FIRE DETECTION

Building regulations require that due consideration must be given in buildings to:

- the flammability of building materials
- the duration of fire resistance of the components expressed in terms of fire resistance classifications
- the integrity of the sealing of openings
- the arrangement of escape routes.

The aim is to prevent the start and spread of a fire, stem the spread of smoke and facilitate the escape or rescue of persons and animals. In addition consideration must be given to effective extinguishing of a fire. Active and passive precautions must be taken to satisfy these requirements. Active precautions are those systems that are automatically deployed in the event of fire; passive precautions are the construction solutions in the building and its components.

Active precautions include smoke and fire alarm systems, sprinkler systems, water spray extinguisher plant, CO_2 extinguishing installations, powder and foam extinguisher plant, and automatic smoke and heat venting systems. Passive precautions relate mainly to minimum structural sections, casings and coatings. In addition to these, other important measures are the layout of rising mains, installation of fire doors and fire windows, construction of supporting floors, water cooling of hollow steel profiles and the dimensioning of casings and coatings for steel profiles.

Fire detectors

A fire detector is a part of the fire alarm system and can trigger a transmitting device that raises the alarm in a remote control centre. There are automatic and non-automatic fire detectors. The latter are those which can be activated manually. Automatic fire detectors are parts of the overall fire alarm system that sense changes in specific physical and/or chemical parameters (either continuously or sequentially in set time intervals) to detect a fire within the monitored area. They must be:

- installed in sufficient numbers and be suited to the general arrangement of the area to be monitored
- selected according to the fire risk
- mounted in such a way that whatever parameter change triggers the alarm can be easily sensed by the detector.

Typical applications for different types of fire detectors

(1) Smoke detectors

These are used in rooms containing materials that would give off large volumes of smoke in the event of a fire.

- Optical smoke detectors: triggered by visible smoke.
- Ionisation smoke detectors: triggered by small amounts of smoke which have not been detected by optical means. These detectors provide earlier warning than optical smoke detectors and are suitable for houses, offices, storage and sales rooms.

(2) Flame detectors

These are activated by radiation emanating from flames and are used in rooms containing materials that burn without smoke, or produce very little.

(3) Heat detectors

These are useful for rooms in which smoke that could wrongly set off other early warning systems is generated under normal working conditions (e.g. in workshops where welding work is carried out).

- Maximum detectors: triggered when a maximum temperature is exceeded (e.g. 70°C).
- Differential detectors: triggered by a specified rise in temperature within a fixed period of time (e.g. a rise of 5°C in 1 minute).

The planning and installation of fire detection systems must be designed to suit the area to be monitored, room height and the type of ceiling and roofing.

Typical extracts from building regulations and guidelines produced by fire and insurance specialists

Fire development If the initial phase of a fire is likely to be of a type characterised by smouldering (i.e. considerable smoke generation, very little heat and little or no flame propagation), then smoke detectors should be used. If rapid development of fire is anticipated in the initial phase (severe heat generation, strong flame propagation and smoke development), then smoke, heat and flame detectors can be used, or combinations of the various types.

Fire detection areas The total area to be monitored must be divided into detection areas. The establishment of these detection areas should be carried out in such a way that rapid and decisive pinpointing of the source of the fire is possible. A detection area must only extend over one floor level (the exceptions to this being stairwells, ventilation and elevator shafts and tower type structures, which must have their own detection areas). A detection area must not overlap into another fire compartment and typically should not be larger than 1600 m^2.

Fire detection systems for data processing facilities The monitoring of electronic data processing facilities places special additional requirements on the planning and execution of fire alarm systems.

Factors influencing detector positions and numbers

(1) Room height

The greater the distance between the fire source and the ceiling, the greater the zone of evenly distributed smoke concentration will be. The ceiling height effects the suitability of the various types of smoke and fire detectors. Generally, higher ceiling sections whose area is less than 10% of the total ceiling area are not considered, so long as these sections of ceiling are not greater in area than the maximum monitoring area of a detector.

(2) Monitoring areas and distribution of the detectors

The number of fire detectors should be selected such that the recommended maximum monitoring areas for each detector are not exceeded. Some standards specify the maximum distance between detectors and the maximum distance allowed between any point on the ceiling and the nearest detector. Within certain limits there may be a departure from the ideal square grid pattern of the detectors.

(3) Arrangement of detectors on ceilings with downstanding beams

Depending on the room size, beams above a specified depth must be taken into account in the arrangement of the fire detectors. Typically, if the area of ceiling between the downstanding beams is equal to or greater than 0.6 of the permissible monitoring area of the detector, then each of these soffit areas must be fitted with detectors. If the portions of soffit area are larger than the permissible monitoring area, then the individual portions of soffit must be considered as individual rooms. If the depth of the downstanding beam is greater than 800 mm, then a fire detector must be provided for each soffit area.

(4) For spaces with multi-bay type roofs

Generally in this case, each bay must be provided with a row of detectors. Heat detectors are always to be fitted directly to the ceiling. In the case of smoke detectors, the distances required between the detector and the ceiling, or the roof, depend on the structure of the ceiling or roof and on the height of the rooms to be monitored. In the case of flame detectors, the distances should be determined for each individual case.

Internal fire spread (surface)

The linings of walls and ceilings can be an important factor in the spread of a fire and its gaining hold. This can be particularly dangerous in circulation areas, where it might prevent people escaping. Two factors relating to the property of materials need to be taken into account: the resistance to flame spread over the surface and the rate of heat release once ignited. Various testing methods are used to establish these qualities. In the UK, a numbered system categorises the levels of surface flame spread and combustibility: 0, with the highest performance (non-combustible throughout), followed by classes 1, 2, 3 and 4.

There are a series of standards that must be complied with relating to allowable class of linings in various locations. For example, for small rooms in residential buildings (4 m^2) and non-residential buildings (30 m^2), class 3 materials are acceptable; for other rooms and circulation spaces within dwellings, use class 1 materials; and for busy public circulation spaces, class 0 materials should be used. Rooflights and lighting diffusers that form an integral part of the ceiling should be considered a part of the linings. There are limitations on the use of class 3 plastic roof-lights and diffusers.

Internal fire spread (structure)

There are three factors to be considered under this heading:

(1) Fire resistance and structural stability

It is necessary to protect the structure of a building from the effects of fire in order to allow people to escape, to make it safe for firefighters to enter the building to rescue victims and tackle the fire, and also to protect nearby people and adjacent buildings from the effects of a collapse. The level of fire resistance required depends on a range of factors: an estimation of the potential fire severity (depending on the use and content of the building); the height of the building; type of building occupancy; the number of floors and the presence of basements. Fire resistance has three aspects: resistance to collapse, resistance to fire penetration and resistance to heat penetration. Building regulations provide tables that set out specific provisions and minimum requirements of these aspects for different structural elements in different classes of buildings.

(2) Compartmentation within buildings

It is often necessary to divide a large complicated building into separate fire-resisting compartments in order to prevent the rapid spread of fire throughout the building. The factors to be considered are the same as those for fire resistance. Regulations stipulate maximum sizes of compartments for different building types. In general, floors in multistorey buildings form a compartment division, as do walls that divide different parts of multi-use buildings. The use of sprinklers can allow an increase in the compartment size in non-residential buildings.

Careful attention should be paid to construction details of compartment walls and floors, particularly the junction details between walls, floors and roofs, such that the integrity of fire resistance is maintained. Strict rules apply to openings permitted in compartment walls and floors, these being restricted to automatic self-closing doors with the appropriate fire resistance, shafts and chutes with the requisite non-combustible properties and openings for pipes and services, carefully sealed to prevent fire spread.

There is a wide range of constructions, each of which offers a specific duration of resistance. For example, a floor of 21 mm of tongue and groove timber boards (or sheets) on 37 mm wide joists with a ceiling of 12.5 mm plasterboard with joints taped and filled, will provide 30 minutes of fire resistance. For 60 minutes' resistance the joists need to be 50 mm wide and the ceiling plasterboard 30 mm with joints staggered. This period is also achieved with a 95 mm thick reinforced concrete floor, as long as the lowest reinforcement has at least 20 mm cover.

An internal load-bearing wall fire resistance of 30 minutes can be achieved by a timber stud wall with 44 mm wide studs at 600 mm centres, boarded both sides with 12.5 mm plasterboard with joints taped and filled. The same will be achieved by a 100 mm reinforced concrete wall with 24 mm cover to the reinforcement. A resistance of 60 minutes is achieved by doubling the thickness of plasterboard on the stud wall to 25 mm, and increasing the thickness of the concrete wall to 120 mm. A 90 mm thick masonry wall will achieve the same 60 minutes resistance (only 75 mm is required for non-loadbearing partitions).

(3) Fire and smoke in concealed spaces

With modern construction methods there can be many hidden voids and cavities within the walls, floors and roofs. These can provide a route along which fire can spread rapidly, sometimes even bypassing compartment walls and floors. This unseen spread of fire and smoke is a particularly dangerous hazard. Steps must therefore be taken to break down large or extensive cavities into smaller ones and to provide 'cavity barriers', fire-resistant barriers across cavities at compartment divisions.

Regulations stipulate the maximum permitted dimensions for cavities depending on the location of the cavity and the class of exposed surface within it. Further stipulations dictate where cavity barriers must be installed (e.g. within roof spaces, above corridors and within walls). Generally the minimum standard of fire resistance of cavity barriers should be 30 minutes with regard to integrity and 15 minutes with regard to insulation. Fire stops must also be considered. These are seals that prevent fire spreading through cracks at junctions between materials that are required to act as a barrier to fire, and seals around perforations made for the passage of pipes, conduits, cables etc.

External fire spread

The spread of fire from one building to another is prevented by the fire resistant qualities of external walls and roofs. They must provide a barrier to fire and resist the surface spread of flame. The distance between buildings (or between the building and the boundary) is obviously an important factor, as is the likely severity of the fire, which is determined by the fire load of a building (i.e. the amount of combustible material contained within). Regulations therefore stipulate the required fire resistant qualities of external walls and the proportion and size of allowable unprotected areas (e.g. windows, doors, combustible cladding, etc.) depending on the type of building and the distance of the façade from the boundary.

For example, the façade of a residential, office, assembly or recreation building at a distance of 1 m from the boundary is allowed only 8% of unprotected area; at 5 m, 40%; and at 12.5 m, 100%. In contrast, the figures for shops, commercial, industrial and storage buildings are: at 1 m, 4%; at 5 m, 20%; and at 12.5 m 50%; and only at 25 m, 100%. More complex calculations are required when the façade is not parallel with the boundary, or is not flat.

Generally, roofs do not need to be resistant to fire from inside the building, but should be resistant to fire from outside, and also resist surface flame spread. Again, the type of roof construction permitted depends on the type of building, its size and its distance from the boundary. Different roof coverings are rated as to their resistance to fire: on pitched roofs; slates, tiles, profiled metal sheet are in the highest category, bitumen strip slates in the lowest. Sheet metal flat roof coverings perform the best, whilst the performance of various bitumen felt roof coverings depend on the types of layers, underlayers and supporting structure.

SMOKE AND HEAT EXTRACTION SYSTEMS

Smoke and heat venting systems

Smoke and heat venting systems comprise one or more of the following elements, together with the associated activation and control devices, power supplies and accessories:

- smoke vents
- heat vents
- mechanical smoke extractors.

Given that they have the task of removing smoke and heat in the event of fire, these systems contribute to:

- preserving escape and access routes
- facilitating the work of the firefighters
- the prevention of flash-over, hence retarding or avoiding a full fire
- the protection of equipment
- the reduction of fire damage caused by burning gases and hot ash
- reducing the risk of fire encroaching on structural elements.

The main function of smoke venting is to create and maintain smoke-free zones in which people and animals can escape from a fire. These zones also ensure firefighters are unimpeded by smoke when tackling the fire and give the contents better protection from damage. In addition, smoke vents contribute to heat venting.

The task of heat vents is to conduct away hot burning gases during the development of a fire. There are two main intentions:

- to delay or retard the flash-over
- to reduce the risk of the fire encroaching on structural elements.

In the same way as smoke vents contribute to heat venting, heat vents contribute to smoke venting.

The working principle of smoke and heat venting systems lies in the property of hot gases to rise. The effectiveness of the system depends on:

- the aerodynamic efficiency of the air venting
- the effect of wind
- the size of the air vents
- the activation of air vents
- the location of the installation relative to the general arrangement and size of the building.

Mechanical smoke extractors

Mechanical smoke extractors perform the same task as smoke vents but use forced ventilation (e.g. fans) to achieve the extraction of smoke. These smoke extractors are particularly useful where smoke vents are neither appropriate nor feasible for technical reasons.

Appropriately sized smoke vents or mechanical smoke extractors can, in principle, be used in the place of heat vents.

In view of their function and how they work, mechanical smoke extractors should be provided:

- for single storey buildings with very large areas and volumes

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- for buildings with long escape routes which cannot be kept smoke-free for a sufficient period by other means
- for buildings subject to particular regulations, in which special protection is necessary
- for buildings housing particularly valuable articles or equipment, or materials that are susceptible to smoke damage and therefore require extra protection.

Arrangement and sizing of smoke and heat vents

Smoke and heat vents should be arranged as uniformly as possible within the roof sections. Special attention should be given to ensuring that, in the event of fire, the smoke and heat vents do not increase the danger of the fire spreading from building to building, or jumping between fire compartments within the building. In this respect, the boundary wall should be considered as a fire wall, for which there are increased requirements.

To conduct the smoke and combustion gases directly to the outside, it is more effective to have a large number of smoke and heat vents with small openings than to provide a smaller number with larger openings. Typically, the spacing between smoke and heat vents and the distance from the lower edge of the structure (eaves) should not be greater than 20 m and not less than the minimum distance from the walls, which is 5 m. The distance of smoke and heat vent openings from structures on the surface of the roof must be large enough to ensure that their operation is not impaired by wind effects.

A possible increase in wind loading should be noted when smoke and heat vents are located at the perimeter of flat roofs.

As a general guideline, in roofs having a slope of from 12° to 30°, the smoke and heat vents should be arranged as high as possible and there must be a minimum of one smoke and heat vent per 400 m^2 of plan surface area (projected roof area). For roof slopes >30°, the required efficiency of the smoke and heat venting should be considered on an individual project basis. In roof areas with a slope of <12°, one smoke and heat vent should serve not more than 200 m^2. Where, due to the building structure, there are further subdivisions of the roof, there must be a minimum of one smoke and heat vent per subdivision.

Smoke and heat venting system efficiency

To ensure the smoke and heat venting system operates at full aerodynamic efficiency, care must be taken to ensure that there is an adequate volume of air in the lower region of the building. The cross-sectional area of the intake vents should therefore be at least twice as large as the cross-sectional area of the smoke and heat vents in the roof.

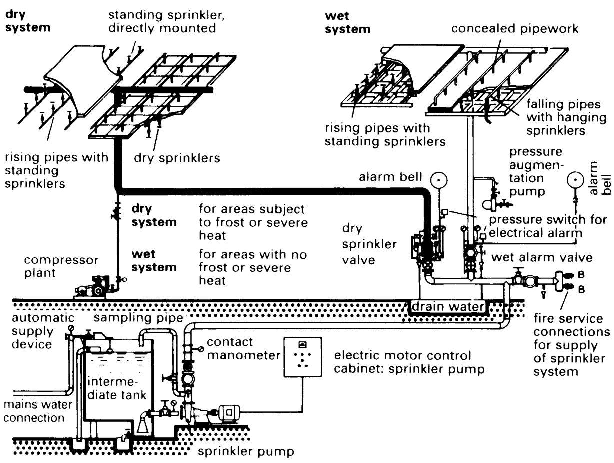
Sprinkler systems

Wet sprinkler systems are systems in which the pipeline network behind the wet alarm valve station is permanently filled with water. When a sprinkler responds, water emerges from it immediately.

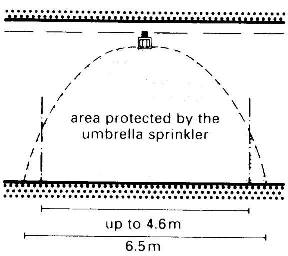
In dry sprinkler systems, on the other hand, the pipeline network behind the dry sprinkler valve station is filled with compressed air, which prevents water from flowing into the sprinkler network. When the sprinkler system is triggered, the retaining air pressure is released and water flows to the sprinkler heads. Dry sprinkler systems are used where there is a risk of frost damage to the pipework.

Normal sprinklers deliver a spherical water distribution towards the ceiling and the floor whereas the water from umbrella sprinklers falls in a parabolic pattern towards the floor. Both kinds can take the form of self-supporting or hanging devices. → ② + ③

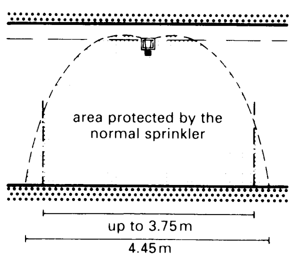
Automatic fire extinguisher systems commonly employ fixed pipelines to which closed nozzles (sprinklers) are connected at regular intervals. When the system is activated, water is released only from those sprinklers where the sealing devices have reached the set response temperatures required to open them. These types of arrangements are also known as selectively operated extinguishing systems.



① **General arrangement of a sprinkler system**



② **Spray characteristics of an umbrella sprinkler**



③ **Spray characteristics of a normal sprinkler**

Sprinkler distribution

A choice can be made between a normal or staggered distribution of sprinklers but where a staggered distribution is proposed the sprinklers should be arranged in as uniform a way as possible.

Spacing between sprinklers; distance from walls and ceilings

The spacing between sprinklers must be at least 1.5m. The maximum spacing is determined as a function of the area the sprinkler is protecting, the distribution of the sprinklers and the fire hazard. This rule does not apply to sprinklers in stacking systems.

The permissible spacing between sprinklers and flat ceilings/roofs varies according to the type of sprinkler and the flammability of the inside of the ceiling or roof. It also depends on the insulating layer of profiled cladding roofs. For trapezoidal section cladding roofs, the minimum spacing of the sprinkler from the ceiling is measured from the lowest point of the corrugation and the maximum spacing is measured from the mean point between the lowest and highest points of the corrugations.

Spacing of sprinklers relative to supporting beams or other structural components

If supporting beams, joists or other obstructions (e.g. air conditioning ducts) run below the ceiling, then the minimum spacings must be maintained between these components and the sprinklers. The exceptions here are side wall sprinklers, installation of which is only permitted for flat ceilings.

Open nozzle systems

Systems with open nozzles are water distribution systems with fixed pipelines, to which open nozzles are attached at regular intervals. When on standby, the pipe network is not filled with water. When the system is activated, the peak flow pressure passes immediately from the water supply into the network of pipes and nozzles.

The water pressure is directed according to the size and shape of the room which is to be protected and the type and quantity of the contents. Depending on the height and type of storage facility, and any wind effects, the system must deliver between 5 and 60 litres per minute per square metre → ④. For room protection systems which are subdivided into groups, the area protected by a group should generally lie between 100 m^2 (high fire risk) and 400 m^2 (low fire risk).

Water spray extinguisher systems are used, for example, in aircraft hangars, refuse bunkers and incinerator facilities, arenas, facilities for containers and combustible fluids, cable ducting, chipwood silos and factories, power stations, and factories making fireworks or munitions.

Extinguisher water pipelines

Extinguisher water pipelines are fixed pipes in structures. They make available the water supply for fire extinguisher hoses, which are connected by valve couplings that can be closed. There are two main types: (1) wet risers, which are extinguisher water pipelines that are continually under pressure, and (2) dry risers, which are pipelines to which extinguisher water is supplied by the fire service when it is required. Wet/dry risers are extinguisher water pipelines which, on the remote activation of valves, are supplied with mains water when required. (→ p. 130.)

The following are typical nominal pipe bore sizes for extinguisher pipes and wall hydrants:

- where there are two interconnected access points: 50mm minimum
- where there are three interconnected access points: 65mm minimum
- where there are four or more interconnected access points: 80mm minimum.

With wet risers, wall hydrants can be accommodated in built-in recesses or in wall cavities. The lower edge of the wall hydrant should be between 800 and 1000mm above floor level.

Dry risers have a nominal diameter of 80mm and have a drainage facility. The couplings of the supply valve should be 800mm above the surface level of the surroundings and the hose connector valve should be 1200mm above floor level.

protected area	minimum water flow l/(min.m^2)	extngshng time, min. (min)	group area (m^2)	number
stages/arenas				
up to 350 m^2, height ≤ 10 m	5	10	–	1
up to 350 m^2, height > 10 m	7	10	–	1
over 350 m^2, height ≤ 10 m	5	10	–	3
over 350 m^2, height > 10 m	7	10	–	3
woodchip silos				
height of layer ≤ 3 m	7.5	30	–	1
height of layer > 3 m ≤ 5 m	10	30	–	1
height of layer > 5 m	12.5	30	–	1
refuse bunkers				
height of layer ≤ 2 m	5	30		–
height of layer > 2 m ≤ 3 m	7.5	30	–	
height of layer > 3 m ≤ 5 m	12.5	30	100–400	–
height of layer > 5 m	20	30		–
foam stores				
storage height ≤ 2 m	10	30	150 min.	
storage height > 2 m ≤ 3 m	15	45	150 min.	
storage height > 3 m ≤ 4 m	22.5	60	200 min.	
storage height > 4 m ≤ 5 m	30	60	200 min.	

(4) **Protected area and water flow rates**

CO_2 FIRE EXTINGUISHER SYSTEMS

Carbon dioxide works as an extinguishant by reducing the oxygen content in the air to a value at which the burning process can no longer be sustained. Being gaseous, it can flood the threatened area rapidly and uniformly to provide very effective protection.

CO_2 is suitable for extinguishing systems in buildings containing the following substances and installations:

- flammable fluids and other substances that react as flammable fluids when burning
- flammable gases, provided that precautions are taken to ensure that following successful extinguishing, no combustible gas/air mixture forms
- electrical and electronic equipment
- flammable solids susceptible to water damage, such as paper and textiles, although fires involving these materials require high concentrations of CO_2 and prolonged exposure to put them out.

Fixed CO_2 systems are frequently used in areas given over to:

- machines that contain flammable fluids, or in which such fluids are used
- paint manufacture, spray painting, printing, rolling mills, electrical switch rooms and data processing rooms.

Typically, where these systems are to be used for the protection of rooms, one nozzle must not safeguard an area greater than 30 m^2. Where rooms are over 5 m high, the nozzles used for general spraying of CO_2 must not only be installed in the upper portion of the room, under the ceiling, but also at a level approximately equal to one third of the room height.

The function of CO_2 systems is to extinguish fires during the initial phase and to maintain a high CO_2 concentration until the danger of re-ignition has abated. These systems consist essentially of CO_2 containers, back-up supplies of extinguishant, the necessary valves and a fixed pipe network with a suitable distribution of open nozzles and devices for fire detection, activation, alarm and extinguisher operation.

Powder extinguisher systems

Extinguishing powders are homogeneous mixtures of chemicals that act as fire suppressants. Their base constituents are, for example, as follows:

- sodium/potassium bicarbonate
- potassium sulphate
- potassium/sodium chloride
- ammonium phosphate/sulphate.

Since the powder is ready for use under normal conditions at temperatures of −20°C to +60°C, it is used for buildings, in closed rooms and also for outdoor industrial applications. Powder extinguishants are suitable, for example, where the following substances and installations are involved:

- solid flammable substances such as wood, paper and textiles, where a suitable powder is required in all cases
- flammable fluids and other substances which, when burning, react as flammable fluids
- flammable gases
- flammable metals, such as aluminium, magnesium and their alloys, for which only special extinguishant powders are employed.

Examples of industrial areas where fixed powder systems are frequently used include chemical plant and associated process plant, underground oil storage facilities, filling stations, compressor and pumping stations, and transfer stations for oil and gas. There are also some installations in which powder extinguishants should not be used. These include areas housing, for example:

- dust sensitive equipment and low-voltage electrical installations (e.g. telephone systems, information processing facilities, measurement and control facilities, distribution boxes with fuses and relays, etc.)
- materials which are chemically incompatible with the extinguishant (i.e. there is the danger of chemical reaction).

Halon room protection systems

Halon is a halogenated hydrocarbon, usually bromotrifluoromethane. Its extinguishing effect is based on the principle that it supresses the reaction between the burning material and oxygen. Halon systems can only be used in extinguishing areas where the room temperature will remain between −20°C and +450°C and neither should there be any equipment with an operating temperature above 450°C in the extinguishing area.

Halon 1301, for example, is suitable for fires in areas containing:

- fluids and other substances that react as flammable fluids when burning
- gases, provided that no combustible gas/air mixture can form after the fire has been extinguished
- electrical and electronic equipment and plant.

Examples of activities and areas for which halon systems are suitable include:

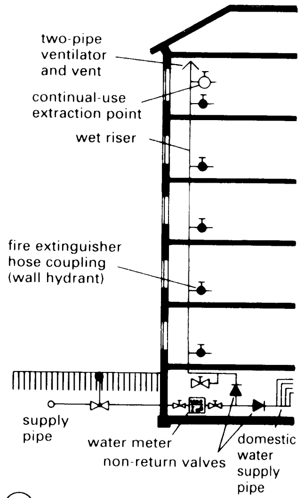
- paint manufacture, spray paint shops, powder coating plant
- electrical equipment rooms
- electronic data processing and archiving rooms.

The possibility of environmental damage cannot be excluded and should be considered where halon systems are proposed.

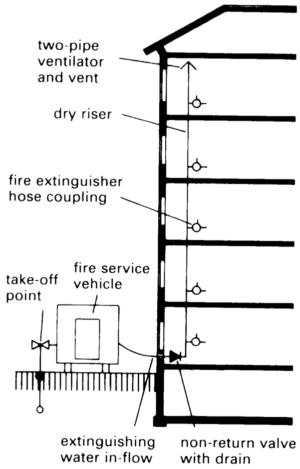
Foam extinguishing systems

Foam systems are used for extinguishing fires in buildings, rooms and outdoors, and they can also be used to form a protective layer over flammable liquids. The foam extinguishant is generated through the action of a water/foaming agent mixture with air. The foaming agents are liquid additives that consist of water-soluble products of protein synthesis and, if required, may contain additional fluorinated active ingredients.

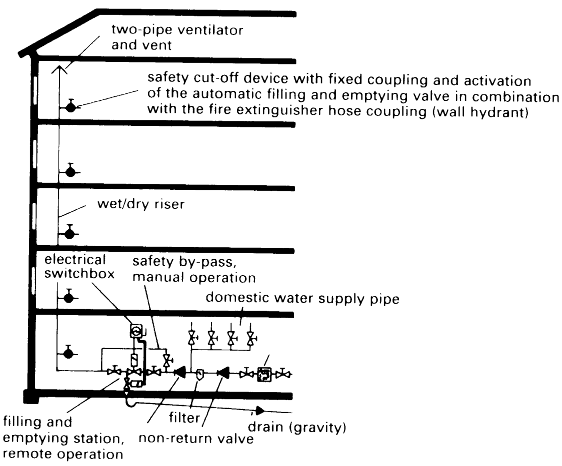
The key characteristics of foam extinguisher systems to be considered are the water application rate, the requisite amount of foaming agent and the minimum operating time (e.g. between 60 and 120 minutes, depending on the type of foam). The system should be sized so that, in the event of a fire, sufficient foam enters the protected area to provide an effective cover. Precautions must be taken to prevent the escape of flammable fluids from the protected area (e.g. upstands). Account must also be taken of flow and spraying distances, possible obstructions, and the spacing and type of objects to be protected.



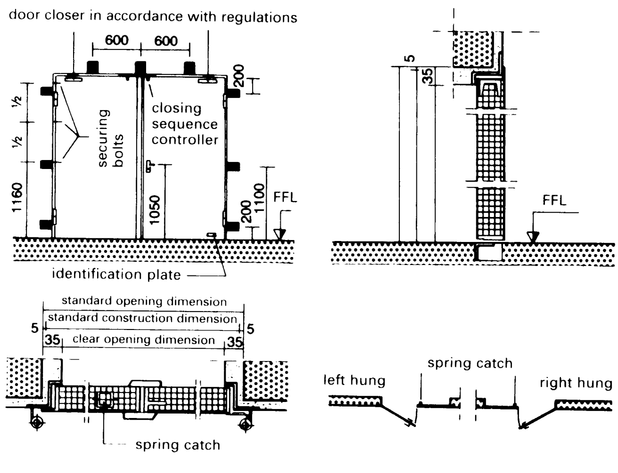
(1) **Wet riser**



(2) **Dry riser**



(3) **Wet/dry risers**



(4) **Example of a 30 minute double door**

FIRE PROTECTION: CLOSURES AND GLAZING

Fire protection closures

Fire protection closures are units comprising:

- a door, or doors, with associated frames and fixings for the frame
- a self-closing device (either a flat spring or door closer with hydraulic damping)
- a closing sequence regulator (on double doors)
- relevant mechanisms required if sliding, roller or vertical lift doors are fitted
- a door lock
- a locking system with release devices for closures, which, during normal usage, must be held open and closed only in the event of fire.

If a fire takes hold, considerable distortion can occur between the wall and the door. Fire protection doors should therefore be considered in conjunction with the method of construction of the wall (i.e. solid walls or stud construction) to ensure that the combination is effective and permissible.

The level of fire resistance is dependent to a large degree on:

- the size of the door and opening
- the precision of manufacture
- the standard of workmanship during installation.

Smoke protection doors

Smoke protection doors are suitable for the limitation of smoke propagation in buildings but they are not fire protection enclosures in accordance with fire regulations. These doors are self-closing doors that are intended, when closed, to stop smoke passing from one part of the building into another.

Closures in walls of lift shafts

Closures in lift shaft walls, particularly the doors, must be constructed to prevent fire and smoke being transmitted to other floor levels. The effectiveness of the closure is then only assured, if suitable lift shaft ventilation is available and the lift cage consists predominantly of fire resistant construction materials. The size of the ventilation openings will be given in the local building regulations. In general, a cross-section of at least 2.5% of the plan area of the lift shaft is required, but this must be at least 0.1 m^2.

Fire protection glazing

Fire protection glazing is a component consisting of a frame with one or more light transparent elements (e.g. panes of fire protective glazing), mountings, seals and means of fixing. It will resist fire, in accordance with the classification, for 30, 60, 90, or even 120 minutes.

Heat radiation resisting glazing These are light transparent components that can be arranged vertically, horizontally or be inclined. They are suitable as fire protection glazing to impede the propagation of fire and smoke and the passage of heat radiation, according to their fire resistance period. Their stability will have been demonstrated in a strength test.

Heat radiation resistant glazing loses its transparency in the event of fire and provides wall-like fire protection. This implies that thermal insulation must be preserved during the whole of the fire resistance period.

This type of glazing is predominantly used internally, although recent developments have rendered it suitable for external use.

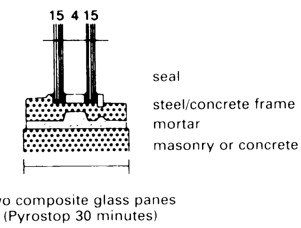
Heat radiation resistant glass consists of two pre-stressed panes 6 mm apart which are prefabricated as a type of double glazing unit. During manufacture, the air between the panes is replaced by an organic, water-containing substance (gel). In the event of fire, the individual pane exposed to the fire cracks and the gel then compensates for the heating by evaporation. Due to the scalding on the surface of the fire protective layer, the glass becomes discoloured and is then non-transparent to light.

Alternatively, this type of glazing may also consist of three or four silicate glass panes, laminated with fire protection layers of gel containing an inorganic compound. These layers provide the fire retarding effect. The gel itself is formed from a polymer, in which the inorganic salt solution is embedded, which is highly water-retentive.

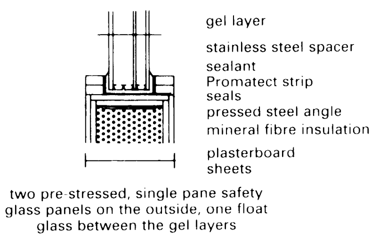
In the event of fire, a thermal insulation layer forms and considerable amounts of energy are absorbed through the vaporisation of the water. This process repeats itself, layer by layer, until the gel in the intermediate layers between all of the panes has been dissipated. In this way, fire resistance times of 30, 60, 90 minutes and longer are achieved.

The gel layers in this heat radiation resisting glazing can only tolerate temperatures between −15°C and +60°C. With regard to temperatures above the permitted upper limit of +60°C, application in individual cases must be decided on the basis of the orientation of the façade to the sun and whether the absorption of radiation by the gel might result in the temperature limit being exceeded. If necessary, the intensity of radiation from the sun must be reduced through the use of protective glass or by other shading precautions. However, as a rule, such precautions are not necessary.

These glazing systems usually have special steel glazing bars, which are thermally isolated, and the surfaces of the frames can be faced with aluminium, if required.



(1) **60 minute fire resistance, heat radiation resistant**



(2) **90 minute fire resistance, heat radiation resistant**

The typical maximum height is 3.50 m, with a maximum individual pane size of 1.20 × 2.00 m. There is also the possibility of replacing individual panes of glass with non-load bearing panels.

Fire resistant glazing without heat radiation resistance These are light transparent components that can be arranged vertically, horizontally or be inclined. They are suitable as fire protection glazing to impede the propagation of fire and smoke according to their fire resistance period. They do not, however, prevent the passage of radiated heat. This type of glazing remains transparent in the event of fire and is as effective as glass for fire protection.

Glazing without heat radiation resistance reduces the temperature of the radiating heat by about one half as it passes through the pane.

This grade of fire resistance can be achieved by three different types of glass:

(1) Wire reinforced glass with spot welded mesh such that in the event of breakage the glass pane is retained by the wire mesh. Maximum resistance up to 90 minutes.
(2) Specially manufactured double glazing units. Maximum resistance up to 60 minutes.
(3) Pre-stressed borosilicate glass (for example, Pyran). Maximum resistance up to 120 minutes resistance as a single pane.

The installation of this type of glazing in the façades of high buildings can prevent the spread of fire from one level to another. This applies especially to high-rise buildings which are subdivided into horizontal fire compartments. On buildings with inside corners, an unimpeded spread of fire can occur in the region of windows but this can also be avoided by using this type of glazing.

Generally, glazing without resistance to heat radiation should only be installed in places which do not serve as an escape route (for example, as light openings in partition panels). If used adjacent to escape routes, the lower edge of the glass should be at least 1.80 m above floor level. The permitted use of this glazing must be decided on an individual basis by the relevant local building authority.

Door glazing

The frames for fire protection glazing, together with the light transparent elements (glass), ensure integrity according to grade of fire resistance in the event of fire. The following materials (and material combinations) have proved to be suitable for the construction of frames:

- steel tube sections with an intumescent protective coating
- plasterboard and wood with, for example, light metal (LM) facings
- light metal sections with fire resistant concrete cores
- heat radiation protected LM laminated sections
- combined sections: concrete outside (paintable), inside of LM, sections of pre-cast concrete (paintable), hardwood sections, heat insulated profiles with steam relieved interstitial air gaps and light metal with fire resistant and penetration resistant concrete cores.

Water cooled structures in steel-framed buildings

A closed circuit cooling system is created by connecting the upper column ends to header pipes from an overhead reservoir. The cooling medium flows to the lower column ends, which are connected to distributor pipes that lead to a riser pipe back to the overhead reservoir. Two circuit systems must be provided following the general structural arrangement of the building. In some cases, building regulations demand that, in the event of the destruction of a structural member, for example, as a consequence of an explosion, the overall structure must remain stable ③. For this kind of catastrophic loading case (i.e. for the failure of every second support), a design stress of 90% of the yield point value is used as a basis for structural calculations.

Typically, four $3\,m^3$ overhead tanks (i.e. $12\,m^3$ of water), are sufficient to counteract a normal fire of 90 minutes duration, involving a spread of fire to two floor levels. On the basis of expert opinion, this also gives a safety margin of almost a third in respect of the available water.

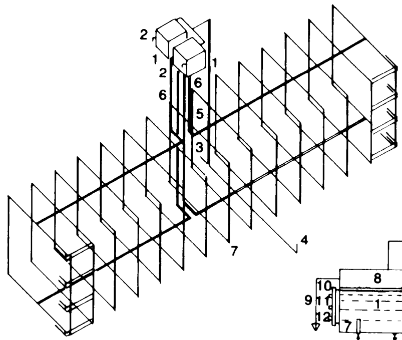
Where the structural columns are outside the building, freezing of the cooling water is prevented by the addition of potassium carbonate in a 33% solution, lowering the freezing point to –25°C. Internal corrosion of the columns of the circulation pipework and of the tanks is prevented by the addition of sodium nitrite to the cooling liquid.

A good example of the use of water cooling is the ten-storey building in Karlsruhe for the Landesanstalt für Umweltschutz (Federal Institute for Environmental Protection). It has $(12 + 12) \times 2 = 48$ steel columns, which are supplied with cooling water circulation such that the 12 + 12 columns are alternately connected to separate water circuits. The two circulatory systems of the front and rear elevations are separate.

Very high temperatures have also been measured on the steel structural elements due to normal warming by the sun in summer. In one instance, following an increase of 30°C, the approximately 33m long outer columns of the building expanded vertically by about 12mm, resulting in displacements of the supports for the continuous, multi-span structural frame. This factor had to be taken into account in the design. Since differences in density of the cooling medium occur due to warming, not only by fire but also through solar radiation, a natural circulation of the coolant takes place and the columns which are heated by the sun are cooled. A favourable effect here is that each of the four cooling systems has columns on both the north and south side of the building, so that a temperature equalisation can take place. Column temperatures of –15°C and +50°C were therefore taken as the basis for calculation. Without the equalisation through the cooling medium, values of around –25°C and +80°C would have had to be assumed in demonstrating structural integrity.

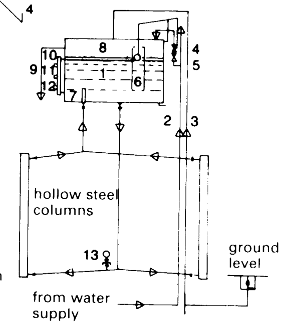
Fire resistance of steel structural elements

The fire resistance duration of structural steel elements for a prescribed level of fire intensity is dependent on the rate of heat increase and the respective critical temperature of the element. The temperature of a steel member increases more rapidly as the ratio of the surface exposed to the fire increases in relation to the steel cross-section. Large steel cross-sections heat up at a slower rate given the same depth of coating, the same material and equal fire surface coverage, and therefore have a greater resistance to fire than smaller cross-sections.

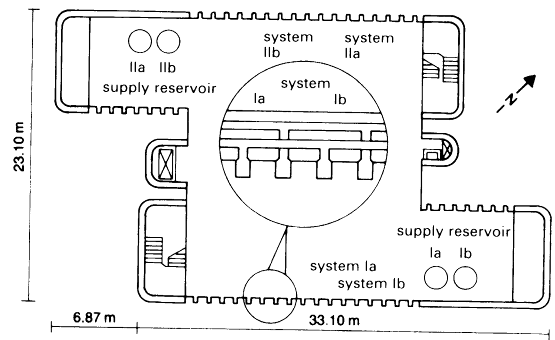


① **Water cooled structure**

1 reservoir
2 feed pipe from water distributor
3 dry riser
4 float valve with water-free test device
5 shut-off valve with sealing control (open)
6 flow regulator pipe
7 stand pipe
8 oil layer
9 overflow
10 overflow alarm
11 normal operation
12 water low level alarm, level monitoring with moveable contacts
13 contact pressure gauge



② **Side view of circulation system with supply reservoir (not to scale)**



③ **Water cooling scheme**

An important influencing parameter for the heating up process is therefore the section factor Hp/A (i.e the ratio of the heated perimeter to nominal cross-sectional area. The characteristics of the coating material are also decisive to this heating up process, as is the adhesion of the coating to the steel surface. The heating up period can be calculated or obtained from fire tests in accordance with relevant standards.

Steel components can fail if the 'critical steel temperature' is reached on critical cross-sections. The fire resistance period is therefore dictated by the time taken for the component to be heated up to this critical steel temperature.

The relationship between section factor, depth of coating and the duration of fire resistance of steel columns and steel girders has been investigated for various types of covering. The results are widely available and should be considered in the light of the possible fire risks associated with the proposed building.

MEANS OF ESCAPE FROM FIRE

Building regulations stipulate what measures must be taken to ensure that occupants of buildings can escape if there is a fire. If there are spaces in the building which have no direct access to the outside, then a route protected from fire that leads to safety must be provided. Different standards apply to different building types as follows:

(1) dwellings, including flats
(2) residential (institutional) buildings, namely those that have people sleeping in them overnight (e.g. hotels, hospitals, old people's homes)
(3) offices, shops and commercial premises
(4) places of assembly and recreation, such as cinemas, theatres, stadiums, law courts, museums and the like
(5) industrial buildings (e.g. factories and workshops)
(6) storage buildings, such as warehouses and car-parks.

Special provisions must be made for escape from very tall buildings.

Factors to be taken into account when designing means of escape from buildings are:

- the activities of the users
- the form of the building
- the degree to which it is likely that a fire will occur
- the potential fire sources
- the potential for fire spread throughout the building.

There are some assumptions made in order to achieve a safe and economic design:

(1) Occupants should be able to escape safely without outside help. In certain cases this is not possible (e.g. hospitals) so special provisions need to be made.
(2) Fire normally breaks out in one part of the building.
(3) Fires are most likely to break out in the furnishings and fittings rather than in the parts of the building covered by the building regulations.
(4) Fires are least likely to break out in the structure of the building and in the circulation areas due to the restriction on the use of combustible materials.
(5) Fires are initially a local occurrence, with a restricted area exposed to the hazard. The fire hazard can then spread with time, usually along circulation spaces.
(6) Smoke and noxious gases are the greatest danger during early stages of the fire, obscuring escape routes. Smoke and fume control is therefore an important design consideration.
(7) Management has an important role in maintaining the safety of public, institutional and commercial buildings.

GENERAL PRINCIPLES

The general principle applied in relation to means of escape is that it should be possible for building occupants to turn away from the fire and escape to a place of safety. This usually implies that alternative escape routes should be supplied. The first part of the route will usually be unprotected (e.g. within a room or office). Consequently, this must be of limited length, to minimise the time that occupants are exposed to the fire hazard. Even protected horizontal routes should be of limited length due to the risk of premature failure. The second part of the escape route is generally in a protected stairway designed to be non-combustible, and resistant to the ingress of flames and smoke. Once inside, the occupants can proceed without rushing directly, or via a protected corridor, to a place of safety. This is generally in the open, away from the effects of the fire.

In certain cases, escape in only one direction (a dead end) is permissible, depending on the use of the building, the risk of fire, the size and height of the building, the length of the dead end and the number of people using it.

Mechanical installations such as lifts and escalators cannot be included as means of escape from fire. Nor are temporary devices and fold-down ladders acceptable. Stairs within accommodation are normally ignored.

Due regard must be given to security arrangements so that conflicts with access and egress in an emergency are resolved.

RULES FOR MEASUREMENT

The rules for measurement relate to three factors: occupant capacity, travel distance and width of escape route.

Occupant capacity is calculated according to the design capacities of rooms, storeys and hence that of the total building. If the actual number of people is not known, then they can be calculated according to standard floor space factors, giving the allotted metre area per person depending on the type of accommodation.

Travel distance is calculated according to the shortest route, taking a central line between obstructions (such as along gangways between seating) and down stairs.

Width is calculated according to the narrowest section of the escape route, usually the doorways but could be other fixed obstructions.

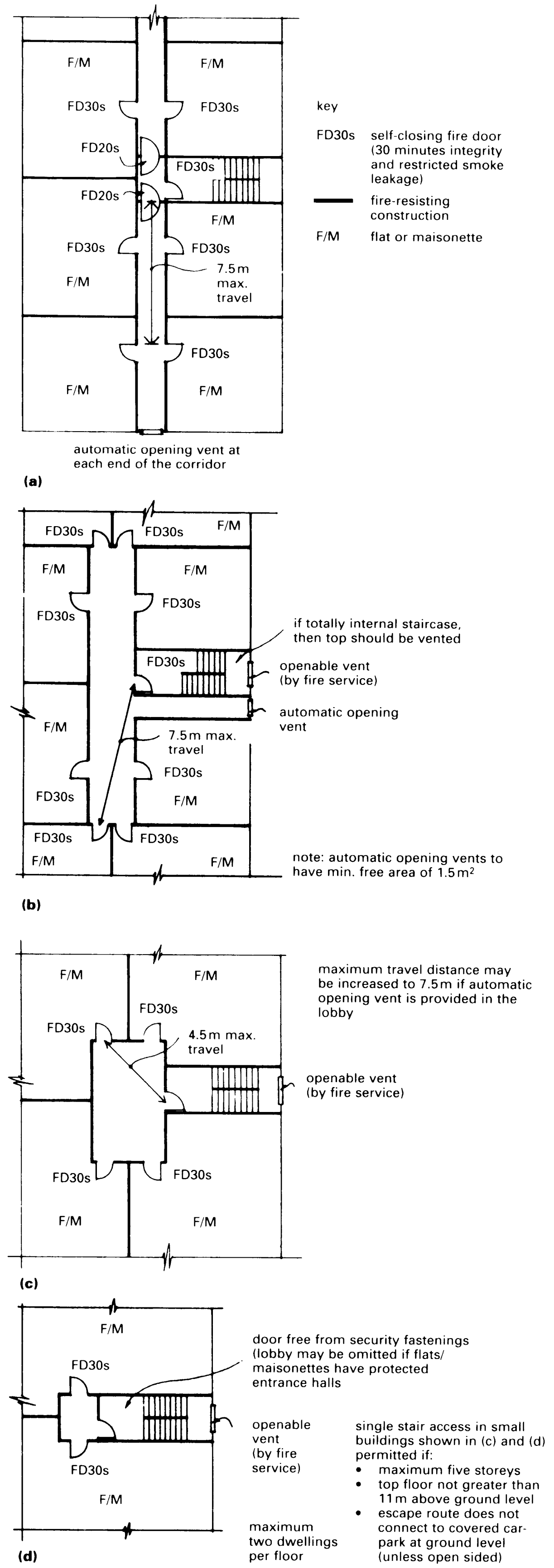
MEANS OF ESCAPE FROM DWELLINGS

The complexity of escape provisions increases with the height of the building and the number of storeys above and below the ground. However, there are recommendations that refer to all dwellings:

Smoke alarms These should be of approved design and manufacture and installed in circulation areas near to potential sources of fire (e.g. kitchens and living rooms) and close to bedroom doors. Installation should be in accordance with the details of the manufacturer and the building regulations. The number of alarms depends on the size and complexity of the building, but at least one alarm should be installed in each storey of the dwelling, and several interlinked alarms may be needed in long corridors >15 m). Consideration must be given to ensure the easy maintenance and cleaning of the alarms.

Inner rooms Escape from these might be particularly hazardous if the fire is in the room used for access. Inner rooms should therefore be restricted for use as kitchens or utility rooms, dressing rooms, showers or bathrooms, unless there is a suitable escape window at basement, ground or first floor levels.

Basements Gases and smoke at the top of internal stairs makes escape from basements hazardous. Therefore basement bedrooms and inner rooms should have an alternate means of escape via a suitable external door or window. Regulations stipulate detailed dimensions for windows and doors used for escape purposes.



(1) Typical arrangements for flats or maisonettes with single common stairs according to the Building Regulations for England and Wales: (a) corridor access, (b) lobby access, (c) and (d) single stair access in small buildings

MEANS OF ESCAPE FROM FIRE

Generally, single dwellings of three or more storeys (or, according to the UK Building Regulations, with one or more floors over 4.5 m above the ground) require protected stairways of 30 minutes fire-resistant construction, furnished with self-closing fire doors.

Dwellings divided into flats or maisonettes should have fire protected access corridors leading to protected common escape stairs. The provision of two stairs giving alternative escape routes is necessary in all but the smallest buildings. It is essential to provide for ventilation of escape corridors and stairs in order to dissipate smoke.

Each flat or maisonette is regarded as a separate fire compartment so only the unit on fire needs to be initially evacuated. Hence, entrance doors to flats and maisonettes must be self-closing fire doors (30 minutes) and open into a protected internal lobby with self closing fire doors which give access to the rooms. (→ (1) + (2))

MEANS OF ESCAPE FROM BUILDINGS OTHER THAN DWELLINGS

General guidelines cover the following features.

Construction and protection of escape routes These cover the fire resistance of the enclosures including any glazed panels and doors (varying according to situation), headroom (2 m minimum), safety of floor finish (non-slip), and ramps (not steeper than 1:12).

Provision of doors These should open at least 90 degrees in the direction of travel and be easily opened (use simple or no fastenings if possible). They should not obstruct the passageway or landing when open (use a recess if necessary) and be of the required fire/smoke resistance depending on the particular situation. Vision panels are required when the door may be approached from both sides or swings two ways.

Construction of escape stairs Escape stairs should be constructed of materials of limited combustibility in high-risk situations (e.g. when it is the only stair, a stair from a basement, one serving a storey more than 20 m above ground level, an external stair or one for use by the fire services. Single steps should be avoided on escape routes, though they are permitted in a doorway. Special provisions apply to spiral and helical stairs. Fixed ladders are not suitable as means of escape for the public.

Final exits These should be very obvious to users and positioned so as to allow the rapid dispersion of escaping people in a place of safety, away from fire hazards such as openings to boiler rooms, basements, refuse stores etc.

Lighting and signing Escape routes should be well lit with artificial lighting, and generally equipped with emergency escape lighting in the event of a power failure. Stairs should be on an independent circuit. In crucial areas, the wiring should be fire resistant. The exits must be well signposted with illuminated signs.

Lift installations and mechanical services, etc. Lifts cannot be used as a means of escape. Because they connect storeys and compartments, the shafts must be of fire resisting construction. The lift doors should be approached through protected lobbies unless they are in a protected stairway enclosure. The lift machine room should be situated over the lift shaft if possible. Special recommendations cover the installation of wall-climber and feature lifts. Mechanical services should either close down in the event of a fire, or draw air away from the protected escape routes. Refuse chutes and refuse storage must be sited away from escape routes and separated from the rest of the building by fire resistant construction and lobbies.

Horizontal escape routes

The number of escape routes and exits required depends on the maximum travel distance that is permitted to the nearest exit and the number of occupants in the room, area or storey under consideration.

Generally, alternative escape routes should be provided from every part of the building, particularly in multistorey and mixed-use buildings. Areas of different use classes (e.g. residential, assembly and recreation, commercial, etc.) should have completely separate escape routes.

Below are examples of typical maximum permitted travel distances in various types of premises. If, at the design stage, the layout of the room or storey in not known (for instance, in a speculative office building) then the direct distance measured in a straight line should be taken. Maximum direct distances are two thirds of the maximum travel distance.

- institutional buildings: 9m in one direction, 18m in more than one
- office and commercial buildings, shops, storage and other non-residential buildings: 18m in one direction, 45m in more than one
- industrial buildings: 25m in one direction, 45m in more than one.

There are more stringent and detailed requirements for places of special fire risk and plant rooms.

Note how the travel distances are much reduced where escape is possible in only one direction. However, this is only suitable where the storey or room contains few people (e.g. less than 50). Rooms at the beginning of an escape route may only have one exit into the corridor; in this case the single directional travel distance should apply within the room and the two directional travel distance should apply to the distance between the furthest point in the room and the storey exit.

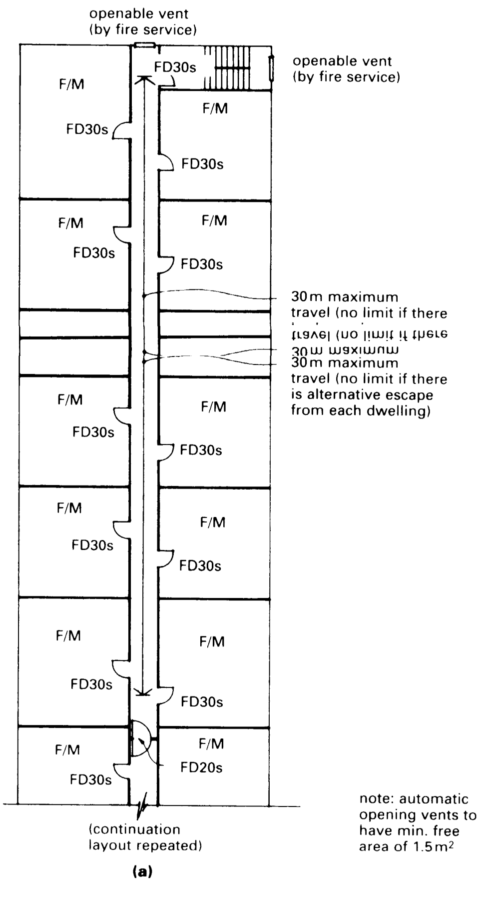
The layout of the exits from a room or storey may be such that from certain parts of the room they do not offer alternative escape routes. Figure ③ shows regulations as applied to two types of room configuration. If the angle of 45 degrees cannot be achieved, then alternative escape routes separated by a fire-resisting construction should be provided, or the maximum travel distance will be that allowed for one direction of travel.

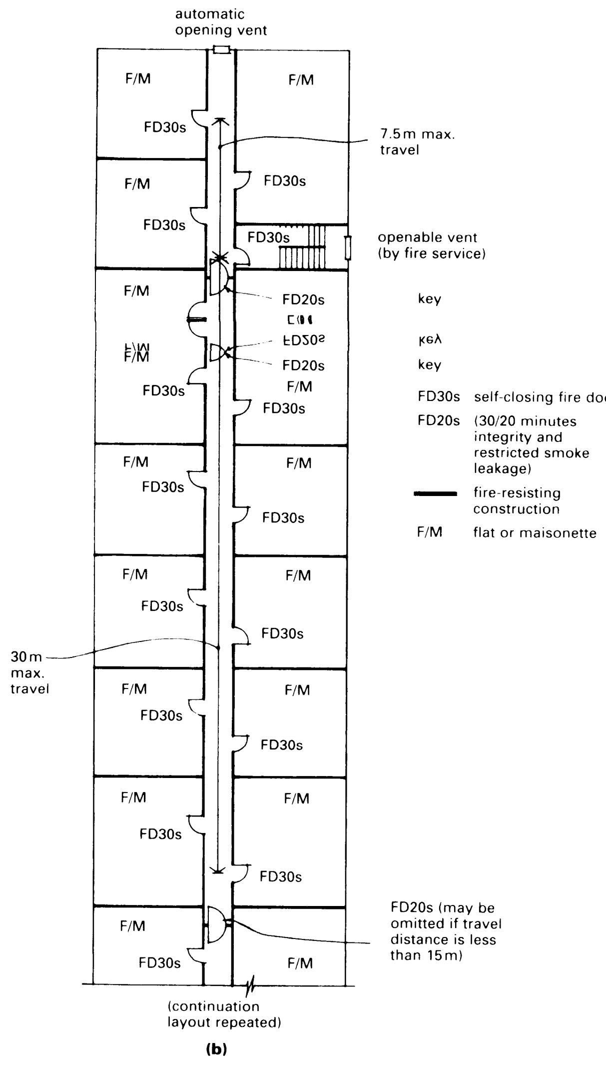
The number of exits and escape routes required depends also on the maximum number of people in the area under consideration. Below are typical requirements:

500 people	2 exits
1000	3
2000	4
4000	5
7000	6
1100	7
1600	8
1600+	8 plus 1 per extra 500 persons

The minimum width of horizontal escape routes is also determined by the number of people using them. Typical values are:

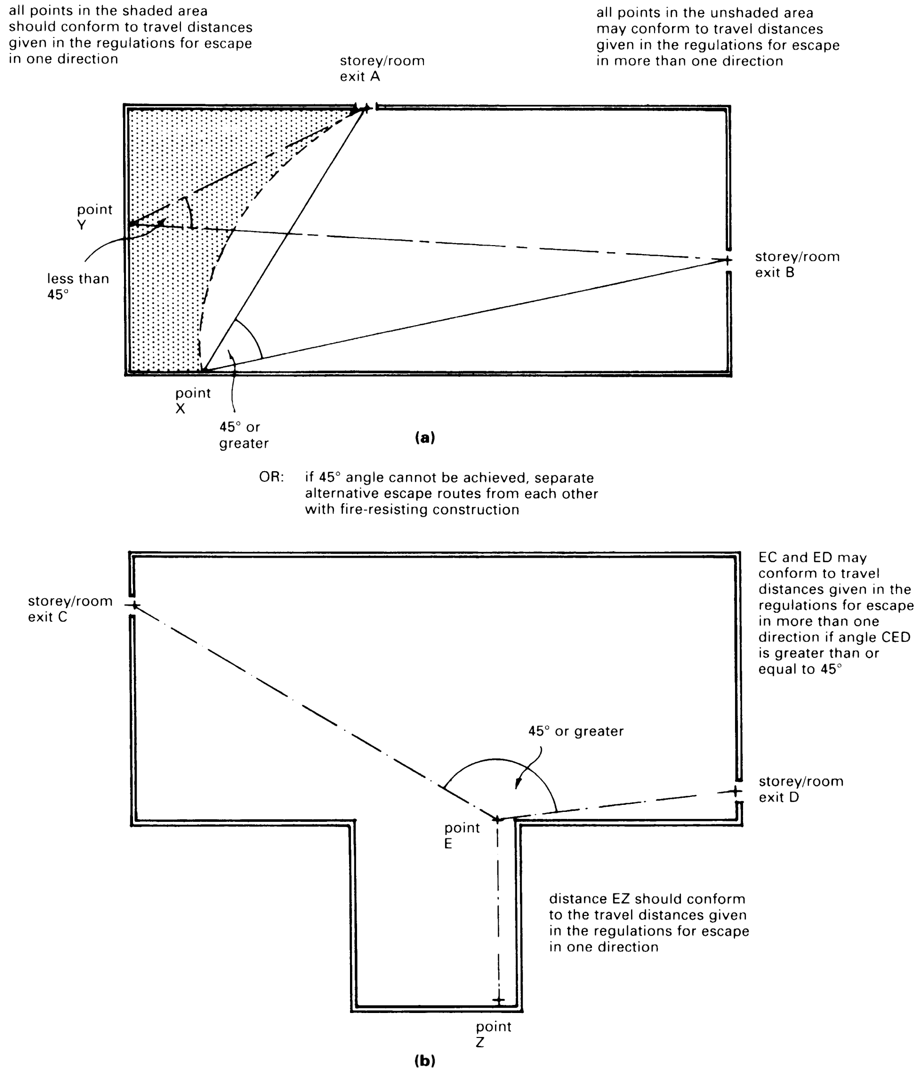
50 people	800mm
110	900mm
220	1100mm
220+	extra 5mm per person





② **Typical arrangements for flats or maisonettes with more than one common stair according to the Building Regulations for England and Wales: (a) corridor access, (b) corridor access with dead ends**

MEANS OF ESCAPE FROM FIRE



(3) **Alternative escape routes in buildings other than dwellings according to the Building Regulations for England and Wales**

The design of escape routes must take into account planning considerations such as:

Inner rooms More stringent rules apply to these than in dwellings, such as reduced travel distances, restrictions on use and occupancy as well as construction and the provision of fire detection equipment.

Relationships between horizontal escape routes and stairways It is important to avoid: the need to pass through one stairway to reach another; the inclusion of a stairway enclosure as the normal route to various parts of the same floor; linking separate escape routes in a common hall or lobby at ground floor.

Common escape routes by different occupancies These should be fire protected or fitted with fire detection and alarm systems. Escape from one occupancy should not be via another.

Escape routes, design factors Fire protection to escape corridors should be provided for in all residential accommodation, dead ends and common escape routes. Other escape corridors should provide defence against the spread of smoke in the early stages of the fire. To prevent blockage by smoke, long corridors (>12 m) connecting two or more storey exits should be divided by self-closing fire doors. Fire doors should also be used to divide dead-end corridors from corridors giving two directions of escape. See (4) for typical arrangements.

Vertical escape routes

These are provided by protected escape stairs of sufficient number and adequate size. Generally, the rules requiring alternative means of escape mean that more than one stairway is required. The width of the stairs should allow the total number of people in the storey or building subjected to fire to escape safely. Wide stairways must be divided by a central handrail. The width should be at least that of the exits serving it, and it should not reduce in width as it approaches the final exit. Typical minimum escape stair widths, depending on the type of building and the number of people they serve, are as follows: 1000 mm for institutional buildings serving up to 150 people; 1100 mm for assembly buildings serving up to 220 people; between 1100 mm and 1800 mm for any other building serving more than 220 people, depending on the number of people and number of floors.

Each internal escape stair should be contained in its own fire-resisting enclosure and should discharge either directly, or by means of a protected passageway, to a final exit. As protected stairways must be maintained as a place of relative safety, they should not contain potentially hazardous equipment or materials. These restrictions do however allow the inclusion of sanitary facilities, a lift well, a small enquiry office or reception desk, fire protected cupboards and gas meters.

MEANS OF ESCAPE FROM FIRE

Reductions in the level of fire resistance are allowed on the outside wall of a staircase, depending on the proximity to other openings in the façade.

Basement stairs need special attention. The danger of hot gases and smoke entering the stair and endangering upper storeys means that at least one stair from the upper storeys should not continue down to the basement. In continuous stairs, a ventilated lobby should separate the basement section from the section serving the upper floors.

External escape stairs are usually permissible as an alternative means of escape, but should be adequately protected from the weather and fire from the building. They are not suitable for use by members of the public in assembly and recreation buildings.

ACCESS FOR FIREFIGHTERS

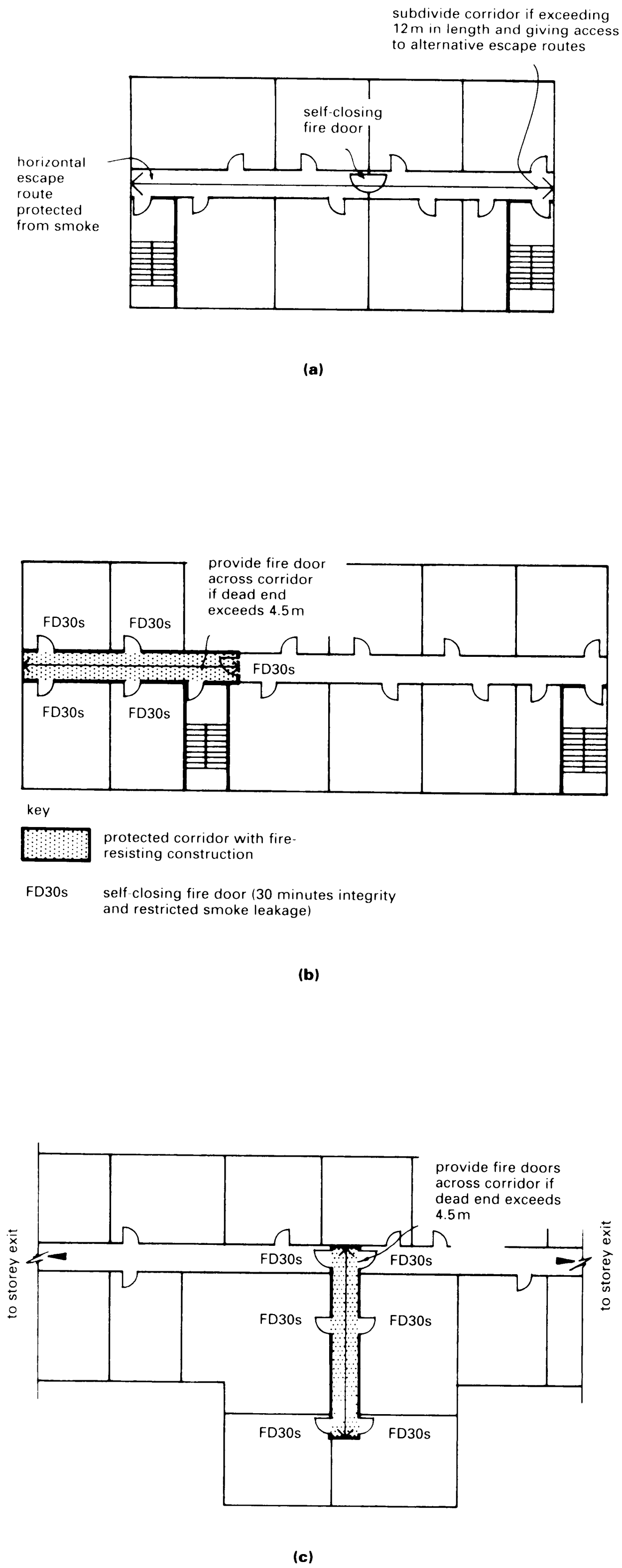
Provision should be made in design to allow firefighters good access to the building in the event of a fire, and to provide facilities to assist them in protecting life and property.

Sufficient access to the site for vehicles must be provided to allow fire appliances to approach the building. Principal appliances are ladders, hydraulic platforms and pumping appliances. Access roads for fire appliances should be at least 3.7 m wide with gates no less than 3.1 m. Headroom of 3.7 m for pumps and 4.0 m for high-reach appliances is required. The respective turning circles of these appliances are 17 m and 26 m between curbs. Allow 5.5 m wide hardstanding adjacent to the building, as level as possible (not more than 1:12), with a clearance zone of 2.2 m to allow for the swing of the hydraulic platform.

Firefighters must be able to gain access to the building. The normal escape routes are sufficient in small and low buildings, but in high buildings and those with deep basements additional facilities such as firefighting lifts, stairs and lobbies, contained within protected shafts, will be required.

Fire mains in multistorey buildings must be provided. These may be wet or dry risers (fallers in basements). → p. 128.

A means of venting basements to disperse heat and smoke must be provided. In basements, flames, gases and smoke tend to escape via stairways, making it difficult for firefighters to gain access to the fire. Smoke vents (or outlets) are needed to provide an alternative escape route for these emissions directly to the outside air and allow the ingress of cooler air. Regulations stipulate the positions and sizes of vents. Either natural venting or mechanical venting in association with a sprinkler system may be used.



(4) **Typical arrangements of escape corridors in buildings other than dwellings according to the Building Regulations for England and Wales**