than 300 seats; and
- D_5, which is not coining under any of the foregoing categories.

There is no specific reference to construction of the places of assembly in the Codes. However, with regard to exit width (section 2 of the unit), the codes specify 60 and 90 respectively for stairs and doors, occupants per unit exit width. In other words, through the stairs and doors of unit exit width 60 and 90 people would pass respectively every minute. The occupant load, which is gross area available to each person, is to be at least 0.6 m^2 per person in an assembly with loose seats and 1.6m^2 per person in an assembly without loose seats but having a space for dancing. The travel distances to safe exit (Section 2 of this unit) are 30 meters for all types of constructions, that is 1,2,3 and 4. The codes further state that types 1.2,3 and 4 construction possesses 4,3,2 and 1 hours fire resistance respectively. That means, in a cinema (for example) the lobby and the auditorium has to be fire separate of at least one hour's duration in order to qualify for the maximum safe exit distance 30 meters (100 ft.). It is not known how many assemblies in the country (cinemas, auditoriums, lecture halls, etc.) safety these conditions.

24.7.2 Breach and Violations

The National Building Codes, 1970 are not mandatory; its provisions are more in the nature of good practices. which are recommendatory in nature. Thus, the unit of exit width is 50 cm, with every 25 cm of clear width is regarded as additional half unit, which may be reduced by 50 per cent if protected by sprinklers. However, for assemblies, no is to be less than 100 cm. in width and, if there are doors, which would open only outwards, be clear wide in such instances is not to be less than 90 cm with the doc fully open. No revolving or sliding doors are allowed. The stairs are to be not less than 100 cm. In width, their treads and risers are to be no less than 25 cms and no more than 19 cm respectively. The handrail is to be at a height of 1 m from the treads, and there are to be not more than 12 stairs in a flight. The fire escapes may have straight flights with a width of 75 cm (minimum), treads of 25 cm (minimum) and risers of 19 cm (maximum in) going directly outside.

When seats are there, the aisle width is to be no less than 1.2 m, with no seat more than 3.8 m from an aisle. There have to be cross aisles of 1 m width for every 10 rows of seats, while the inclination in the auditorium must not exceed 1 in 10. A manual fire alarm system is to he provided when seating capacity exceeds 500. The call-points are to be placed near the doors and exits so that the ushers can use them in the event of an emergency or when needed. A sprinkler protection system is desired, but a hydrant system with outlets (at least two) on all the floors, lobbies, staircase landings, etc. is a must.

With regard to pandals in the open, these are vulnerable not only to accidental fires, hut also fires resulting from electrical short circuits. The wiring there is generally loose and the numerous joining, etc. fix lighting and other purposes are always prone to short circuits giving rise to arcing and sparking leading to fires. Moreover, such pandals are usually made of cloth over bamboo/wooden/steel pipe frames, with the very high fire hazard of a stretched cloth. The rapid flame spread (unit 8) of such cloth can be somewhat reduced by soaking it in borax-water solution for a time, but such treatments do not last long. In any event, such pandals should never have brick walls as its sides. As in the Dahwale tire, such fixed sides prevent people from fleeing in all directions and coming out to safety by pulling down the frames and cloths on the sides. Also there has **to** be some basic firefighting equipment like buckets and extinguishers in such pandals along with some people who know how to use such equipment.

24.8 FIREIS IN SHOPS AND BUSINESS PREMISES

What has been said in regard to outsiders in section 24.7 is equally applicable to shops and business establishments during a fire. It may not be amounting to a great number of people, that is, the outsiders may be only a few people if a few shops or business establishments are involved in the incident. If, however, the accident occurs in an old section of the Cities of the country, then the number of people involved would alarmingly increase. In such areas, the shops and business establishments would be clustered together in quite a small area. They would be facing each other across narrow lanes, sometimes as harrow as a meter or so. They would be adjoining each other, the partitioning walls flimsy, consisting of me brick width only. Added to this will be the electrical wiring, mostly of a loose and temporary nature, thereby increasing the hazards already present. Usually the shopkeepers or the business owners would be staying in the rooms/tenements over their shops/offices, and introduce the hazard of naked flames from cooking. Generally, the shops and business establishments deal in non-hazardous items like cloth, grain, hardware, etc. But it is also possible that there could be a paint shop or a business dealing in plastic manufactured goods. If, however, there is a godown for flammable chemicals, then it is only a matter of time before it is struck by disaster (as happened in La1 Kuan). For instance, under the zoning provisions of the National Building Codes, 1970, there is no place for a flammable chemicals godown in a business area. However, the NBC is not enforceable by law, and even if it is, it will be difficult to find out such Violators. Under such circumstances, it is for the people there, the shopkeepers and the businessmen to spot and stop such violations for their own safety. There would be usually a committee or association of concerned people in such areas, who would be in a position to rectify matters. Other measures like provision of primary firefighting equipment (buckets and extinguishers), assigning fire-watching duties to some of the chowkidars and installation of manual fire-alarm call-points in suitable locations could also be taken. The modern version of the old city's shopping/business quarters is usually a tall building of, say, about 5 stories. The measures discussed in section 6 of this unit are applicable there with special emphasis on smoke dispersal. It has been the experience of multi-storied shopping malls (in western countries) that smoke dispersal in a tire constitutes one of the major problems.

24.9 MAINTENANCE AND TESTING

Why maintenance! Maintenance of equipment and machinery is necessary because unlike people, they cannot take care of themselves. However, just like people, they tell us the conditions under which they are working; overload, loss of lubrication and so on which are apparent from the various meters and indicators they are provided with generally. We: can also find out that the conditions are not proper by their sounds (groans, squeaks and tattles), smell (burning insulation) and touch (running hot). Thus, maintenance, itself vital for all kinds of machinery, is doubly so when it relates to protection equipment. Because if they are in readiness, are capable of doing their designed duty, when it is required at the time of emergencies, at the time of dire needs, only then, we: can say that they have served their purpose. Actually, there are instances when emergency situations have developed but protection equipment's were out of service for repairs, thus stressing the need why such equipment must always be in a state of readiness. With regard to the situation when they are under essential repairs, it is customary to make: some kind of alternative arrangement for the time they are out of service.

Testing is a component of maintenance without which we cannot be sure that our protection systems are in readiness. For instance, pump drawing water from a stream or a large reservoir usually have a jack-well near the pump house, the pump suction pipe and foot-valve being indeed it. Dead dogs, cats, discarded shoes, assorted shapes and sizes of wooden furniture as also the moss growing in water have often fouled-up the foot valve and the strainer on numerous occasions resulting in loss of suction and the pump failing to deliver water. Imagine such a situation when water is needed in the hydrants to tight a fire, and it would be apparent what a grave and costly mistake it was not to routinely check the pump by running it for five minutes early in the day.

The third aspect of maintenance is trouble shooting, which may be regarded as the remedial ensures taken after we have listened to the "complaints" of the machinery. For instance, if the pump is noisy or vibrates too, much, then it could be due to high suction lift, that is the bump is lifting water from a level, which is below the usual. Other, indicators are that it would lose suction from time to time, its delivery pressure will be low and so will be the volume if water it is designed to deliver and so on.

Normally, the manufacturers operating manual gives the details of maintenance, testing and trouble-shooting, to which findings from experience may be added. Considering those pumps, their drivers, and associated piping form the bulk of the equipment in fire protection systems, we will review these aspects briefly next. It will not be a comprehensive treatise, because that will rather extend the scope of this unit, cluttering it with too, many details.

24.9.1 Pumps

For maintenance and operation, a trained, pump man must always be available day and night to run the pump as and when necessary. It is also necessary to run the pump every day for at least five minutes in order to test it. The level of water from where suction is drawn is to be checked daily, the pump glands and packing are to be kept tight and the suction and discharge valves worked regularly, and examined periodically where sand and other impediments are likely to be drawn by suction, if repairs are needed, such work is to be taken in hand immediately. With regard to trouble-shooting, for instance, the pump is likely to be overheated and it may consume more power than is normal, if its impeller is obstructed. Overheating may also occur when the pump is not primed before start-up. In the latter event there could also be no discharge from the pump. Such improper functioning of the pump is to be properly investigated (trouble-shooting) at once and remedial measure taken without delay.

24.9.2 Drivers (Motors and Engines)

Lubrication of the bearings is to be carried out properly, the grease cups regularly checked and filled up as and when necessary. The motor starter contacts are to be checked on a regular basis and cleaned up. To ensure that the motor is in good condition, its insulation resistance is to be checked once in four months and records kept of the readings. For hydrant systems, a weekly test of the motor (and pump) is to be carried out with all valves initially closed and then with at least two jets in operation. This test with jets is to be so carried out that all hydrant-valves get tested by rotation in due course.

For sprinkler pumps and their prime movers, a weekly test would be carried out by opening the installation test valve and noting the time and the Line pressure at which the pump starts automatically. With the pump running a record of the pressures above and below the installation valve flapper is to be kept and the alarm song checked for a clear ringing sound and not a halting one. The cut off values are to be worked periodically to dislodge the debris deposited on their seats.

As regards trouble-shooting, there could be loss of lubrication in engine leading to overheating. The engine may smoke excessively while running at idling speed, indicating clogged spray nozzles. The pump may not move due to faults in the electrical circuit of the electrical motor drive and so on. All such defects and faults and their resulting effects can be reasonably foreseen and averted if a well thought out maintenance programme is initiated and carried on with diligence.

24.9.3 Pipe Work

Piping and pipe works are a general feature of almost all protection systems, and their upkeep and maintenance is no different from those of other industrial process lines like air, steam and water. However, their operational readiness is more important than the others because they are required to work when the others are knocked out due to some accident4 for this reason, the hydrant and sprinkler main lines are laid underground keeping clear of all vulnerable areas and are not taken inside buildings without special protective measures like cut-off values, etc. Even then, there are instances when such underground lines have been damaged, situations when cut-off values isolated such damaged sections so as to put in service the remainder of the network. And to ensure that the hydrant values are operational, a regular programme of checking their spring coupling mechanism, their washers, their value seems and seats is necessary. One unusual problem is that of theft, the value body and the components being of solid brass. Aluminum valves are there, but they control very rapidly. In any event, it might also be necessary for the fire protection staff Lo be vigilant in this regard.

24.24.4 special Systems

The pipe work of the special systems, like most of the sprinkler pipes (excepting the mains) is above ground and is therefore visible. Any external damage. which could render them out of service, is thus spotted at once and rectified without much loss of time. Even then, there should be a regular programme of checking the brackets. Hangars and supports of such pipe work to find out likely areas of disruption and reactions vulnerable to some newly added hazard. Anyway, it is necessary to check the discharge build horns, especially those in outdoor locations, because birds and insects often build nests inside them. It is also necessary to keep the control mechanism and the associated instrumentation in good working order.

24.10 FIRE DAMAGED BUILDINGS

The site of a fire-damaged building at first sight represents a rather depressing picture. There would be smoke-blackened walls and roofs, sodden and soggy with water and half burnt building content lying among pools of sooty water and above everything an all pervasive acrid smell burnt matter. However, the actual extent of damage may not be as bad, which could be guessed by an experienced assessor, for work in this field depends very much on experience. It would be possible to guess reasonably accurately the scale of damage and to determine whether to demolish the building or to repair it. Then there would be the insurance company whose view in this not be the same as the owners there by leading to controversies.

24.10.1 site Inspection

The purpose of the inspection is two-fold, to find out how stable the building is, whether it will stand or collapse, the latter depending on the severity of the fire. Drawings of the building would be needed to find out which components are carrying the loads. and their roles relative to each other. Inspection would reveal swelling, cracking, bowing, etc. of such members and their consequent weakening. It would also indicate the state of the connection between such load bearing members, thereby to form an idea whether it would remain unaffected or fail. With regard to KCC structures, particularly important is the spelling of the beams and columns and the weakening thereof due to the heat-affected exposed reinforcements. It seems there is an instance in which a RCC building did not behave in the manner it was designed to be. The columns in the lower floors (fire affected) appears to have transmitted tensions to the relatively cool upper floors.

24.10.2 The Extent of the Fire (Severity)

This exercise, carried out to determine how severe, the fire was, is normally carried out by rough and ready methods with help from thumb rules. There are, however, other methods as well in which experimental findings in laboratories as also observations under closely controlled conditions are employed. Thus, the first method is to check with are fire brigade the details of their firefighting operations The time the was received, the state the fire when firefighting operations commenced, the number of jats used and assistance (if any) from in-house fire protection systems like hydrants and Sprinklers, Finally, the time taken to control and to extinguish the fire together with any features like explosions, sudden increase in intensity are noted and reviewed. It is possible for people with experience to make a reasonably correct yes the severity of the fire from such details.

The second method is to look for fire signatures, tell-tale signs that convey to the observer the conations prevailing during the fire. The behavior of various materials in fire well-documented and by comparing the condition of the fire-affected debris with these observations, an idea of the temperature attained during the fire can be formed. It is important in this connection to remember the position of the debris. at the ceiling level (high-temperatures) fie floor level (high temperature, relatively) during the fire, before making any estimation, thus a ceiling fan will present a moderate severity with its Hades drooping and aluminum components molten, while a table fan will perhaps he Slightly burnt and smoke blackened, but otherwise intact. Anyway signs left by the fire the debris give a fair indication of the temperatures reached. For instance, Table 24.6 shows the temperature at which different substances melt, compiled by the Research Establishment, U.K. SO, if we find among the debris, materials belonging to the pump, it would give us all idea of the temperatures' attained during the fire.

Table 24.6: Effects of Temperature on Materials

Effects	Temperature ^{o}C
Polythene collapses	120
Polythene shrinks	120
Polythene melts	150
Polystyrene melts	250
Cellulose becomes dark	200-300
Solders run	250
Lead softens	300-350
Aluminium softens	400
Aluminium melts	650
Glass softens	700-800
Melting point of silver	950
Melting Point of brass	800-1000
Melting Point of copper	1100
Melting Point of cast iron	100-1200

The third method is used where wood is a material of construction and has been used extensively as building elements. Laboratory experiments have shown that in wood pieces of large cross-sectional area, the depth of char (blackening due to formation of carbon) depends on the temperature at the surface. By measuring the depths, of the char in various pieces of wooden

building components of large cross-sectional areas, it would to find out the approximate surface temperatures. This is a step, which is to be taken with utmost care, because of the consequences any improper judgment will lead to. Nevertheless, for buildings with a relatively small fire outbreak and very little or moderate damage, the decision to retain the building after repairs will not be too difficult. Nor the decision to pull down a severely fire-affected building would be causing any problem. It is, however, the buildings with indeterminate fie-damages, which apparently did not affect the stability too much, the decision to demolish or not will be full of problems. In such an event, it would be necessary to completely remove the debris and to remove all blackening due to smoke and soot so as to make a very
meticulous exarnin4tion of all surfaces.

24.10.3 Second Look

Having made an assessment of the severity of the fire in the building and the tentative decision to repair the building, the next step is to make a very detailed and close examination of the building in order to form an idea of the residual strength of the various members as also of the building as a whole. To do this a line and level survey, whenever appropriate is to be carried out. It will give us an idea of the deflections and deformations in the building, which is to be compared with the deflections for which the building was designed. In particular, all horizontal movements, which often away from the seat of fire, are to be carefully noted.

Now the proceedings have reached the stage when the nature of the future surveys would depend on the main material of construction: RCC, steel or masonry. As stated earlier spalling is a good indicator of the fire effect on the member, though not always. A large area of spalling could he the action of a cold jet of water 011 the hot concrete surface. However, a smoke-blackened spelling indicates that it occurred during the early stages of the fire. It is also important to note the colour of the fire-affected concrete, a feature we discussed in Unit 8. Also to be noted is the presence of cracks, not of much consequence tension zones, but of serious concern in compression zones of slabs and columns and beams. With regard to steel, considering that structural steel usually regains most of its strength on cooling, the? would be perhaps little loss of strength. It is, however, important to examine the integrity of the connections due to deformations, if there were some. As for masonry, it is mainly used either for buildings of low-heights or as curtain walls in framed structures The main effect of fire on masonry is expansion or movements in the structures due to thermal action on frames and films. This, however, is less likely in low-height buildings, in which a substantial quantity of wood is used as a building material. While the assessment is going on, the structural numbers are to be tested for residual strength. This could be in the form of non-destructive tests or by taking samples from the imaged *p*ortions along with control specimens taken for this purpose from undamaged questions.

24.10.4 More Checks and Repairs

The proceedings here can be started with hammer and chisel, admittedly not a scientific method, it still gives a rough and ready idea about cement quality and strength. The other method is to take 40 mm dia. cores from the fire-damaged portion and to test them in compression in accordance with apparently the only standard available for this purpose, viz. BS 1 88 1 : Part 120,1983, The measured strength is then to be related to an equivalent cube strength using appropriate empirical formulas. However, it is a problem to get cores of sufficient integrity from fire-damaged areas. Also, it is useful to watch out for color changes along the lengths of the cores, since this also gives idea of residual strength. In the ultrasonic pulse velocity measurement test for determination of residual strength, it is first necessary to establish base valves of pulse velocity and strength. Access to both sides of the member is needed and there is a limitation to thickness not exuding 200 nm. There is also the photo luminescence test in which the changes in the silica in the sample give an indication of the temperatures reached. However, this is a specialized equipment, which may not be always available.

The second method is to take a hardness indentation to measure Brineel Hardness, because there is a direct sensibly linear relationship between Brineel Hardness Number (BHN) and tensile strength. In structural steel, there is no loss of strength on being heated up to 600 ºC, based on 0.2 per cent proof test, but there is a loss of 30 per cent strength at 100ºC temperature. Figure 24.19 shows the relevant curves.

The repair of steelwork is usually in the form of partial replacement when the original structure is deformed beyond the point of reuse. Where the steelwork has remained unaffected, it is generally found that the fire protection system assigned to it has been affected considerably and needed partial or total replacement. Where masonry has been affected more or less superficially, a surface repair with plaster-based products generally I suffice. Timber on wooden components, when they are fire-affected usually has to be replaced.

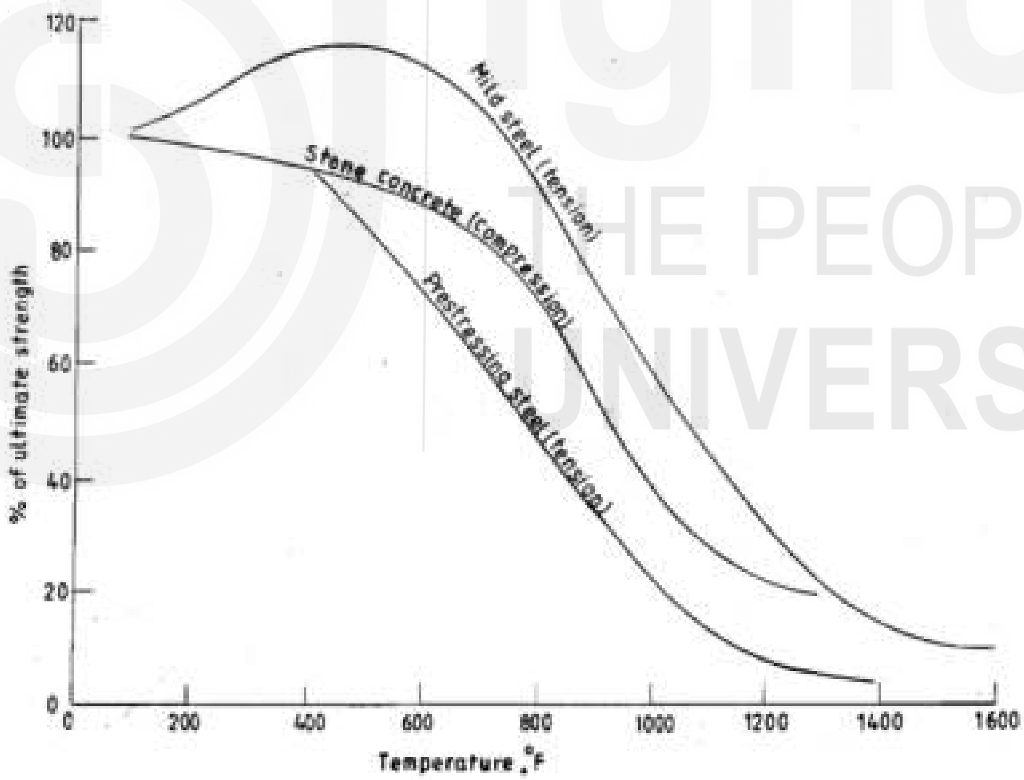

Figure 24.19: Effect of Temperature on Strength

Concrete structures offer a wide scope of repair and strengthening measures, which we will discuss in a general way. It is important that any repair must satisfy the design criteria of the original structure such as strength, durability, deflection and so on. Where strengthening of the structure is required, it is essential that the new sections are not only able to carry forces within the new structure but are also capable of transmitting forces to the old existing structure. This means, in effect, that there is sufficient lap length between I the new and the old and existing reinforcement. Repairs are also carried out by cement, spraying (gunite), resin repairs and over-cladding. For the gunite treatment to be effective, it is necessary to clean the surfaces thoroughly so as to ensure that the gunite bonds fully with the existing concrete. In order to enhance and assist integrity, it may be, necessary to place very light wire-mesh within the depth of the repair. Sections which are - lightly damaged and where the spelling is shallow, the repairs can be carried out by are applying resins. As, however, resins generally soften at 80°C, their integrity in a future fire situation would remain doubtful. Anyway, this can be avoided by arranging for special fire protection and by covering the resin-treated areas by light plaster finishes. In walls and slab soffits with slight damage, over-cladding can be carried out by covering in the affected area with plaster board and battens. As for columns, glass-reinforced cement panels may be used to cover with the gap between the columns and the panels filled either by either mortar or concrete.

Safety precautions taken in demolition of structures for reasons other than fire-damage can also be flowed while pulling down a fire-affected structure. There is, however, one important difference in the sense that the integrity of the structure could be very much weakened by the fire, and as a result very little physical efisort would be needed to demolish it. Moreover, there are some additional aspects, which are to be taken care of before pulling the structure down. The fire may involve toxic materials and the products of combustion, thus could be of toxic nature. It would, therefore, be necessary to fully clean and vent the structure before starting demolition process. Asbestos insulation might have been used in the structure on pipes, tanks and beams. This asbestos has to be removed specially without creating any health risk, also before demolition. There could be basement likely to be partly or completely full of water running off during firefighting operations. This water could also be toxic and would have to be specially disposed off without contaminating other effluents.

24.11 SUMMARY

Reviewing what we have gone through so far, we find that life safety is the main aim of all safety efforts because if lives are lost, then all other safety measures are of little consequence. Of course, property losses are also to be avoided, and the insurance measures in that regard takes little ***or*** no care of life-safety related issues. Accordingly, we have placed more emphasis in our discourses on fires in various occupancies. The sections on maintenance and testing and on fire-damaged structures give only a glimpse of the issues involved so as to stimulate the reader's interest further.

FURTHER READING

- **Hand book of Electrical Engineering** S.L Bhatia Khanna publishers, Delhi-6, 1976
- **Handbook of Electrical Engineering** SL Bhatia (Khanna Publishers, Delhi)
- **Electrical Power** Dr S.L. Uppal (Khanna Pub.)
- **Air-conditioning and Ventilation of Buildings;** Croome-Gale & Roberts.
- **Air-conditioning Engineering** Jones.
- **Principles of Refrigeration** Roy J. Dossat.
- **ASHRAE Handbooks.**