ASTUTIS

NEBOSH International General Certificate in Occupational Health and safety

Element 10

Fire

Element 10: Table of Contents

10.0 Learning outcomes

The learner should be able to:

- Do a general risk assessment in their own workplace – profiling and prioritising risks, inspecting the workplace, recognising a range of common hazards, evaluating risks (taking account of current controls), recommending further control measures, planning actions.

  5-11 Produce a risk assessment of a workplace which considers a wide range of identified hazards (drawn from elements 5-11) and meets best practice standards (*'suitable and sufficient'*).

10.1 Introduction

Costs due to losses from fire number in the tens of billions globally, and have been roughly estimated as approximately 1 per cent of global GDP per annum.

For Europe as a whole, the annual toll of fire deaths is measured in many thousands, with those suffering fire injuries numbered at many times more. Ways of protecting inhabitants from these dangers therefore merit serious attention.

The World Fire Statistics Centre (WFSC) published research in 2011 indicating the direct costs of fire losses across WFSC member countries as shown in Table 10.1.

Country / Currency	Direct losses			Cost as percentage of GDP 2006-2008
	2006	2007	2008	
Singapore S$	125	110	110	0.05
Slovenia SIT				0.07 [2002-2004)
Australia * AU$	860	885	990	0.08
Czech Republic Kc	2 200	2 450	3 700	0.08
Spain** €			910	0.08 [2008)
Poland zl	750	920	1 450	0.09
New Zealand NZ$	165	180		0.11 [2005-2007)
United States US$	13 000	16 500	17 500	0.11
Japan ¥	625	600	605	0.12
Germany €	3 300	2 950	2 850	0.13
United Kingdom £	1 650	1 700	1 900	0.13
Netherlands €	745	900	1 050	0.16
Finland €	260	315	305	0.17
Italy €	2 200	2 500	3 150	0.17
Sweden kr	4 300	5 400	5 950	0.17
Denmark kr	3 000	4 050		0.20 [2005-2007)
France €	3 300	3 400	4 550	0.20
Norway kr				0.22 [2003-2005)

* Australian data is calculated from figures provided in the Report on Government Services 2011 and may be influenced by specific methodological features of that publication.

** Spanish figures rely upon internal WFSC estimates derived from Spanish insurance data and have not had adjustments applied. Consequently, this data should be regarded with caution.

Table 10.1: Adjusted direct losses (in millions, except for Japan-billions)

UK figures

Costs

In 2004, the total cost of fires in England and Wales was estimated at £7.03 bn, equivalent to approximately 0.78% of the gross value added of the economy.

The average cost of a fire in a commercial building was estimated at £43 800, of which the cost of fire damage to property was £27 700.

The impacts of fire are many and varied UK government reports typically break the total costs down into three categories:

a. **costs in anticipation:** the costs of protection and prevention measures undertaken to prevent or mitigate the damage caused by fire
b. **costs as a consequence:** the costs incurred as a result of fire, due to exposure of property, individuals or the environment to fire and its products, the cost is borne by a range of victims including individuals, private firms and society
c. **costs in response:** the costs of extinguishing and clearing up after fire, society bears the majority of these costs.

Reported statistics for 2017/18 in Great Britain show:

- 167 150 fires attended (3% up on 2016/17)
- 334 fire-related deaths (27% up on 2016/17)
- 7 290 non-fatal casualties (3% up on 2016/17)
- There were 15 900 fires recorded in buildings other than dwellings compared to 15 600 in 2016/17.

Over the last 10 years the figures for all types of fires and fire injuries have been falling.

The tragic incident at Grenfell Tower in June 2017 has resulted in the statistical increases shown above.

The Association of British Insurers (ABI) has reported an increasing trend for the insured costs of fire with commercial fires costing £865 million plus an additional £200 million in business interruption insurance costs in 2008.

USA figures

Costs

The National Fire Protection Association (NFPA) has estimated the total costs of fire for 2014 at $328.5 billion, or roughly 1.9% of U.S. gross domestic product.

The total cost of fire in the United States, as it is defined, is a combination of the losses caused by fire and the money spent on fire prevention, protection and mitigation to prevent worse losses, by preventing them, containing them, detecting them quickly, and suppressing them effectively. The 2014 figures are shown in Table 10.2.

Expenditure	
Direct – Active fire protection (fire departments costs)	$90.1
Indirect – Passive fire protection (building, maintenance, planning, insurance etc)	$159.4
Loss	
Direct – Human loss (statistical deaths & injuries)	$40.4
Direct – Property loss	$13.2
Indirect	$1.9
Total	$328.5

Table 10.2: Total costs (in billions) of fire – USA, 2014.

10.2 Fire principles

Fire initiation

Fire comes from a chemical reaction between oxygen (usually from the air) and a fuel (*e.g.* wood or petrol).

For the reaction (combustion) to occur the fuel must be heated to its ignition temperature.

Once the combustion process is underway it is self-perpetuating. The heat of the flame itself keeps the fuel at the ignition temperature, so it continues to burn as long as there is fuel and oxygen around it.

For a fire to start the three components of fuel, oxygen, and heat (ignition source) must be present. To put out a fire one of the three components must be removed. This is often presented as a *'fire triangle'*.

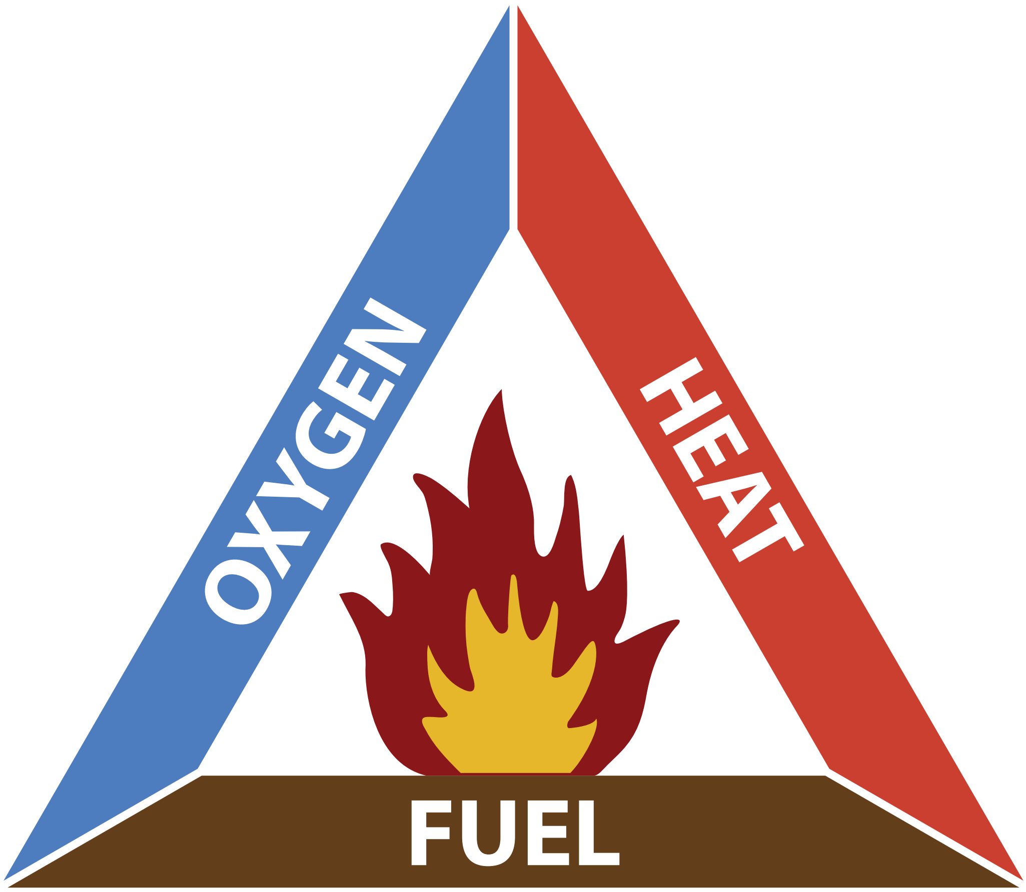


Figure 10.1: Fire triangle

Ignition sources

Potential ignition sources are any possible sources of heat which could get hot enough to ignite material found in the workplace. These sources could include:

- smokers' materials
- naked flames, *e.g.* gas or liquid-fuelled open-flame equipment
- electrical, gas or oil-fired room heaters
- hot processes/hot work, *e.g.* welding by contractors
- heat sources, such as microwaves or radio frequencies
- frictional generated heat from mechanical equipment
- static charge from mechanical equipment, *e.g.* conveyor belts
- poor electrical installations, *e.g.* overloads, heating from bunched cables, damaged cable
- light fittings and lighting equipment too close to stored products
- obstruction of equipment ventilation causing overheating
- spontaneous ignition and self-heating, *e.g.* oil soaked rags or paint scrapings
- malicious fire starting (arson).

Fuel sources

Anything that burns is fuel for a fire. The risk assessment should identify anything that will burn reasonably easily and could provide fuel for a fire or cause it to spread to another fuel source. Some of the most common fuels found in workplaces are:

- flammable liquids and solvents or liquid based products, such as petrol, white spirit, cooking oils, paints, varnishes, thinners and adhesives
- flammable gases such as liquefied petroleum gas (LPG), flammable refrigerants and flammable gas propelled aerosols
- stored goods including foodstuffs, plastics and rubber, especially high piled or racked storage
- paper products, such as stationery, advertising material and decorations
- packaging materials
- plastic and timber storage aids such as pallets
- textiles and soft furnishings
- waste products, particularly finely divided items such as shredded paper and wood shavings, off-cuts, dust and litter.

Materials used to line walls and ceilings, *e.g.* polystyrene or carpet tiles, and the fixtures and fittings should also be considered.

Oxygen sources

The main source of oxygen for a fire is in atmospheric air. This is provided in the workplace by natural airflow through doors, windows and other openings or mechanical air conditioning systems and air handling systems, or a combination of both.

Additional sources of oxygen include:

- oxidising materials (*e.g.* chemicals such as peroxides or fireworks/pyrotechnics) which can provide a fire with additional oxygen and so help it burn
- oxygen supplies from cylinder storage and piped systems, *e.g.* oxygen used in welding processes or for medical use.

Fire classification

Fires may be classified in a number of different ways *e.g.* by ignition source or fuel. The most widely used system classifies fires according to the material undergoing combustion. This system does not define a particular class of fire involving an electrical risk. Classes A, B, C, D, F and electrical fires are explained in Table 10.3.

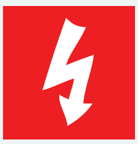
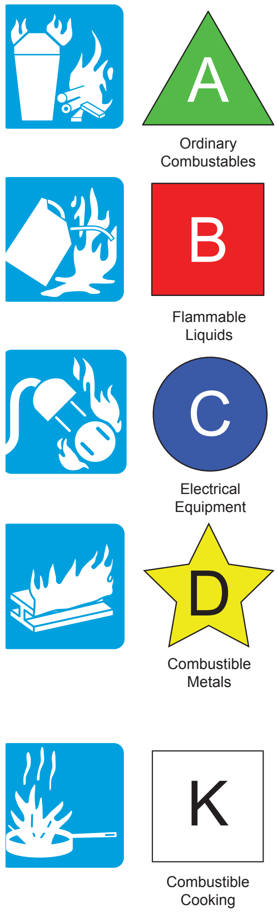
Pictogram	Classification and examples
	**Class A:** fires involving solid materials, usually organic in nature, typically results in the formation of glowing embers. All solid materials, usually organic (contains compounds of carbon) *e.g.* wood, textiles, paper, curtains furniture and plastics.
	**Class B:** fires involving liquids or liquefiable solids, *e.g.* petrol, oil, paint and some waxes and plastics, (Not cooking fats or oils – see Class F). May be sub-classified by whether or not they mix with water.
	**Class C:** fires involving gases, *e.g.* natural mains gas, liquefied petroleum gases (LPG, *e.g.* butane or propane) and medical or industrial gases.
	**Class D:** fires involving metals. Combustible metals or metal powders such as magnesium, potassium and sodium.
	**Class F:** fires involving cooking media (vegetable or animal oils and fats) in cooking appliances. The high temperature (>360°C) means that class B extinguishants are not suitable.
	**Electrical Fires (Unofficial Class E):** "Electrical fire" is not an official fire class. Electricity is an ignition source that will feed the fire until removed. Following isolation of the electrical supply the fire can b e treated (generally) as Class A. If isolation o the electrical supply is not certain a non- conducting extinguishant should be used.

Table 10.3: Fire classification



Green	**Class A** extinguishers put out fires in ordinary combustible materials such as cloth, wood, rubber, paper, and many plastics.
Red	**Class B** extinguishers are used on fires involving flammable liquids, such as grease, gasoline, oil, and oil-based paints.
Blue	**Class C** extinguishers are suitable for use on fires involving appliances, tools, or other equipment that is electrically energized or plugged in.
Yellow	**Class D** extinguishers are designed for use on flammable metals and are often specific for the type of metal in question. These are typically found only in factories working with these metals.
White	**Class K** fire extinguishers are intended for use on fires that involve vegetable oils, animal oils, or fats in cooking appliances.

Table 10.4: NFPA Fire Classifications - USA

The international pictograms for fire classifications as per ISO 7165:2009 *'Fire-fighting – Portable fire extinguishers – Performance and construction'* are shown in Figure 10.2.

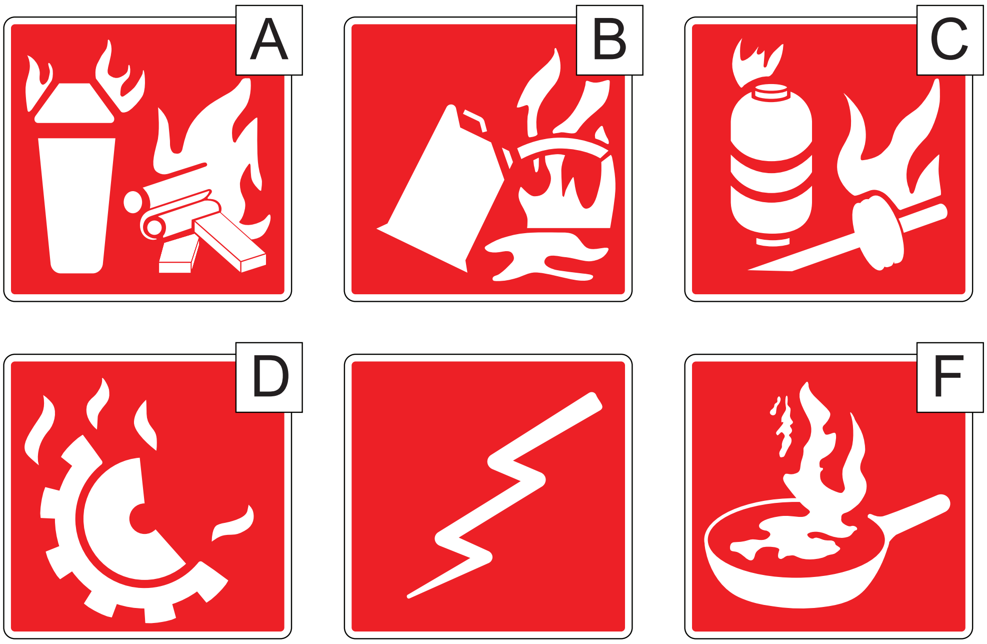


Figure 10.2: ISO fire classification pictograms

Heat transmission and fire spread

As mentioned earlier, fire is self-propagating through direct flame contact (*i.e.* direct burning). Thermal energy is also transmitted by conduction, convection and radiation.

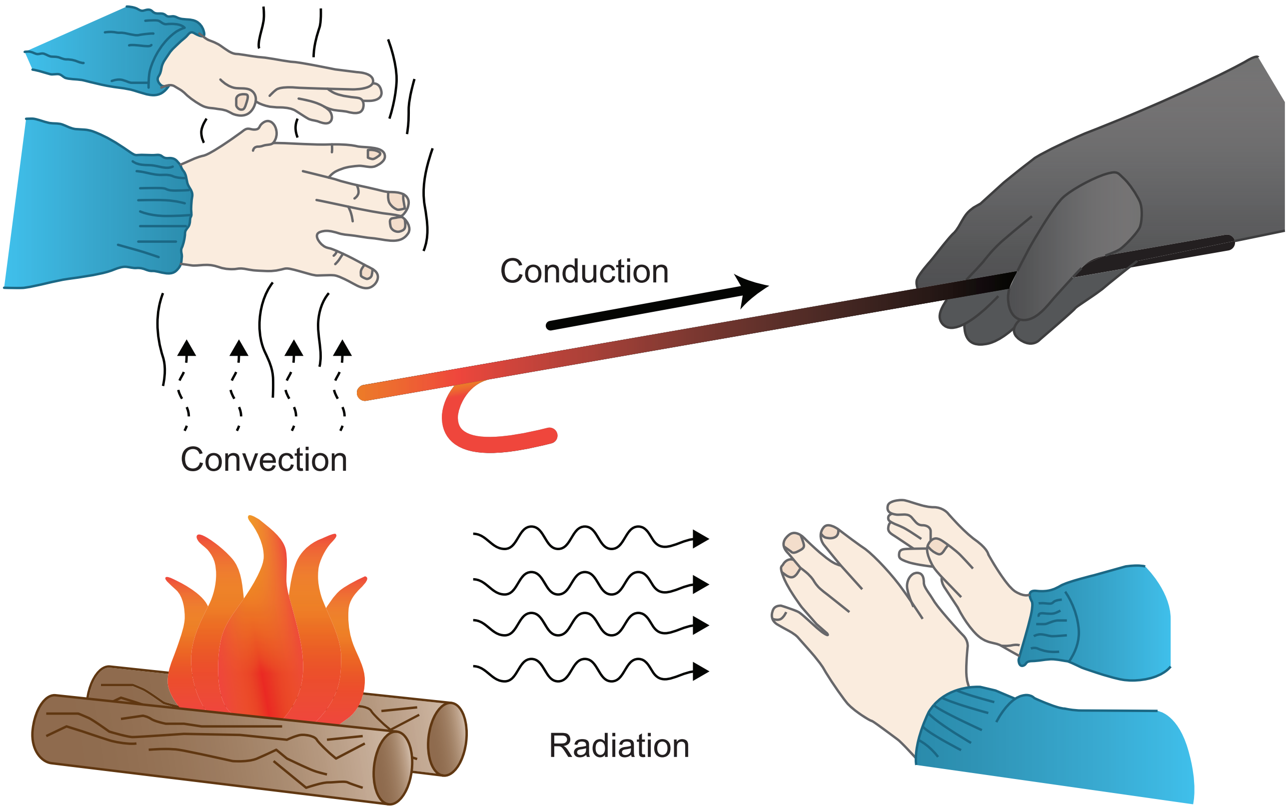


Figure 10.3: Conduction, convection and radiation

Conduction may occur in solids, liquids or gases, although it is most clearly present in solids. In conduction, heat energy is passed between molecules with heat flowing away from the source of heat towards low temperature regions.

The ability to conduct heat (thermal conductivity) varies between materials. Most metals are classed as good conductors though the ability to conduct heat varies widely between metals.

In a building fire heat energy can be conducted along unprotected structural steelwork and plumbing pipe work, enabling fire spread from compartment to compartment.

Convection occurs only in liquids and gases and involves the movement of heated liquid or gas molecules from the source of heat to cooler areas allowing cooler molecules to replace them before being heated and establishing a circulation of convection currents.

Convection causes the updraft in chimneys. In a building fire convection currents convey hot gases upwards through stairwells and open lift shafts spreading the fire to the upper levels. As the hot gases escape from the upper levels, cool air enters at low level to replace them. This helps to maintain the burning.

Heat may also be transmitted by *radiation* which does not require an intervening medium. Heat is radiated as infra-red radiation and behaves in the same way as light (visible radiation) in that it travels in straight lines, will cast shadows, and will be transmitted through some materials and not others.

Fire may spread between buildings by radiation, unless separation distances are adequate.

10.3 Preventing fire and fire spread

The traditional approach to fire safety management / management of fire precautions involves a two tiered approach, as shown in Figure 10.4. Fire prevention strategies reduce the likelihood of a fire and fire protection strategies protect the people, the building and other assets should a fire occur.

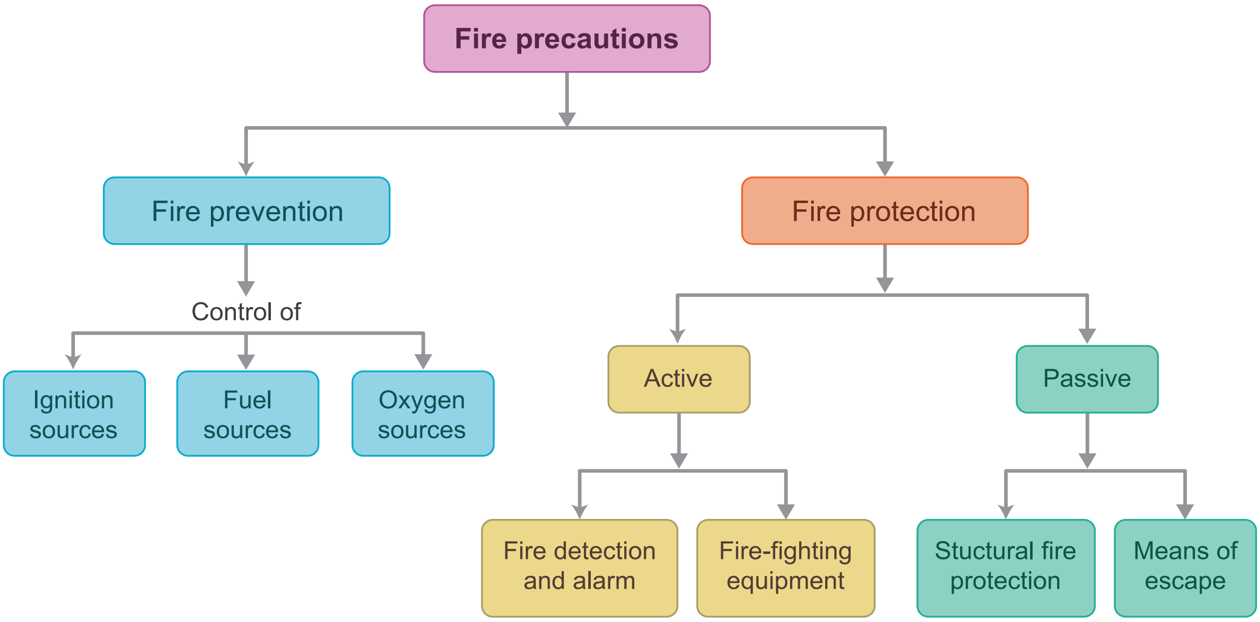


Figure 10.4: Fire precautions

This section discusses fire prevention and structural fire protection measures to prevent fire spread. Fire alarms and fire-fighting equipment are discussed in Section 10.4, and means of escape and evacuation strategies are addressed in Section 10.5.

Fire prevention

Fire prevention strategies are based on keeping the sides of the fire triangle apart, by controlling ignition sources, fuel sources, and oxygen sources.

Control of ignition sources

Examples of expected precautions are shown in Table 10.5.

Ignition source	Precautions
Smoking materials	• Smoking not permitted in workplace • Safe designated smoking areas
Plant and equipment	• Suitable equipment (for job and environment) • Properly maintained • Suitably located (away from combustible materials) • Safe systems for refuelling
Hot processes / hot work	• Correct equipment • Properly maintained • Competent workers • Permit to work
Electrical installations and electrical equipment	• Installation designed, inspected and maintained by competent person to BS7671 with no unauthorised modifications • Inspection and testing of portable appliances
Malicious fire starting (arson)	• Prevention of unauthorised access • Secure storage of combustible and flammable materials • Security patrols, security lighting, CCTV

Table 10.5: Control of ignition sources

Control of fuel sources

Most workplaces have plenty of potential fuel sources available. Furniture, fixtures and fittings, packaging materials, waste, stationery supplies, raw materials and product may all be combustible with sufficient ignition energy.

Control of fuel sources includes:

- specifying flame retardant / non-combustible furniture and furnishings
- effective stock control and efficient waste disposal to ensure quantities on site are kept as low as possible
- good housekeeping to ensure that materials are stored appropriately in suitable locations (away from ignition sources), and that dust is not allowed to accumulate.

Storage of flammable and highly flammable liquids in work rooms and other locations

Flammable and highly flammable liquids are categorised under the EU regulation on Classification, Labelling and Packaging of substances and mixtures (CLP) as shown in Table 10.6.

CLP pictogram and signal word		Hazard class and category	Hazard statement	Criteria
Flammable liquids				
	Danger	Flammable liquid Category 1	H224: Extremely flammable liquid and vapour	Flashpoint <23°C and initial boiling point ≤35°C
		Flammable liquid Category 2	H225: Highly flammable liquid and vapour	Flashpoint <23°C and initial boiling point ≤35°C
	Warning	Flammable liquid Category 3	H226: Flammable liquid and vapour	Flashpoint ≥23°C and ≤60°C

Note:

≤ means less than or equal to ≥ means greater than or equal to

Flashpoint the lowest temperature at which a substance vaporises sufficiently to form an ignitable mixture in air. Flashes when an ignition source is introduced but stops burning when the ignition source is removed.

Table 10.6 CLP flammable liquid categories

The basic principles for safe working with flammable liquids can be summarised with the acronym **VICES** (Table 10.7).

Ventilation	Prevents volatile vapours forming a flammable or explosive mix with air.
Ignition	Ignition sources should be removed or controlled so that should a flammable mix of vapour and air occur it cannot be ignited.
Containment	Suitable storage of flammable liquids to contain spills.
Exchange	Swapping flammable materials for less flammable materials.
Separation	Storage of flammables away from other stored materials and processes.

Table 10.7 VICES

Examples of HFLs include petrol, solvents, thinners and adhesives, which give off vapours which are highly flammable, toxic, and generally heavier than air.

Only the minimum amount of flammable liquid needed to carry out work should be stored in workrooms.

Plastic containers of highly flammable liquids will melt in a fire spilling their contents and fuelling rapid fire growth.

The risk is reduced by:

- keeping quantities to a minimum
- proper arrangements for storage
- suitable arrangements for the disposal of solvent contaminated materials.

No more than 50 litres of highly flammable liquids should be stored in a workroom and then only in a suitably located, fire-resisting cabinet or bin that will contain any leaks.

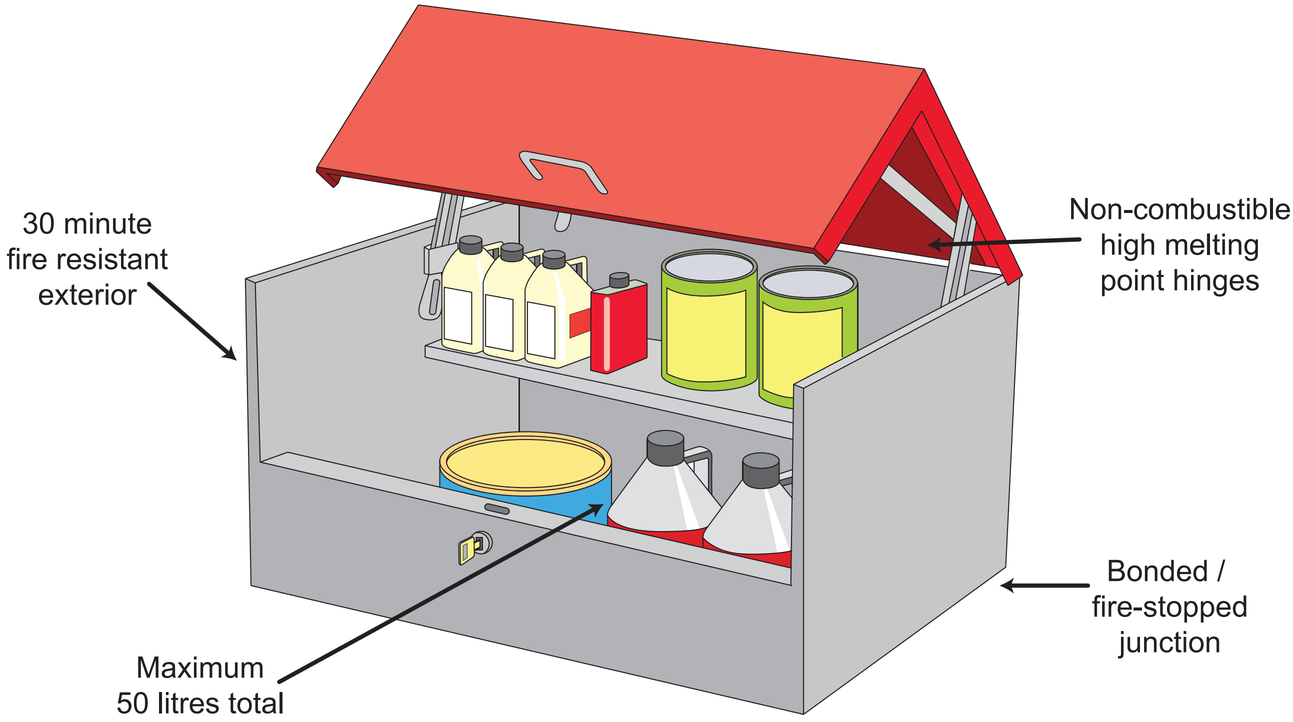


Figure 10.5: HFL storage cabinet

Quantities greater than 50 litres should be stored in a dedicated store and containers which are nominally empty or are not currently needed should be returned to that store.

There should be no potential ignition sources in areas where flammable liquids are used or stored and flammable concentrations of vapours may be present.

Any electrical equipment used in these areas, including fire alarm and emergency lighting systems, needs to be suitable for use in flammable atmospheres.

Prevention of fire spread

Compartmentation

Compartmentation is the division of a building into fire-resisting compartments (a fire compartment may comprise one or more rooms and may encompass more than one storey).

A fire-resisting compartment is separated from adjacent areas by fire-resisting elements of construction and is designed to contain a fire for a predetermined duration to limit the spread of fire and smoke.

The compartment provides time for occupants to escape or take refuge by containing a fire until it can be extinguished, and limits the extent of fire damage, aiding recovery and business continuity.

A fire compartment is only as good as its weakest link. To be effective, the enclosing boundaries (*i.e.* walls floors and ceilings) must be able to resist the spread of fire. This requires that:

- all enclosing surfaces have an appropriate level of fire resistance (30 minute steps)
- all junctions of constructional elements are effectively sealed
- all holes are fire stopped
- ducting that passes through a compartment boundary must be fire resisting and/or provided with fire dampers
- openings are protected by self-closing fire doors, fire-resisting shutters or curtains
- structural stability must be maintained for the required period.

Fire-resisting doors

Fire-resisting doors are necessary in any doorway located in a fire-resisting compartment. An effective fire-resisting door will hold back fire and smoke, preventing escape routes becoming unusable, and preventing the fire spreading from one area to another.

All fire-resisting doors are rated by their performance when tested to an appropriate British or European standard. The level of protection provided by the door is measured, primarily by determining the time taken for a fire to breach the integrity of the door assembly, together with its resistance to the passage of hot gases and flame.

Fire resistant doors are available providing 20, 30, 60 or 120 minutes of protection.

Timber doors typically require a gap of 2-4 mm between the door leaf and the frame to ensure that the door closes flush into its frame when smoke seals are fitted. For fire-resisting purposes the gap is normally protected by installing an intumescent seal, in either the door or, preferably, the frame.

The intumescent seal expands in the early stages of a fire and enhances the protection given by the door.

Glazing units, hinges and door furniture must provide the same level of protection as the door. The complete door and frame should be tested as a set.

Fire-resisting doors should be fitted with an appropriately controlled self-closing device that will effectively close the door from any angle.

On escape routes that are used regularly by significant numbers of people, or by people with impaired mobility an automatic door hold-open/release device may be more appropriate than self-closer. These use an electromagnetic device to hold open self-closing fire doors during normal use and releasing the door in the event of a fire alarm allowing the self-closing mechanism to close the door.

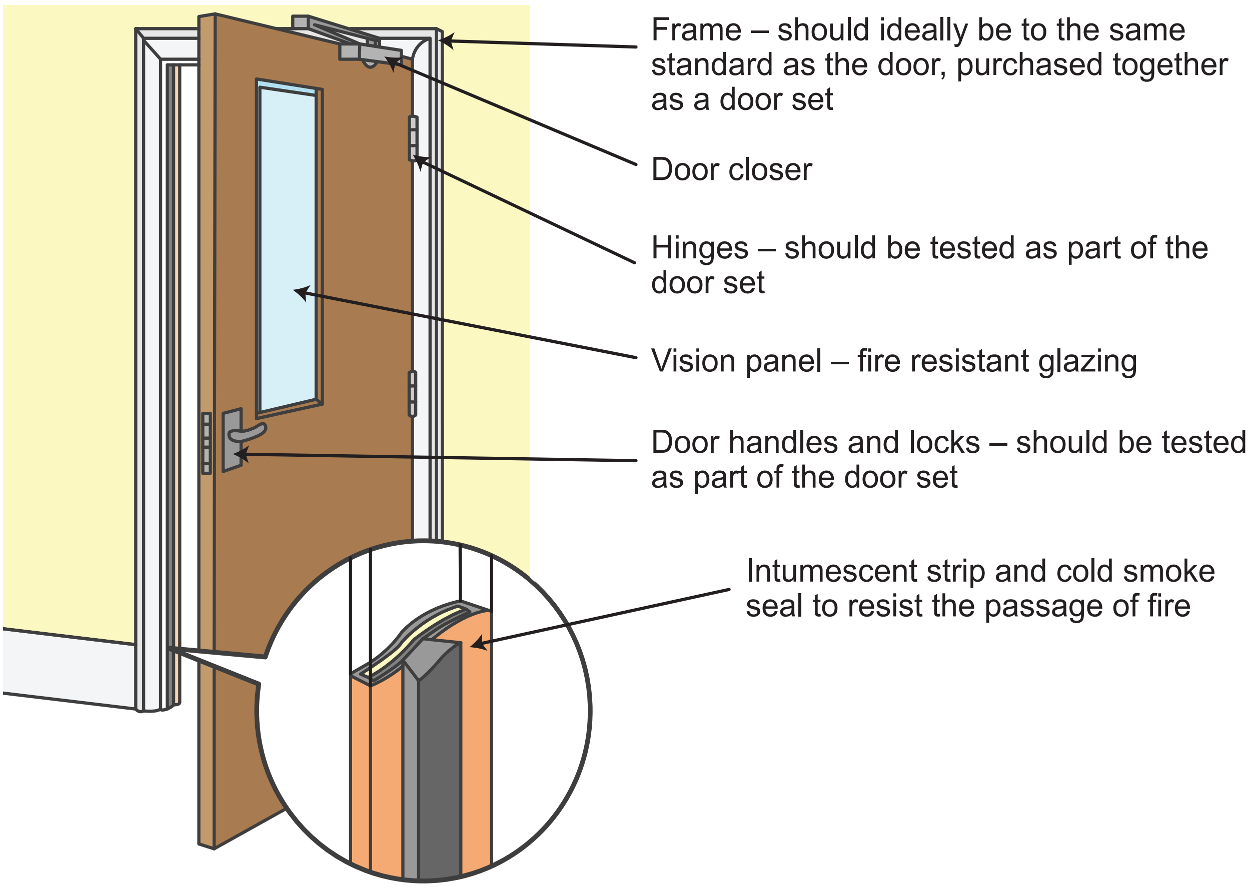


Figure 10.6: Fire resistant door

Protection of whatever the type of building, typical situations that may assist the spread of fire and smoke include:

- Vertical shafts – examples: lifts, open stairways, dumb-waiters or holes for moving stock around.
- False ceilings, especially if they are not fire-stopped above walls.
- Voids behind wall panelling.
- Large roof cavities, particularly in cold stores.
- Unsealed holes in walls and ceilings where pipe work, cables or other services have been installed.
- Doors, particularly to stairways, which are ill-fitting or routinely left open.

Fire stopping

The term 'fire-stopping' relates to products used for sealing apertures (*e.g.* where services pass through compartment walls) and rectifying imperfections of fit or design tolerance between the fire-resisting fixed elements of a building to restrict the passage of fire and smoke. The fire-stopping products must take up any imperfections of fit at all times and have the same fire rating as the fixed elements of which they form a part and/or interface. This may be achieved by:

- swelling, spreading or deforming to achieve their performance (intumescent materials)
- remaining stable and resilient.

Properties of common building materials

Table 10.8 details the major structural materials and their typical performance characteristics in a fire.

Material	Characteristics in fire
Timber	Timber burns though the burning or charring rate is predictable and varies slightly with the type of timber and not with the severity of the fire. The timber behind the charring plane is largely unaffected and able to perform structurally as intended.
Stone	Building stone is typically granite, limestone or sandstone. Granite contains free quartz which expands very rapidly at 575°C completely shattering the rock. Limestone (calcium carbonate) decomposes into free lime and CO2 at approximately 800°C. The interior is protected by the outer skin. Sandstone will shrink and crack in a fire at temperatures between granite and limestone.
Bricks	Traditionally in the UK bricks were made of fired clay. Concrete bricks and sand-lime bricks (calcium silicate) are now also popular. Brick performs better than stone in a fire
Concrete	Concrete consists of aggregates, cement and water mixed to form a mouldable material which sets hard with high compressive strength and durability. Concrete expands on heating and then shrinks as it dries out. The stresses arising can result in spalling of surface material.
Concrete blocks	Blocks made with limestone aggregates have higher fire resistance. The fire resistance is greatly improved if plastered both sides with a lightweight gypsum plaster.

Table 10.8: Characteristics of structural materials in fire (1 of 2)

Material	Characteristics in fire
Reinforced or pre-stressed concrete	Fire resistance depends on the mass of concrete around the steel reinforcement. Critical temperature (loss of 50% of cold strength) for mild steel is 550°C and 400°C for high tensile steel. Reinforced concrete will deflect considerably under load but is unlikely to collapse suddenly.
Structural Steel	Structural steel loses 2/3 of its strength at 593°C and will sag and twist in the direction of and in proportion to the load applied. Steel joists expand on heating (A 10m joist will expand 600mm at 500°C) which may cause load bearing support walls to collapse.
Other metals	Lead flashings and plumbing melt at 327°C Aluminium alloy cladding: Stability affected at 100°C to 225°C, high expansion rate, high thermal conductivity, melts at 660°C
Glass	Non-combustible. May be a weak point in a fire barrier as it will break at high temperatures.
Plasterboard	Consists of a core of set gypsum or anhydrite plaster bonded to external facings of heavy paper. Gypsum is non-combustible. Will retard fire spread until paper burns and gypsum core breaks up.
Asbestos sheets and boards	Asbestos cement sheets contain up to 15% asbestos. Shatter in the early stages of fire. Asbestos insulating/wall boards are 80% asbestos 20% lime-silica bonding agent. Non-combustible but will contract and bow away from heat source.
Plastics	The term covers a broad range of chemicals. Generally plastics are combustible and the combustion products are likely to be toxic.

Table 10.8: Characteristics of structural materials in fire (2 of 2)

Electrical equipment in flammable atmospheres

Hazardous areas are defined as *'any place in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of workers.'*

Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

Zone	Description	Common limit values
Zone 0 (Gases) Zone 20 (Dusts)	An area in which an explosive gas atmosphere is present continuously or for long periods	Explosive atmosphere for more than 1000 h/yr
Zone 1 (Gases) Zone 21 (Dusts)	An area in which an explosive gas atmosphere is likely to occur in normal operation	Explosive atmosphere for more than 10, but less than 1000 h/yr
Zone 2 (Gases) Zone 22 (Dusts)	An area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it occurs, will only exist for a short time	Explosive atmosphere for less than 10 h/yr, but still sufficiently likely as to require controls over ignition sources

Table 10.9: Hazardous zones

Selection of appropriate electrical equipment requires knowledge of the classification of the hazardous area (as in Table 10.9) and the temperature class or ignition temperature of the gas or vapour involved.

The types of electrical protection suitable for use in different zones are shown in Table 10.10.

Zone 0	Zone 1	Zone 2
Category 1 Equipment	Category 2 Equipment	Category 3 Equipment
'ia' Intrinsically safe Ex s – Special protection if specifically certified for Zone 0	*'d'* – Flameproof enclosure *'p'* – Pressurised *'q'* – Powder filling *'o'* – Oil immersion *'e'* – Increased safety *'ib'* – Intrinsic safety *'m'* – Encapsulation *'s'* – Special protection	Type *'n'*

Table 10.10: Types of electrical protection

Common fire detection and alarm systems

A fire detection and alarm system may be manual or automatic.

A *manual alarm system* consists of break-glass units and alarm sounders connected to a control panel and can only be activated by an individual operating a break glass unit after detecting a fire.

An *automatic system* adds smoke and heat detectors to the above and is designed to raise the alarm to give early warning, whether or not people are present.

Automatic fire alarm systems are designed as *'P systems'* which are designed with an emphasis on property protection or *'L systems'* which are primarily designed for the protection of life.

Information from a fire detectors signal is sent to and processed by the fire alarm control panel. Fire detection systems are classified according to the way the information is sent and processed as either:

- conventional monitored systems
- addressable systems (including addressable analogue).

In a *conventional monitored system* the detection points (either smoke or heat) are wired in radial circuits from the control panel. At the end of each circuit, a resistor or semiconductor device creates a known resistance across the circuit providing a steady-state reference. If a detector is activated by a fire, the steady-state resistance of the circuit to which it is connected will be altered and the fire alarm will be raised.

As each radial circuit from the control panel will have a number of detectors connected to it, identification of the location of a fire is limited to the affected circuit (or Zone).

In an *addressable system* detectors are connected in loops rather than radial circuits and each detector is allocated a unique identification *'address'*.

Addressable analogue systems use detectors that constantly relay information on their operating condition to the control panel.

Break-glass call points

A break-glass call point is designed to allow a person to raise the alarm, in the event of a fire, by breaking a glass cover to activate the alarm.

Break-glass call points should be located:

- on exit routes and, in particular, on floor landings or staircases and at all exits to the open air
- so that no person need travel more than 45 m in order to operate one
- at a height of 1.2 m above the floor in a conspicuous, readily accessible position.

Fire detectors

Fire detectors are designed to detect one or more of the four characteristics of fire, namely:

- heat
- smoke
- combustion gas (such as carbon monoxide)
- infra-red or ultraviolet radiation.

They may detect:

- a pre-determined threshold of a characteristic (*e.g.* a temperature)
- a rate-of-change of the characteristic (*e.g.* a rate of increase of temperature).

They may be designed as point or line detectors, where:

- point detectors detect at a defined point(s) within a protected area
- line detectors are capable of detecting the characteristic along a defined line within the protected space.

Heat detectors may be point type or line type detectors, they may respond to a fixed temperature or a rate of rise of temperature.

Point smoke detectors utilize one (or both) of two principles:

- *ionization chamber smoke detectors* detect smoke by the reduction it causes in current flow between electrodes in an ionization chamber
- *optical smoke detectors* detect smoke by means of the light scatter that results from the presence of a small light source within the detector.

Optical beam smoke detectors are effectively line type smoke detectors. They comprise a light source (usually infra-red) and a receiver. They detect the presence of smoke as it obscures the light source.

Aspirating smoke detection systems draw air samples, by a pump or fan, through sampling points to a central detector which may be an ionization chamber or optical detector.

Smoke may also be detected by *video techniques*, in which closed circuit television (CCTV) cameras monitor the protected space. The CCTV signals are analysed electronically to detect the presence of smoke by as it obscures the camera's field of view.

Combustion gas detectors are point-type detectors that respond to one (or more) of the gases produced by a fire, *e.g.* carbon monoxide.

Flame detectors detect the infra-red and/or ultraviolet radiation that is emitted by flame. Both types use radiation-sensitive cells that *'see'* the fire either directly or through built-in lenses or reflectors.

Multi-sensor fire detectors contain more than one sensor, each of which responds to a different physical and/or chemical characteristic of fire.

Choice of fire detection principle

No individual detector is suitable for all applications. The choice will depend primarily on:

- the speed of response required (to satisfy the fire safety objective, *e.g.* safe evacuation)
- the need to minimize false alarms
- the nature of the fire hazard.

The following also need to be taken into account:

- the nature and quantity of the combustible materials present, including ease of ignition, heat release rate, likely form of combustion (*e.g.* smouldering or flaming) and propensity for smoke production
- probable rate of fire growth and spread
- the nature of the environment (*e.g.* humidity, temperature, cleanliness, extent of pollutants and nature of work processes)
- the proposed fire evacuation strategy
- the height and geometry of the protected area
- the attendance time of the fire service (particularly in the case of Category P systems)

- other active and passive fire protection measures present
- the susceptibility of contents to heat, smoke and water
- the speed of response to fire and the probable false alarm rates, of different types of fire detector.

Cost, suitability for the environment and maintenance requirements are also considerations. In some circumstances, a mixture of different types of detector may be necessary to ensure early detection or to minimise false alarms.

The pros and cons of the different detector types are shown in Table 10.11.

Type of detector	Pros	Cons
Heat detectors	Can detect clean burning fires, (*e.g.* alcohol) before a smoke or combustion gas detector. Greatest resistance to environmental conditions and greatest immunity to false alarms. Require minimum attention during system maintenance.	Less sensitive to most fires than all other types of fire detector. Unlikely to detect smouldering fires. Will not operate until flames reach about one-third of the distance to the ceiling Not suitable in clean rooms where early warning of the presence of smoke is required.
Optical smoke detectors	Sensitive to optically dense smoke. Well suited for use in escape routes because they detect visible smoke and might operate before the escape route becomes impassable.	Less sensitive to the small particles found in clean-burning fires with little visible smoke. Cannot detect the products from clean-burning fires (*e.g.* alcohol) (Unless incorporating thermal turbulence detection).
Ionization chamber smoke detectors	Particularly sensitive to smoke containing small particles, such as are produced in rapidly burning flaming fires.	Less sensitive to the larger particles found in optically dense smoke from smouldering fires.

Type of detector	Pros	Cons
Smoke detectors (general)	Much faster response to most fires than heat detectors.	Likely to give false alarms from work process fumes and dust etc.
Aspirating smoke detection systems	Much higher sensitivity than other smoke detectors. Used in clean rooms where a small fire could cause unacceptable damage.	Relatively insensitive to free burning fires supported by a plentiful supply of oxygen.
Flame detectors	Specialized applications, such as detection of fires in plants handling or storing highly flammable liquids or gases.	Unable to detect smouldering fires. Relatively high cost.
Combustion gas detectors	Most sensitive to smouldering fires.	CO detectors can be immune to false alarms from dust, steam and cigarette smoke.

Table 10.11: Pros and cons of fire detectors

Provision of PFE

Class A (carbonaceous solids) materials are generally present in all premises and occupancies.

Minimum provision of Class A portable fire extinguishers (PFE) would be 2 x 13A extinguishers on each storey for floor spaces of up to 400 m^2. For smaller premises <100 m^2 1 x 13A extinguisher would suffice.

For larger spaces the provision can be calculated by multiplying the floor area in m^2 x 0.065.

A 13A rating means that the extinguisher is capable of extinguishing a fire in a 1.3 m test crib under test conditions.

In addition to general Class A provision the risk assessment should determine the need for additional hazard specific provision.

Class B (flammable liquids) should be provided for on a room by room basis. And is based on the surface area of a single open-topped container of flammable liquid (*e.g.* mixing vessel, dip tank, spillage in bunded area).

A rating of 21B means that the extinguisher is capable of extinguishing a fire of 21 litres of fuel in a test tray with a surface area of approximately 0.66 m^2 under test conditions.

Different types of extinguisher with the same rating may have different characteristics.

Powders are probably the most effective medium against class B fires but are not effective if part of the fuel surface is shielded from the powder discharge. Foam is effective against contained fires where it will provide semi-permanent protection, but is not effective against running fires.

- Re-ignition of fuel is less likely with a foam extinguisher than powders or gases.
- Class C (gas) fires require the presence of 1 x special powder extinguisher.
- Class D (metal) fires require a specialist assessment for provision of PFE.

Class F (fats and cooking oils) provision is based on the ability to cope with a fire of specified surface areas under test conditions.

For *electrical* and class F fires the first objective should be to isolate the power. For class C the fuel supply should be isolated.

Siting of PFE

Extinguishers should be located in conspicuous positions on brackets or stands where they will be readily seen by persons following an escape route, but not where a potential fire might prevent access to them.

Suitable locations include: near to room exits, corridors, stairways, lobbies and landings.

A record should be kept, on a plan, of the type, number and location of the extinguishers.

Small extinguishers (<4 kg) should be mounted so that the handle is approx. 1.5 m from the floor. For larger, heavier extinguishers this should be about 1 m from the floor.

Heavy extinguishers should not pose a risk of injury by being dislodged. Suitable brackets should be used if necessary to hold the extinguisher in place.

Extinguishers should be available for immediate use at all times. It should not be necessary to travel more than 30 m from the site of the fire to reach an extinguisher (20 m in higher risk situations). Similar positions on each floor are advisable.

Extinguishers should not be placed in concealed positions behind doors, in cupboards or deep recesses, or in positions where they might cause obstruction to exit routes or be damaged by trolleys, nor should they be placed over or close to heating appliances.

If the view of an extinguishers is obscured its position should be indicated by suitable signs.

Extinguishers provided to deal with special fire risks should be sited near to the fire risk concerned, but not so near as to be inaccessible or place the operator in undue danger in case of fire.

The operation of extinguishers is affected by temperature. Extinguishers are marked with the temperature range within which they will perform satisfactorily and should not be exposed to storage temperatures outside the marked range.

Extinguishers should not be located in unduly corrosive atmospheres unless they have been:

- specially treated by the manufacturer
- specially housed in purpose designed boxes
- provided with protective covers designed for the purpose.

Inspection and maintenance of PFE

All portable fire extinguishers will require periodic inspection, maintenance and testing by a competent person.

Depending on local conditions such as the likelihood of vandalism or the environment where extinguishers are located, carry out brief checks to ensure that they remain serviceable.

In normal conditions a monthly visual check by a competent person should be appropriate. Local environmental conditions or risk of vandalism may dictate more frequent checks.

The monthly check should ensure that:

a. each extinguisher is correctly located in the designated place
b. each extinguisher is unobstructed and visible
c. the operating instructions are clean, legible outward facing
d. each extinguisher has not been operated, is not damaged, and has no missing parts
e. the pressure gauge or indicator reading is within operational and safety limits
f. the seals and tamper indicators are not broken or missing.

The responsible person should also ensure that extinguishers, along with any spare gas cartridges and replacement charges, are maintained regularly.

Basic services of all extinguishers should be conducted annually, an extended service of water and powder extinguishers should be undertaken every five years, and an overhaul of gas extinguishers every ten years.

Training in the use of PFE

Decisions will need to be made regarding who is expected to use PFE. This may be emergency response team members, staff with specific responsibilities such as fire marshals, or staff in an area with a specific fire risk. It is unlikely that all staff would be expected to use PFE.

All staff identified as expected to use PFE will require adequate training. Such training should deal with:

- how to operate the different types of fire extinguisher
- an assessment of the physical capability of staff to carry and operate different sizes of fire extinguisher
- the maximum distance it is reasonable for individuals to carry a fire extinguisher

- the necessity of maintaining a route to safety so that the operator can turn away from the fire and escape
- an indication of the maximum size of fire a staff member should try to extinguish (expressed in common terms such as a single wastepaper basket).

All training should be repeated at least annually.

Fire extinguishing media

Methods of extinguishing fire

The fire triangle (Figure 10.1) showed that fuel, oxygen and heat energy are needed for combustion to occur.

Fire-fighting generally involves depriving the fire of one or more of these factors, so methods of extinguishing fire can be classified as:

- starvation – limiting fuel
- smothering – limiting oxygen
- cooling – limiting heat.

1. Starvation

Fires can be starved of fuel in three ways:

- by removing potential fuel from the vicinity of the fire, *e.g.* by draining fuel from burning tanks
- by removing the fire from the mass of combustible material *e.g.* pulling apart a burning haystack
- by dividing the burning material into smaller fires.

2. Smothering

Smothering works by preventing fresh air reaching the seat of the fire and thus allowing combustion to reduce the oxygen content in the confined atmosphere until it extinguishes itself.

Fire blankets and foam, powder and gas extinguisher can all help to smother a fire.

Figure 10.7: Starvation, smothering and cooling

3. Cooling

Combustion will stop as soon as the rate of cooling exceeds the rate of heat generated by the combustion process.

Cooling the fuel is the main way in which water is used to extinguish fires.

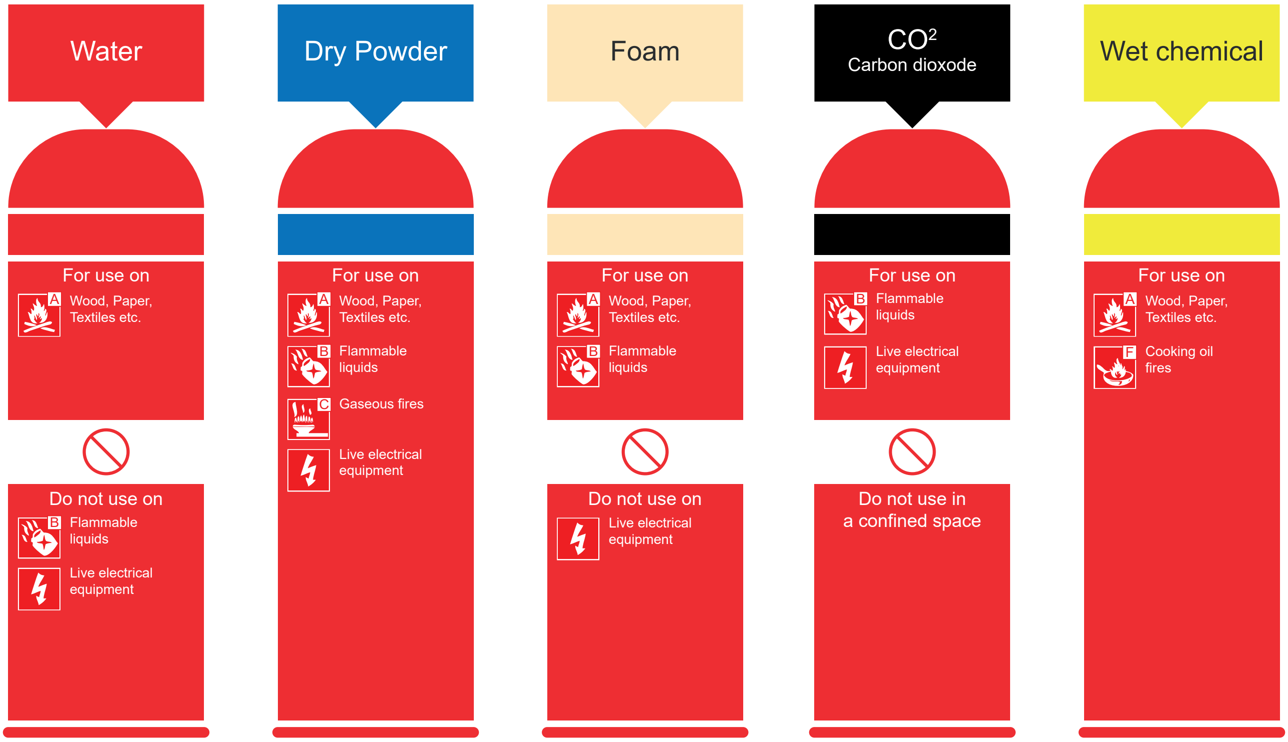


Figure 10.8: Portable Fire Extinguishers – extinguishing Media

Extinguishing media

Water

Water is the most efficient, cheapest and most readily available medium for extinguishing fires of a general nature.

Water is generally ineffective against fires involving liquid fuels (as it sinks below the surface of the fire), and is not suitable for use around live electrical equipment.

Foam

Fire-fighting foams have been developed primarily to deal with the hazards posed by liquid fuel fires.

They are either protein based or synthetic based, depending on the chemicals used to produce them.

Carbon dioxide and inert gases

Carbon dioxide extinguishes by smothering. Reducing the oxygen content of the air by about 20 to 30% is necessary to cause complete extinction, depending on the nature of the burning material.

Carbon dioxide is quick and clean, electrically non-conducting, non-toxic and non-corrosive. Most fabrics are unharmed by it.

Dry chemical powders

Dry powder is very effective at extinguishing flame (*'rapid knock-down'*), and is particularly valuable in tackling a fire involving an incident in which someone's clothes have been soaked in flammable liquid, and ignited.

Fire suppression systems

Water sprinkler systems

A conventional automatic sprinkler system consists of pipes and heat-sensitive sprinkler heads connected to a water supply. Fire is detected by individual sprinkler heads, which open to release water, in the form of spray, to the seat of the fire. The alarm is raised at the same time and the fire is kept under control until the arrival of the fire brigade.

Figure 10.9: Sprinkler head in warehouse racking

When sprinklers are present, the chances of dying in a fire are reduced by 50% to 75% and the average property loss per fire is cut by 50% to 65%.

As the action of the sprinklers is likely to reduce the rate of burning of a fire, and the mass smoke flow, there are number of possible benefits to building designers, including:

- the travel distance to an exit can potentially be increased without reducing the level of peoples
- building compartment areas/volumes may be increased over that for a similar non-sprinkler system building

- fire resistance levels of structural components may be reduced
- the separating distance between buildings may be reduced by one half.

Foam

Foam systems are most commonly used to protect flammable liquid pool/surface fire hazards. Foam is not suitable for live electrical hazards or three-dimensional running fuel fires.

Gas flooding

Gaseous systems are an effective means of attacking fires in electrical risks such as electronic data processing (EDP) facilities, control rooms and communications equipment, ordinary class A hazards such as record stores, as well as class B hazards such as flammable liquid fires in plant enclosures and flammable liquid stores.

Modern gas flooding systems use halocarbons or inert gas mixes.

Gaseous systems are *'clean'*, *i.e.* they limit smoke generation and leave no post-fire residues for clear-up.

Access for fire and rescue services and vehicles

As highlighted in **Element 2**, consideration should be given to access for fire and rescue services and other vehicles when planning traffic routes. For example:

- **Roadways**:
  - width of gateways – minimum 3.1 m for most emergency vehicles
  - width of road – minimum 3.7 m for most emergency vehicles
  - turning circle
  - clearance height – gantries, overhead pipework etc.
  - laden weight of emergency vehicle (*e.g.* pumping fire appliance approx. 12.5 tonnes and hydraulic platforms approx. 17 tonnes).

Obstructions to access

All access roads for Fire & Rescue Service appliances should be kept clear of any obstructions, including trees, lamp standards, etc. which may obstruct vehicular movement or foul the ladders on vehicles. It may, however, be considered necessary to restrict unauthorised entry and various arrangements as discussed below. Before any obstructions are installed the proposed arrangements should be agreed with the Fire and Rescue Service. Key issues include:

- posts and bollards – obstruction of hydrants and/or access by emergency vehicles
- speed control humps
- pedestrianisation of high streets and shopping areas etc.
- enforced no parking zones and/or the provision of passing bays on roads reduced to a single lane
- provision of an extra *'emergency gate'* for large and/or hazardous premises
- padlocks for the purpose of securing bollards, posts or gates must be capable of being cut open in an emergency with the bolt croppers carried on emergency vehicles.

10.5 Fire evacuation

Means of escape

Once a fire has started, been detected and a warning given, everyone in the premises should be able to escape to a place of total safety unaided (staff will need to be appointed to assist people with disabilities or special needs).

Escape routes should be designed to ensure, as far as possible, that any person confronted by fire can turn away from it and escape to a place of reasonable safety, *e.g.* a protected stairway.

Fire resisting construction

Where an escape route needs to be separated from the rest of the premises by fire-resisting construction, *e.g.* a dead-end corridor or protected stairway:

- doors walls, floors and ceilings on protected escape routes should be capable of resisting the passage of smoke and fire for long enough so that people can escape from the building
- where suspended or false ceilings are provided, the fire resistance should extend up to the floor slab level above
- cavity barriers, fire stopping and dampers in ducts should be appropriately installed.

For means of escape purposes a 30 minutes fire-resisting rating is normally enough.

Capacity of escape routes and stairways

The escape routes must have adequate capacity for people to escape safely in sufficient time to ensure their safety in case of fire.

The capacity of an escape route is measured by the number of persons per minute that can pass through the effective usable width (narrowest point) of the escape route.

The capacity is determined by a number of factors including the:

- width of the route
- time available for escape
- ability of the persons using them.

Route width

A width of at least 750 mm can accommodate up to:

- 80 people in higher risk premises
- 100 people in normal risk premises
- 120 people in lower risk premises.

A width of at least 1050 mm can accommodate up to:

- 160 people in higher risk premises
- 200 people in normal risk premises
- 240 people in lower risk premises.

An additional 75 mm should be allowed for each additional 15 persons (or part of 15).

Note:

The minimum width of an escape route should not be less than 750 mm (unless it is for use by less than five people in part of the premises) and, where wheelchair users are likely to use it, not less than 900 mm.

Stairways should be at least 1050 mm wide and in any case not less than the width of the escape routes that lead to them.

Stairways wider than 2100 mm should normally be divided into sections, each separated from the adjacent section by a handrail, so that each section measured between the handrails is not less than 1050 mm wide.

Doors

Doors on escape routes should

- open in the direction of escape
- ideally be fitted with a safety vision panel.

At least two exits should be provided if a room/area is to be occupied by more than 60 persons.

While not normally acceptable, the use of ladders, floor hatches, wall hatches or window exits may be suitable for small numbers of able-bodied, trained staff in exceptional circumstances.

Time available for escape

About two thirds of the time available to escape is taken up by the initial reaction to the developing situation, checking what other people are doing and working out whether the situation is real or false. The actual movement away from the area of the fire takes up the final third.

To take account for the limited available time for people to travel to a place of reasonable safety, the length of escape routes needs to be kept as short as possible. The suggested travel distances are shown in Table 6.9.

Travel distance

Having established the number and location of people and the exit capacity required to evacuate them safely, the adequacy of the number and location of existing exits should be determined.

This is done by considering the distance people have to travel to reach them (Table 10.12).

Escape routes	Suggested range of travel distance
Where only a single route is provided	12 m – Higher fire-risk areas 18 m - Normal fire-risk areas 25 m – Lower fire-risk areas
Where more than one escape route is provided	25 m – Higher fire-risk areas 45 m - Normal fire-risk areas 60 m – Lower fire-risk areas

Table 10.12: Travel distances

Travel distances are flexible and may be increased or decreased depending upon the level of risk (see later) after appropriate fire-prevention measures are in place.

In new buildings, designed and constructed in accordance with modern building standards, the travel distances will already have been calculated.

The actual distances to be travelled by people when escaping needs to be considered, allowing for walking around furniture or display material etc. (see Figure 10.10).

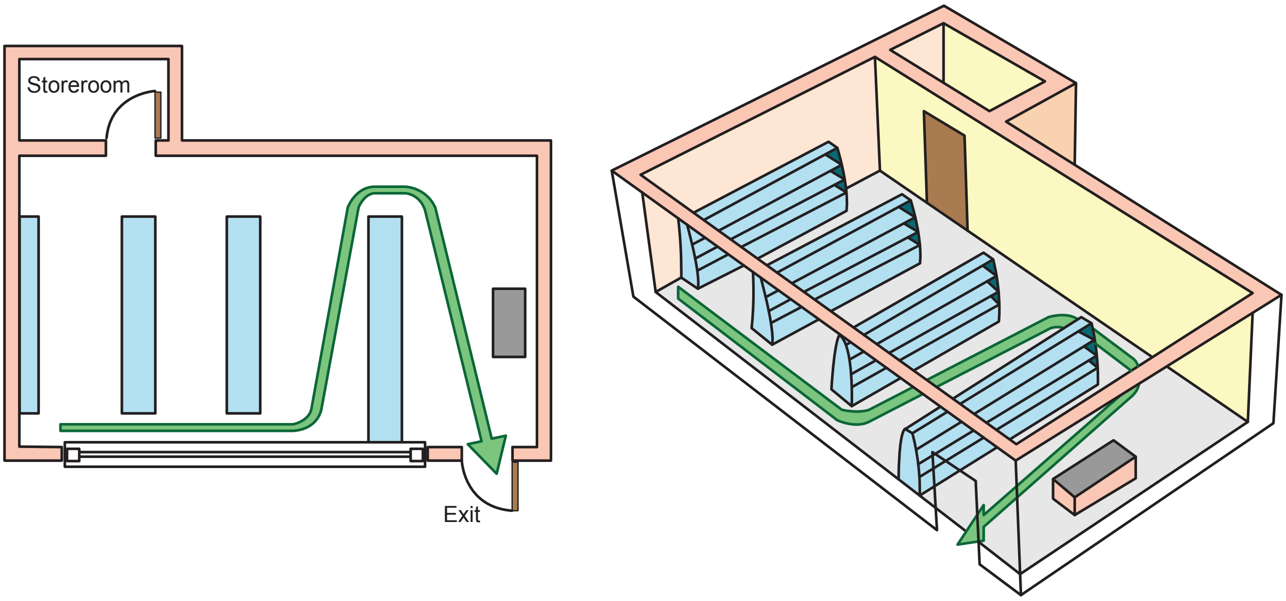


Figure 10.10: Measuring travel distances

The distance should be measured from all parts of the premises (*e.g.* from the most remote part of the workplace) to the nearest place of reasonable safety which is:

- a protected stairway enclosure (a storey exit)
- a separate fire compartment from which there is a final exit to a place of total safety
- the nearest available final exit.

Levels of risk

Appropriate travel distances vary according to the level of risk in the premises (or part of them).

Most workplaces will be *normal risk*.

Higher risk premises are those where:

- there is a likelihood of a fire starting and spreading quickly
- a fire could start and grow without being quickly detected and a warning given and affect the escape routes before people are able to use them.
- Higher risk premises include those where:
- significant quantities of flammable materials are used or stored
- ready sources of ignition are present, *e.g.* heat producing machinery and processes
- significant numbers of the people present are likely to move slowly or be unable to move without assistance
- the construction provides hidden voids or flues through which a fire could quickly spread.

Lower risk premises will have:

- low occupancy levels/able bodied occupants
- very little chance of a fire
- few (or no) highly combustible or flammable materials or other fuels
- fire cannot spread quickly and will be quickly detected.

Management of escape routes

Escape routes should be managed and maintained to ensure that they remain usable and available at all times when the premises are occupied.

Corridors and stairways that form part of escape routes should be kept clear and hazard free at all times. Items that may be a source of fuel or pose an ignition risk should not normally be located on any corridor or stairway that will be used as an escape route.

Emergency escape lighting

People will need sufficient lighting to be able to find their way to a place of total safety if there is a fire.

Where escape routes are internal and without windows, or the workplace is used during periods of darkness, including early darkness on winter days, then some form of backup to the normal escape route lighting (emergency escape lighting) is likely to be required.

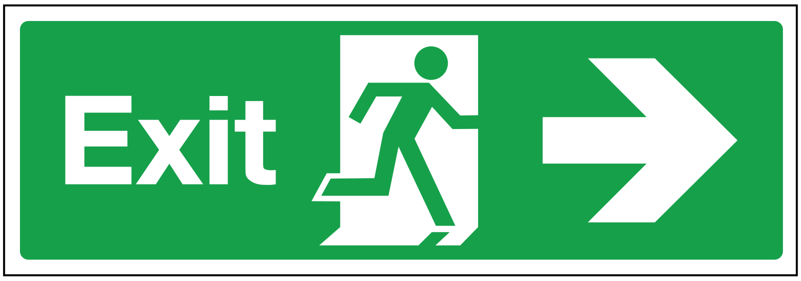
In small premises, where the escape routes are simple and straightforward, borrowed lighting from street lamps or provision of torches may be acceptable.

In larger, more complex premises it is likely that an automatic emergency escape lighting system will be needed to illuminate all the escape routes. Where people have difficulty seeing conventional signs, a *'way-guidance'* system may need to be considered.

Emergency lighting systems should be tested regularly to ensure they will work effectively when required.

Signs

Signs must be used, where necessary, to help people identify escape routes, find fire-fighting equipment and emergency fire telephones.



Signs must be in pictogram form to comply with the Health and Safety (Safety Signs and Signals) Regulations. The pictogram can be supplemented by text if this is considered necessary to make the sign more easily understood.

Notices

Notices must be used, where necessary, to provide the following:

- instructions on how to use any fire safety equipment
- the actions to be taken in the event of fire
- help for the fire and rescue service (*e.g.* Location of sprinkler valves or Electrical cut-off switches).

All signs and notices should be positioned so that they can be easily seen and understood.

Emergency evacuation procedures

The primary objective of an evacuation strategy is to ensure that in the event of a fire, the occupants of a building can reach a place of ultimate safety outside the building.

There are two basic approaches to evacuation:

- total evacuation, which may be simultaneous or phased
- progressive evacuation.

Total evacuation strategies

Total simultaneous evacuation is the standard approach used in premises where it would be unreasonable to expect the occupants to remain in an affected area for a prolonged time when there is a fire.

Typically the fire alarm sounders indicate an immediate evacuation and all occupants proceed to a place of ultimate safety.

A *phased evacuation* occurs in two stages. Key staff is alerted before the alarm sounders are activated giving an opportunity to investigate, confirm the fire and prepare the evacuation response. A phased approach is commonly used in multi-storey premises where people on the storey most at risk are evacuated in the first instance and then the remaining storeys are evacuated at phased intervals.

Progressive evacuation

Progressive horizontal evacuation strategies are typically used in hospitals and nursing homes. Vulnerable people are initially evacuated into an adjoining fire compartment on the same storey, allowing time for the fire service response and organising for full evacuation to a place of ultimate safety, if necessary.

Zoned evacuation strategies are often adopted in large retail developments, to avoid significant operational losses as a consequence of a relatively small fire. Occupants are moved away from the affected zone to an adjacent zone while the fire-affected zone is brought under control.

Fire marshals

Staff expected to undertake the role of fire marshals (often called fire wardens) would require more comprehensive training. Their role may include:

- helping those on the premises to leave
- checking the premises to ensure everyone has left
- using fire-fighting equipment if safe to do so
- liaising with the fire and rescue service on arrival
- shutting down vital or dangerous equipment
- performing a supervisory/managing role in any fire situation.

Training for this role may include:

- detailed knowledge of the fire safety strategy of the premises
- awareness of human behaviour in fires
- how to encourage others to use the most appropriate escape route
- how to search safely and recognise areas that are unsafe to enter
- the difficulties that some people, particularly if disabled, may have in escaping and any special evacuation arrangements that have been pre-planned
- additional training in the use of fire-fighting equipment
- an understanding of the purpose of any fixed fire-fighting equipment such as sprinklers or gas flooding systems
- reporting of faults, incidents and near misses.

Fire drills

The best way to evaluate the effectiveness of the emergency plan is to perform a fire drill. This should be carried out at least annually but may need to carry them out more often, *e.g.* in workplaces with high staff turnover.

A well-planned and executed fire drill will confirm understanding of the training and provide helpful information for future training.

The responsible person should determine the possible objectives of the drill such as to:

- identify any weaknesses in the evacuation strategy
- test the procedure following any recent alteration or changes to working practices
- familiarise new members of staff with procedures
- test the arrangements for disabled people.

Who should take part?

Within each building the evacuation should be for all occupants except those who may need to ensure the security of the premises, or people who, on a risk-assessed basis, are required to remain with particular equipment or processes that cannot be closed down.

Premises that consist of several buildings on the same site should be dealt with one building at a time over an appropriate period unless the emergency procedure dictates otherwise.

Where appropriate it may be helpful to include members of the public in the fire drill – ensuring that all necessary health and safety issues are addressed beforehand.

Carrying out the drill

For premises that have more than one escape route, the escape plan should be designed to evacuate all people on the assumption that one exit or stairway is unavailable because of the fire.

This can be simulated by a designated person being located at a suitable point on an exit route. Applying this scenario to different escape routes at each fire drill will encourage individuals to use alternative escape routes which they may not normally use.

When carrying out the drill it may be helpful to:

- circulate details concerning the drill and inform all staff of their duty to participate. It may not be beneficial to have *'surprise drills'* as the health and safety risks introduced may outweigh the benefits
- ensure that equipment can be safely left
- nominate observers
- inform the alarm receiving centre if the fire-warning system is monitored (if the fire and rescue service is normally called directly from your premises, ensure that this does not happen)
- inform visitors and members of the public if they are present
- ask a member of staff at random to set off the alarm by operating the nearest alarm call point using the test key, this will indicate the level of knowledge regarding the location of the nearest call point.

The roll call/checking the premises have been evacuated

A roll call should be undertaken as soon as possible at the designated assembly point(s), and/or fire wardens' reports following their *'sweep'* of the premises. People who are unaccounted for should be noted. In a real evacuation this information will need to be passed to the fire and rescue service on arrival.

Check that people have assembled at the evacuation point

Once the roll call is complete or all reports have been received, allow people to return to the building. If the fire-warning system is monitored inform the alarm receiving centre that the drill has now been completed and record the outcomes of the drill.

Monitoring and debrief

Throughout the drill the responsible person and nominated observers should pay particular attention to:

- communication difficulties with regard to the roll call and establishing that everyone is accounted for
- the use of the nearest available escape routes as opposed to common circulation routes
- difficulties with the opening of final exit doors
- difficulties experienced by people with disabilities
- the roles of specified people, *e.g.* fire wardens
- inappropriate actions, *e.g.* stopping to collect personal items, attempting to use lifts etc.
- windows and doors not being closed as people leave.

On-the-spot debriefs are useful to discuss the fire drill, encouraging feedback from everybody.

Later, reports from fire wardens and observations from people should be collated and reviewed.

Any conclusions and remedial actions should be recorded and implemented.

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