

Code of practice for

Fire precautions in the chemical and allied industries

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British Fire Services' Association	Fire Brigades Union
British Gas plc	Health and Safety Executive
British Retailers' Association	Home Office
Building Employers' Confederation	Incorporated Association of Architects and Surveyors
Chartered Institution of Building Services Engineers	Institute of Building Control
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Department of Health	London Fire and Civil Defence Authority
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Department of the Environment (Construction Industries Directorate)	National Council of Building Material Producers
Department of the Environment (Property Services Agency)	Royal Institute of British Architects
Department of the Environment for Northern Ireland	Royal Institution of Chartered Surveyors
	Scottish Development Department
	Timber Research and Development Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Consulting Engineers	British Compressed Gases Association
Chemical Industries Association	Engineering Equipment and Materials Users' Association
Fire Extinguishing Trades Association	Institute of Petroleum
Institution of Chemical Engineers	International Institute of Safety Management
Manufacturing, Science Finance Union	
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Foreword

This British Standard code of practice has been prepared under the direction of the Fire Standards Policy Committee. It supersedes BS 5908:1980, which is withdrawn.

The main purpose of this code of practice is to help designers and managers of chemical works to minimize fire hazards. The code is also intended to be of assistance to local authority fire brigades and planning departments.

The main aim of fire precautions is to prevent fire. In the event of fire starting the aims become the prevention of loss of life and injury and, by the extinction of the fire, the reduction of material damage and production loss.

This code refers to operation of existing works, the design and operation of extensions, and also the design and operation of works at new locations. Guidance offered includes selection and layout of plant sites, and methods of fire defence and protection. Throughout the code it is assumed that plant and machinery are, in general, of adequate technical design, suitable for their purpose and safe to operate.

The recommendations contained in this code are made in the light of the best technical information known to the committee at the time of writing, but since a wide field is covered, it has been impossible to consider every possible factor that might affect a designer's or a manager's decision on a particular point. Therefore, while the aim has been to give in the text (supplemented by references to other sources of specialized knowledge) as full and helpful an account as possible of the background information available within the stated scope, this information should be applied in practical situations with discretion and with due regard to local circumstances.

The code is intended for use as a safety handbook relating to fire, for personnel involved in the design, operation and maintenance of equipment having a fire risk.

Established codes which are more specific to a particular industry, and provide an equivalent standard of fire safety, may be used as an alternative to BS 5908 in establishing fire precautions. An example is the series of Codes (including Marketing and Refining) produced by the Institute of Petroleum.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 96, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This code of practice gives guidance on the nature of fire hazards in the chemical and allied industries. It includes plant design, siting, separation distances, control and maintenance aspects of plant and the design and operation of warehouses and storage areas. Fire prevention and firefighting are also considered.

Appendices to the code give details of regulations, and list references.

NOTE The titles of the publications referred to in this British Standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 4422 apply.

NOTE Terminology relating to the principles of initiation, spread and extinction of fire is given in clause 5. Attention is also drawn to **E.9.16**.

Section 2. Legal background

3 General

Legal requirements on fire precautions are contained in a framework of separate but overlapping Statutes, administered by a number of different authorities. This legislation ranges from broad general Statutes which apply to all places of work to those which are particular to specific processes or to the storage, transportation and use of hazardous materials. With certain exceptions, administration of these legal requirements may be considered to fall within two main categories.

a) *General fire precautions*, including means of escape, certification, firefighting and fire warning systems, etc., are largely dealt with under the Fire Precautions Act 1971 (see 4.1) administered by the appropriate fire authority.

b) *Process fire precautions*, concerned with the prevention of the outbreak of fire through activities are largely dealt with under the Health and Safety at Work etc. Act 1974 and associated legislation, administered by the Health and Safety Executive, except where enforcement responsibility rests with the local authority by virtue of the Health and Safety (Enforcing Authority) Regulations 1977.

The principal exception to this general statement applies in the case of premises which are subject to the Fire Precautions (Special Premises) Regulations 1976, where legal requirements on both general and process fire precautions, including certification, are administered by the Health and Safety Executive.

Specific requirements made under the Health and Safety at Work etc. Act 1974, and under the Factories Act 1961 also provide for safety, health and welfare in factories. The two Acts and associated regulations are, for chemical factories, administered by Health and Safety Executive, HM Inspectorate of Factories.

Factories where scheduled explosives are manufactured are licensed under the Explosives Act 1875 and this and associated regulations are administered by the Health and Safety Executive, HM Inspectorate of Explosives.

The Fire Authority issues Fire Certificates under the Fire Precautions Act 1971 for certain factories and offices, and has general powers under section 10 of that Act in all workplaces. Similar functions in respect of Crown premises are exercised by the Home Office or Scottish Home and Health Department. The Fire Certificate (Special Premises) Regulations 1976 state that the Health and Safety Executive is the certifying authority in a number of classes of premises (set out in the schedule to the regulations), which include a number of chemical plants.

Building Regulations (see 4.5) do not apply to licensed buildings in an explosives factory or magazine. However, the standards laid down by the regulations should be adopted, specifically varied by the construction schedule or the licence.

Where premises are registered for the storage of radioactive substances under the Radioactive Substances Act 1960, the registration may be put into effect subject to conditions of storage for such material which may include fire precautions.

In some areas there is local legislation affecting various aspects of fire protection in buildings. Town and Country Planning Acts lay down requirements in respect of new developments and are administered largely by the Local Authorities, who should be consulted at an early stage even when new works or alterations are being considered.

Legislation in Northern Ireland is similar but there may be differences in administration.

4 Statutory requirements

4.1 The Fire Precautions Act 1971 and the Health and Safety at Work etc. Act 1974

See also Appendix A.

The Fire Precautions Act 1971, as amended by the Fire Safety and Safety at Places of Sport Act 1987, includes provisions as to means of escape in case of fire, fire warning systems, firefighting equipment and fire training and applies to buildings and structures only, except that "escape" means escape to some place of safety beyond the building.

The Act does not lay down general requirements but requirements are specified in the fire certificate issued under the Act by the fire authority. The Fire Precautions Act 1971 does not deal specifically with fire hazards arising from particular manufacturing processes. Such hazards are dealt with under the Health and Safety at Work etc. Act 1974 and associated legislation.

Under the Health and Safety at Work etc. Act 1974, regulations have been issued (e.g. the Fire Certificates (Special Premises) Regulations 1976). The requirement in these regulations are broadly parallel to those of the Fire Precautions Act 1971. They require the issue of a fire certificate specifying in detail the standards of all general fire precautions which are to be maintained at the specified premises. The fire certificate is issued by the Health and Safety Executive.

Requirements for general fire precautions and adequate means of escape in factories and offices not requiring a fire certificate are contained in section 9 (A) of the Fire Precautions Act 1971.

4.2 The Factories Act 1961

Specific requirements exist under this Act and special regulations have been made under this Act for particular processes and hazards (see A.1).

4.3 The Explosives Act 1875

Factories in which explosives are manufactured are licensed by the Health and Safety Executive under the Explosives Act 1875, as amended. Subsidiary legislation requires that premises at which acetylene is stored (other than stored in specifically approved cylinders) need to be approved by the Executive when the gas is kept at pressures greater than 620 mbar¹). Facilities for storage of explosives up to a maximum quantity of 1 800 kg are licensed by the Local Authority. Facilities for larger quantities are subject to the issue of a magazine licence by the Executive.

Details of regulations and orders, including those covering compressed acetylene, made under the Explosives Act 1875, can be found in "Guide to the Explosives Act 1875" obtainable from Her Majesty's Stationery Office.

4.4 The Petroleum (Consolidation) Act 1928

This Act specifies that petroleum spirit, with minor exceptions, shall not be kept on unlicensed premises, and makes provision for the licence to deal generally with matters affecting safekeeping. Licences are drawn up in terms which take account of the special nature of the risk involved.

Premises subject to the Notification of Installations Handling Hazardous Substances Regulations 1982 where petroleum spirit is kept are required to be licensed by the Health and Safety Executive; other premises are licensed by local fire authorities.

There are a number of orders and regulations made under the Petroleum (Consolidation) Act 1928, to cover such substances as petroleum mixtures, calcium carbide and liquid methane. There are also regulations governing petroleum spirit kept for use as fuel for engines and also for spirit stored in plastics containers.

4.5 Buildings Regulations 1985; Building Standards (Scotland) Regulations 1981; Building Regulations (Northern Ireland) 1977

4.5.1 The Building Regulations 1985. The construction of new factories in England and Wales and, in certain cases, alterations and extensions to existing premises should comply with the Building Regulations 1985. The following items in the regulations are particularly concerned with fire precautions:

- a) structural fire precautions;
- b) means of escape in case of fire (in certain dwellings, shops and offices only);
- c) chimneys, flue pipes, hearths and fireplace recesses;
- d) heat-producing appliances and incinerators.

4.5.2 The Building Standards (Scotland) Regulations 1981. The construction of new factories and alterations to existing premises in Scotland should comply with the Building Standards (Scotland) Regulations 1981. The following items in the Regulations are particularly concerned with fire precautions:

- a) structural fire precautions;
- b) means of escape from fire and assistance to fire services;
- c) chimneys, flues, hearths and the installation of heat producing appliances.

4.5.3 Building Regulations (Northern Ireland) 1977. The controls are similar to those for England and Wales (see 4.5.1).

4.6 Housing and Planning Act 1986

This Act introduces a new section, entitled Hazardous Substances, which is inserted into the Town and Country Planning Act 1971. This section makes provision for local authorities to require consent in order to store or use hazardous substances in excess of specified quantities, known as "controlled quantities". Consent in some instances may be granted subject to certain conditions, but these conditions will be in agreement with advice given by the Health and Safety Executive.

¹) 1 mbar = 100 N/m² = 100 Pa.

4.7 The Notification of Installations Handling Hazardous Substances Regulations 1982 (NIHSS)

These Regulations require that a person shall not undertake any activity in which there is, or is liable to be at any one time, more than the notifiable quantity of hazardous substances, unless he or she has notified the Health and Safety Executive. This information provides the Health and Safety Executive with a list of installations which will help in defining priorities in inspection programmes (see **E.10.20**).

4.8 The Control of Industrial Major Accident Hazards Regulations 1984 (CIMAH)

The principal objectives of these Regulations are the prevention of major accidents arising from industrial activities, the limitation of effects of such accidents both on man and on the environment and the harmonization of control measures to prevent and limit major accidents in the European Community. The industrial processes covered by the Regulations are defined in terms of processes and storage involving specified dangerous substances. This has the effect of embracing most of the chemical industries using substances which have dangerous, flammable, explosive or toxic properties (see **E.10.19**).

Section 3. Principles of initiation, spread and extinction of fire

5 Terminology

5.1 Flammability

A flammable material is any gas, vapour, liquid, dust or solid which is capable of burning with a flame. However, many liquids and solids, though regarded as flammable, nevertheless do not normally burn. The application of heat to such materials can release vapour which can burn with oxygen, producing heat which can release further vapour for combustion.

Flammable substances are characterized by upper and lower flammable limits, between which the gas or vapour mixed with air is capable of sustaining combustion. These limits are referred to as the lower flammable limit "LFL" and the upper flammable limit "UFL", and are usually expressed as percentages of the material mixed with air by volume and occasionally as grams of material per cubic metre of air (see BS 4422-1 and **E.8.16**).

Flammable limits are tabulated for many flammable substances in reference documents and standards. See BS 5345-1, and **F.3.1** and **F.3.2** of this code. Flammable limits and flash points (see **5.2**) are important properties and need to be available for any potentially flammable materials handled in an industrial process, in order to design for safe working conditions.

It should be noted that increasing temperature and/or pressure widens the flammability range, and some substances (e.g. certain halogenated hydrocarbons) which are classed as non-flammable at ambient temperatures may have a limited flammability at elevated temperature or pressure. This may give rise to an explosion or fire from exposure to heat such as that from a welding operation. For example, dichloromethane and trichloroethane can both form flammable mixtures with air. In case of doubt, the technical literature should be consulted regarding the flammability characteristics of such substances.

5.2 Flash point

5.2.1 Introduction. The flash point of a flammable liquid is the temperature at which the vapour pressure is sufficient to give a concentration of vapour in the air which corresponds to the lower flammable limit. See also BS 4422-1. The flash points of many common industrial liquids are tabulated in reference works (see **E.8.16**, **F.3.1**, **F.3.2** and BS 5345-1).

There are several methods for measuring the flash point, which fall into two general types: the open cup and closed cup methods. Flash points measured by the open cup method are generally a few degrees higher than for the closed cup method.

Within these two main divisions there are further variations to enable the flash points of products of different classification (see **5.2.3**) to be correctly determined. Test methods are given as a series of Parts of BS 2000.

Substances having a lower flash point are more likely to evaporate readily to give a flammable mixture. Petrol, for example, has a flash point considerably below 0 °C and it should be regarded as a hazardous liquid at all ambient temperatures. Lubricating oil generally has a flash point above 100 °C, and it is correspondingly much safer to handle at likely ambient temperatures.

5.2.2 Legislation. Flammable liquids are classified according to flash point in the following legislation.

a) *Factories Act Premises.* In factories or other places where the Factories Act applies, the Highly Flammable Liquid and Liquefied Petroleum Gases Regulations 1972 apply to flammable liquids with flash points of less than 32 °C, and which support combustion when tested in a specified manner.

b) *Petroleum storage.* Under the Petroleum (Consolidation) Act 1928 and associated legislation, petroleum spirit is defined as: "petroleum which when tested in a prescribed manner gives off a flammable vapour at a temperature less than 22.8 °C (the Act refers to 73 °F)". "Petroleum" includes crude petroleum, oil made from petroleum or from coal, shale, peat or other bituminous substances, and other petroleum products. This legislation applies wherever petroleum, etc., is kept, including Factories Act premises.

NOTE The petroleum industry normally classifies its products, whichever legislation applies, into hazard categories based on flash points of 21 °C, 55 °C and 100 °C (see **5.2.3**).

c) *Conveyance.* The Classification, Packaging and Labelling of Dangerous Substances Regulations 1984 classifies a "highly flammable" liquid as having a flash point less than 21 °C. However, if the flash point is below 0 °C and the liquid has a boiling point less than or equal to 35 °C, it is classed as "extremely flammable".

A liquid having a flash point equal to or greater than 21 °C and less than or equal to 55 °C is classed as "flammable". The flash points quoted are generally determined by a "closed cup" method, the particular details being as specified in the appropriate regulations.

5.2.3 Classification. There are several different ways of classifying flammable liquids but for the purposes of this code the following classification from the Institute of Petroleum "Refining Safety Code" is used.

- | | |
|---------------|--|
| Class I | Liquids which have a flash point below 21 °C. |
| Class II (1) | Liquids which have flash points from 21 °C up to and including 55 °C, handled below flash point. |
| Class II (2) | Liquids which have flash points from 21 °C up to and including 55 °C, handled at or above flash point. |
| Class III (1) | Liquids which have flash points above 55 °C up to and including 100 °C, handled below flash point. |
| Class III (2) | Liquids which have flash points above 55 °C up to and including 100 °C, handled at or above flash point. |

Unclassified liquids have flash points above 100 °C. It will be noted that class II and class III liquids may be subdivided in accordance with the circumstances in which they are handled.

Unclassified liquids should be considered as class III (2) when handled at or above their flash points.

To comply with the Highly Flammable Liquids and Liquefied Flammable Gases Regulations (A.1.2), account should be taken of all the characteristics of hydrocarbons and non-hydrocarbons to be bulk stored, including the vapour pressure attainable in summer, and the possible emission of toxic, noxious, as well as flammable vapours.

5.3 Fire point

The fire point of a flammable liquid is the lowest temperature at which the liquid, when placed in an open container, will give off sufficient vapour to continue to burn when ignited.

NOTE The fire point is usually a few degrees above the open flash point (see 5.2.1).

5.4 Auto-ignition temperature

The minimum temperature at which a material will ignite spontaneously under specified test conditions.

6 Explosion

An explosion is an abrupt oxidation or decomposition reaction or a non-chemical effect producing an increase in temperature, pressure or both simultaneously. This results in a rapid release of energy generally accompanied by noise and a pressure wave. The term is properly used to describe different kinds of events when the energy release is sudden.

Explosions may be classified in the following way.

- a) *Physical explosion.* Examples of physical explosions, in which there is no chemical reaction, are over-pressurizing a vessel and the explosive vaporization of water due to very rapid heating. Although a flame may not be involved in the explosion, the result can give rise to a flammable atmosphere.
- b) *Chemical explosion.* Chemical explosions may be divided into uniform and propagating explosions.

- 1) *Uniform explosion.* In a uniform or homogeneous explosion the chemical reaction occurs throughout the mixture immediately, e.g. controlled exothermic reaction.

- 2) *Propagating explosion.* In a propagating explosion, the chemical reaction involves only a thin layer of flammable mixture. The reaction zone moves through the remainder of the mixture.

Deflagration describes the situation when the flame front travels at a sub-sonic speed.

Detonations are propagating reactions in which the flame front travels as a shock wave, at or above the speed of sound. In some circumstances a deflagration can develop into a detonation.

Maximum explosion pressures are calculable for known compositions. They vary according to conditions and may reach pressures of several bar (see E.8.3, E.9.10, E.9.11 and E.9.12).

A vapour cloud explosion is a particular type of propagating explosion, the severity of which depends on the degree of confinement (among other factors).

c) *Boiling liquid expanding vapour explosion* (“BLEVE”). A “BLEVE” is a physical explosion which is usually followed by a propagating explosion. If a pressure vessel containing a liquefied flammable gas or a flammable liquid is heated by an external fire, the vessel wall above the liquid level may become sufficiently heated to cause wall failure. The vessel may then rupture into a number of pieces which may travel considerable distances. This is accompanied by an explosive pressure effect, followed by a fireball (see E.9.1 to E.9.3, E.9.17 and E.15.26).

Damage criteria for transient fireballs are different from those for steady state fires. This is largely due to the short duration of the fireball, typically in the range 5 s to 30 s for fuel mass of 10 t to 2 000 t respectively.

Table 1 gives the damage criteria for steady state fires, in intensity units (kW/m^2). Table 2 gives the damage criteria for transient fireball radiation, in dose units (kJ/m^2) (see E.15.26, F.4.2 and F.4.3).

Table 1 — Damage caused at various incident power levels from a steady state fire

Incident power	Type of damage caused
kW/m^2	
37.5	Sufficient to cause damage to process equipment
25	Minimum energy required to ignite wood at infinitely long exposures (non-piloted)
12.5	Minimum energy required for piloted ignition of wood, melting plastic tubing, etc.
4.5	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds; however, blistering of skin (1st degree burns) is unlikely
1.6	Will cause no discomfort to long exposures

Table 2 — Fireball radiation dose criteria

Dose threshold	Effect
kJ/m^2	
600 to 1 800	Secondary fires
375	3rd degree burns
250	2nd degree burns
200	Onset of serious injury
125	1st degree burns
65	Threshold of pain, no reddening or blistering of skin caused

7 Modes of ignition

7.1 Common causes

A fuel-air mixture may be ignited by a naked flame, an incandescent particle or an electrical spark of sufficient energy. Cutting and welding processes are common causes of fire; others include smouldering embers, cigarette ends and electrical insulation failures.

7.2 Heat and sparks

A common cause of heat and sparks which could provide a source of ignition is the friction of metal parts in rotating or reciprocating machinery.

Frictional sparks from hand tools or nailed boots have been known to cause fires, especially when reactive materials are involved. Heat or sparks generated by power driven tools or equipment may cause ignition, particularly when grinding or concrete bursting. Machine bearings could also be a source of ignition if they are allowed to overheat.

All internal combustion engines should be regarded as sources of ignition unless suitably protected (see clause 34).

Ignition may occur when sufficient heat is supplied by conduction, radiation or convection to raise any material to its auto-ignition temperature. This may happen with inadequately designed chimney flues or engine exhausts, or if there is an uncontrolled fire nearby. Mineral oils dripping on to hot surfaces may degrade and produce vapours which ignite above the hot surface.

Reference should be made to Appendix B of BS 5345-1:1976. Static electrical discharges require special consideration and are dealt with in clause 58.

7.3 Spontaneous heating

Spontaneous heating may lead to combustion of materials generally thought to be stable at ordinary temperatures. For example, heat may be generated by slow oxidation within a coal stockpile or in oil-soaked lagging. When the heat generation within a mass is greater than the heat loss from it, the material will get hotter, usually accelerating the process, until the temperature is high enough to cause combustion, i.e. spontaneous combustion occurs. See E.4.14 and E.9.15.

Fairly rapid oxidation of oil spilled on overalls, rags, lagging or any finely divided material occurs when in contact with a warm surface. Vegetable or lubricating oils and glycols are particular examples; a man leaning on a hot pipe for a few minutes may discover his clothing is smouldering. The spontaneous heating may occur at a temperature well below the flash point or auto-ignition temperature of the oil. For fire hazards with thermal insulation on plant see clause 46.

Certain chemicals may heat up on exposure to air or moisture or even ignite spontaneously. Some examples are as follows.

- a) Finely divided materials, such as metals or certain catalysts in powder form (e.g. hydrogenation catalysts widely used in the oils and fats industry) are pyrophoric on drying out and exposure to air. Such catalysts are frequently supplied as a suspension in water and if rags or paper are used to mop up any spillage, these can smoulder and burst into flames on drying-out.
- b) Traces of catalyst, rust or other contaminants can cause exothermic polymerization of certain reactive substances in storage, with disastrous results. Examples of such reactive substances are ethylene oxide, acetaldehyde, styrene and acrylonitrile.
- c) If a tank has stored any material containing hydrogen sulphide, other sulphur compounds or sludges from leaded gasoline, all deposits should be regarded as potentially pyrophoric. Advice on the preparation and cleaning of such equipment is given in **E.6.3**.
- d) Hydrogen leaking from high pressure systems often ignites spontaneously.
- e) There are numerous highly reactive chemicals, e.g. peroxides, polynitro compounds and acetylides, that require specialist knowledge and consideration.
- f) Thermite reactions, e.g. between aluminium alloys and rust, may occur.

NOTE The use of oxygen presents a special hazard in that auto-ignition temperatures may be drastically lowered and also ordinary combustion may become uncontrollable.

8 Smoke

8.1 General

Smoke consists of particulate matter suspended in the gaseous products of combustion or organic (i.e. carbon containing) materials. Smoke is formed by the products of partial combustion of the burning material as well as the products of thermal decomposition and includes carbon dioxide, carbon monoxide and polycyclic aromatic hydrocarbons. Finely divided oxides from the burning of metals such as magnesium may also become airborne to some extent.

8.2 Smoke generation

The composition and quantity of smoke produced by a material in a fire are not solely characteristic of that material but depend upon fire conditions. Among other factors, smoke emission depends upon the air supply, temperature of the fire and the presence of other materials.

Moisture content also affects smoke emission. Dampness slows down the rate of combustion of carbonaceous matter and reduces completeness of combustion, giving rise to increased generation of smoke. The evaporated water also changes the appearance of the smoke.

8.3 Hazards

Smoke is a serious hazard to life; the three main factors are:

- a) toxicity and/or lack of oxygen;
- b) obscuration of vision;
- c) high temperature.

The presence of poisonous, asphyxiating or carcinogenic substances in smoke can cause collapse, death or long term effects. The presence of irritating substances causes more smoke to be breathed in whilst coughing and causes running eyes which can obscure vision. The temperature of the smoke is an important factor, as hot smoke gases can cause serious lung damage.

Carbon monoxide is the major hazard in smoke from organic materials, but other toxic products may be present, such as hydrogen cyanide, ammonia, hydrogen sulphide, sulphur dioxide and hydrogen chloride. The diffusion of hot smoke within buildings can cause carry over of ignition, and in the open air convection effects can cause incandescent particles to travel several hundred metres in severe cases and cause secondary fires.

9 Modes of combustion

9.1 General

Liquids in bulk do not burn. Before combustion is possible, vapour or mist has to be given off and then mixed with air.

Under controlled burning conditions, as in a furnace, the behaviour and properties of the flames from gaseous, liquid or solid fuels are alike. It is the state of physical dispersion that mainly affects the burning pattern and heat release in both controlled and uncontrolled fires, i.e. the situation obtaining before ignition occurs.

When a flammable fluid is released, the following two questions need consideration.

- a) What happens at initial ignition where there could be an extensive pre-mixed cloud of dust, mist or vapour which may be rapidly and completely burned; i.e. an explosion?
- b) What controls the severity of an ongoing fire from a leak or spillage in any form?

Some of the physical effects are described in this clause. Further information on combustion behaviour and related risks is given in **E.13.1**, **E.15.2** and **E.15.3**.

9.2 Flammable liquids

The vapour cloud associated with a liquid below its boiling point does not usually extend for more than a few metres from the liquid surface. Ignition can take place anywhere in the cloud where the fuel/air ratio is within the limits of flammability and a flame travels through the cloud. A hot liquid of high flash point is just as dangerous as a cold liquid of low flash point; in fact it may have a lower auto-ignition temperature.

At initial ignition the size of the vapour cloud is not likely to be very extensive unless there has been widespread spillage or exposure of the liquid surface. A flame will travel to all exposed surfaces of liquid above its flash point, provided sufficient air is mixed with the vapour. If the vapour is confined, the pressure wave is often sufficient to rupture the container or building, and this is true for all flammable vapour, mist and dust clouds.

The severity of a pool fire is controlled by rate of vapour formation, which depends on the area of liquid surface and the rate of heat supply. Spillage and splashing increases the area of exposed liquid. The rate of heat supply to the upper surface of a burning liquid is usually limited and an open tank may burn relatively quietly. Jet fires or pressurized leaks cannot be extinguished by common means unless the leak is stopped. If a liquid is already at its boiling point, much greater quantities of vapour will be involved.

High molecular weight materials normally considered low risk, such as heavy oil or petroleum residues, can present fire hazards from low auto-ignition temperatures, e.g. 200 °C, even though they may have high flash points, e.g. greater than 100 °C. For example, ignition of these materials can occur in contact with hot lagging.

9.3 Flammable gases, vapours and mists

Ignition of a pre-mixed cloud of gas, vapour or fine liquid droplets causes an explosion as in a petrol engine. The flame front can accelerate as the distance increases. When the cloud is widespread or unconfined, severe blast and fire damage may be caused over a wide range, particularly when the cloud engulfs congested areas. See **E.9.14** and **E.15.25**.

Suppression of the explosion is impossible except when automatic high speed detection and extinguishant injection is employed in a confined space.

The size of the flammable cloud is governed by the total quantity of fuel available, the rate of release, vaporization, entrainment and the degree of mixing with air. The size of aperture and the pressure behind it obviously affect the rate of release. The degree of mixing with air depends on density of fluid, velocity discharge and subsequent dispersion by diffusion and draught effects; these may be natural or artificial, e.g. steam or water sprays. Mists may be more dangerous than vapour clouds because they may contain a greater overall concentration of flammable component; they may also ignite well below the accepted flash point of the liquid in bulk. The release of a saturated vapour under pressure to atmosphere may result in ignition through electrostatic phenomena.

Some of the most dangerous clouds are generated by the release from containment under pressure of a liquefied flammable gas or a boiling liquid. A very large premixed vapour and mist cloud may spread rapidly and encounter a source of ignition many hundreds of metres away, with catastrophic results. Only a small fraction of the energy is liberated as blast, but this can still do considerable damage.

Secondary fires may ensue from the initial explosion. The rate of ongoing burning is obviously related to the rate of release of further supplies of gas or vapour.

9.4 Flammable dusts

Under certain conditions fine particles of a flammable solid which are dispersed in air may ignite and explode. Such explosions cause a rapid increase in pressure in the containing structure and if the equipment is not strong enough to withstand this pressure, extensive damage and injury can occur. An additional hazard arises if an initial explosion disturbs local deposits and accumulations of flammable dust, resulting in a larger dust cloud which may cause a more severe secondary dust explosion. Materials that are liable to cause dust cloud explosions include agricultural products, organic chemicals, pharmaceuticals, plastics, wood products, metals and coal.

Tests are available to determine whether a cloud of a particular dust is explosible or not, and further information on this subject is given in **E.4.1** and **E.4.2** and in BS 6713-1. Precautions should always be applied to equipment which handles explosible dusts, and specific guidance should be sought from **E.8.3**, **E.8.6**, **E.9.5** and **E.9.6**.

It should be noted that some dusts which do not explode when in suspension are still capable of burning under these conditions and that, in addition, some non-explosible dusts can burn when settled. It is therefore possible for certain non-explosible dusts to present similar fire hazards to those of explosible dusts. In the case of a fire at a plant where explosible dusts are present, great care should be taken when attempting to extinguish it so as to prevent the fire from contacting an explosible dust cloud. Where settled dust is burning, the fire control methods should not stir the dust into suspension. Although small confined volumes of dust may be allowed to burn themselves out under continuous surveillance, the usual approach is to extinguish the fire. Selection of the most suitable extinguishing medium will usually depend on factors such as the composition of the dust, its situation, and the presence of other hazardous materials and equipment nearby.

9.5 Escape of flammable materials

9.5.1 Travel of flammable vapour. Most hydrocarbon liquids give off flammable vapours which are heavier than air. Such vapour, under conditions of still air or slight wind, may not disperse but may drift a considerable distance, particularly downhill or through trenches and ducts.

Ignition at some remote point could then result in a "flash back", i.e. flame coming back to the source.

9.5.2 Travel of flammable liquid. The distance which flammable liquid may travel on escape from its containing vessel will depend upon whether there is some external means, such as a fire wall or natural barrier, to hinder further flow. Should flammable liquids enter drains, sewers, trenches or ducts, they may be carried to remote points where ignition may occur in areas normally considered to be safe (see 15.2).

9.5.3 Sudden release of flammable materials. Where a liquid under pressure at a temperature in excess of its boiling point is suddenly released to atmosphere a large cloud of vapour or mist will immediately form. Such a sudden release may find a source of ignition, giving a fire or explosion. Leaks from pressurized sources can on ignition give jet fires of intense severity.

10 Controlling fire

The most effective precautions are those made at the design stage. Particular care should be given to the design and construction of buildings and structures as regards their compartmentation and spatial separation (see clause 22).

The containment of liquid spillage is important in all plant and storage areas (see clauses 29 k), 33.3.5 and 54.4), and, in general, the slope of the ground should be such as to drain away from the proximity of vessels and equipment.

Plant design should be such that potential leakage is reduced to a minimum. Equipment drains should not exceed 20 mm bore and where practicable other drain points should be blanked off when not in use. Where sample points are not susceptible to blockage, they should not exceed 6 mm bore. The possibilities of danger due to freezing or evaporate cooling in the open position should be borne in mind. For example, when water is drained from LPG vessels, there should always be two drain valves in series and the second drain valve should be provided with a spring return.

Leakage from pumps and overflow from tanks should be channelled into suitable drains, which should be regularly flushed and cleaned (see clause 15). Liquid handling areas should have proper kerbs and drains. Sections of open drain channel should be limited in length to avoid flame travel to adjacent parts of the plant.

Plants which include glass or plastics pipes can fail rapidly in a fire situation. For calculations on heat transmission from fires and its effects see F.2.1. General guidance is given in E.2.1.

11 Principles of extinction

Fires may be extinguished by:

- a) Removal of heat, e.g. by use of water;
- NOTE In some applications the use of water may be specifically prohibited.
- b) Smothering or removal of air or oxygen;
- c) Shutting off the supply of fuel;
- d) Interference with the combustion process.

See also section 14.

Section 4. Site selection and layout

12 Selection of site

12.1 General considerations

In order to select a good site, many technical factors should be borne in mind. The choice of site should have regard to the nature of the plant and its associated hazards which will depend on the process involved; adjacent fire hazards (e.g. the proximity of buildings, factories, plants, tips and vegetation); and the facilities which are available for fire prevention and protection. Some of the factors will be the subject of consultation with the appropriate authorities and other organizations such as insurance companies. The accessibility of the site for firefighting appliances and space for the manoeuvring and parking of appliances should be taken into account (see clause 13).

Requirements under NIHSS (4.7), CIMAH (4.8), the Housing and Planning Act (see 4.6) and other applicable local legislation will require consideration.

12.2 Contour of the ground

The contour of the ground, including hollows, ditches and streams, should be considered in relation to the possible effects of accidental release of flammable liquids and vapours heavier than air (see 9.5.1 and 9.5.2), and to firefighting water run-off (see clauses 15 and 70).

12.3 Composition of the ground

When a full investigation into the composition of the ground is required, it should be carried out in accordance with BS 5930. Possible hazards due to seismic activity should be considered.

12.4 Safe spacing

In addition to the requirements of safe working and convenient maintenance, the following items will require to be considered when siting new installations.

- a) Safe distances from the site boundary, having regard to the possibility of future development on adjoining property (see clause 17 and section 6).
- b) Safe spacing of hazardous plant from all other plant, administration, service areas, etc. (see clause 17). The potential effect of the structural collapse of high plant in a fire should be considered in relation to its surroundings. For LPG installations, see clause 17 and E.10.9.
- c) Provisions and safe spacing of storage areas (see section 7). See E.6.4 and E.10.11.
- d) Provision with space for the safe disposal of waste materials (see clause 35).
- e) Access for fire service vehicles to plant and space for firefighting and suitable location of hydrants (see clauses 13, 14 and 71).

- f) Avoidance of effects of possible escalation.
- g) The location of loading and unloading facilities.
- h) The proximity of radio transmitters (see BS 6656 and BS 6657).

12.5 Adjacent risks

The potential danger to life and property in relation to the adjoining community should be considered in conjunction with risks from adjoining factories, airports, road, rail and water transport.

Guidance on these matters is given in clause 17.

12.6 Prevailing wind

The effect of prevailing winds may need to be taken into account when considering the location of the site in relation to neighbouring sites.

12.7 Availability of firefighting resources

Consideration should be given to the standard of cover which is normally provided by the fire authority for the area (see B.7) and to the availability of water for firefighting and cooling of threatened installations (see clause 70).

13 Access for firefighting vehicles and firefighting within the site

Roads or access over firm ground should be provided to allow fire appliances to approach within reasonable distance of the hazard. Access should be kept free of obstruction. In certain circumstances, railway lines may impede access for fire appliances. Each case will have to be considered individually in relation to the prevailing circumstances and the size of the hazard, but access should be provided within 18 m to 45 m of the hazard. Water supplies should be available at these places (see clause 70).

A peripheral road should be provided with access to the public road system at two points at least. Connecting roads should be arranged to permit approach from two directions to all major fire hazards on site.

Roadways for fire appliances, if they do not permit two lanes of traffic, should be provided with passing spaces. Cul-de-sacs are undesirable, but, if unavoidable, adequate turning areas should be provided.

Each large storage of flammable material or major plant process unit should be accessible from not less than two sides. If access is only possible from two sides, these should, wherever possible, be the longest opposite sides.

The design of the road layout will be dependent upon the complexity or otherwise of the plant and therefore the type(s) of fire appliances likely to be employed in firefighting at a specific chemical plant. National guidance on this subject has been promulgated to chief officers of fire brigades in England and Wales in Fire Prevention Note No. 1/70 which is updated as required to take account of developments in appliance design. In Scotland, the Building Standards (Scotland) Regulations (current edition) is relevant. Proposed schemes will be subject to planning approval and many, if not all, will require access for firefighting purposes to be to the satisfaction of the fire authority. Early consultation with this authority is recommended (see **B.7**). Road widths, gate widths, clearance heights, turning circles and axle loadings for the various types of vehicles likely to be called to the hazard will be items for consideration. These could include vehicles other than firefighting appliances such as heavy bulk foam and/or carbon dioxide carriers.

One or more hardstandings should be provided beside each open water source to enable fire appliances to be positioned at strategic points, where this is necessary to prevent blocking roadways. A waiting area should be allocated near each main entrance to the site as a rendezvous point for appliances where this is warranted by the size or nature of the installation.

A scheme of this nature should be considered in consultation with the fire authority (see **B.7**).

14 Water supplies

An adequate supply of water for all purposes should be readily available. This supply has to be sufficient to ensure that normal process requirements are always met and that at the same time sufficient additional water is available for both firefighting and fire protection (e.g. cooling of adjacent plant during firefighting elsewhere in the plant). For each item of plant and each building or storage unit the water requirements for firefighting and fire protection should be predetermined (see clause **70**).

The appropriate water authority and/or water company should be consulted at the planning stage if there is any intention to make use of public water supplies or to abstract from other sources of water. Mandatory standards for the provision of fire mains and hydrants in certain sizes of buildings, depending on use, height and area, are given in the Building Standards (Scotland) Regulations. See also **E.11.7**.

15 Drainage, interceptors, gas traps and bunds

15.1 Drainage arrangements

The disposal of industrial effluents and drainage is subject to stringent control under statutory regulations and local bye-laws.

The water authority does not permit the entry of flammable or harmful substances into the drainage system of any public authority or natural water course under the authority's control. This also applies to site drainage in so far as is practicable.

Adequate drainage for storm water should be provided and special provisions such as pumps, run-off areas, etc., may be necessary for the disposal of water used in firefighting operations.

Consideration should be given to the possible danger from the mixing of incompatible effluents. Flammable vapours can arise if hot fluids, e.g. steam condensate, mix with hydrocarbons in drainage systems.

15.2 Interceptors

If the liquid is not miscible with water, the whole of the effluent should be passed through efficient interceptors. Interceptors should be located at the perimeter of the fire risk areas. To avoid overloading the main interceptors, primary interceptors may be used in the collecting areas to give preliminary separation. Precautions against sedimentation and freezing of the interceptors may be necessary.

With water-miscible flammable liquids the concentration should be below that which could produce flammable vapour mixtures. Suitable traps or lutes may also be needed to prevent the spread of fire, unless a fully-flooded drainage system is used. Where water-miscible flammable substances (e.g. methanol) are flushed into site drains, the concentration of the effluent should be diluted below that which would create flammable vapours in the drains.

15.3 Gas traps

Where flammable gas or vapour may be entrained in effluents, suitable gas traps should be incorporated. Where interceptors are fitted, gas traps should be upstream.

Gas traps should be fitted with vents to liberate the gas at a height which will not cause danger or annoyance.

15.4 Bunded areas

Means should be provided to remove surplus water, including that used for the cooling of adjacent vessels, from within any bunded area. For details of bunded areas see **33.3.5**. In addition it may be necessary to make provision for the removal of water used for firefighting, and the advice of the local fire authority should be obtained.

16 Storage and loading areas

The location and spacing of storage and loading facilities requires consideration in relation to adjacent risks and is dealt with in section 7.

17 Segregation

A prerequisite to the siting and control of areas where the risk of fire or explosion may exist is the identification of all plant operations and storage facilities which have a fire risk, because they either contain a possible source of fire or explosion, or may be involved in an external fire.

The potential hazard will be influenced by the ease with which the substance(s) may ignite, explode or support combustion (see clauses **6** and **10**); by the probable rate of fire development and by the quantity and nature of materials at risk. See also clause **9** (modes of combustion).

The effects may result in:

- a) risk to the general public, site personnel and firefighters due to fire, dense smoke, explosion or the release of toxic material;
- b) possible damage to plant and material stock;
- c) production losses and consequential losses.

Care should be given at the layout stage to the methods of grouping of plant and storage areas so as to avoid the likelihood of escalation of the results of a fire or explosion (see **E.10.3** and **E.15.24**). BS 6656 gives guidance in assessing the potential ignition hazard from the inadvertent extraction of energy radiated from transmitting aerials to plant where a potentially flammable atmosphere may be present.

Section 5. Buildings and structures

18 General

This section of the code applies to buildings, structures (and other similar erections) including items of external plant. It deals with structural protection and general precautions.

19 Legal and insurance considerations

Legal and contractual obligations should be anticipated in the design and planning stages and also when modifications and change of use are envisaged. At the same time, account should be taken of the requirements of other bodies such as the insurers, to avoid possible difficulties and unnecessary expense when buildings and plant are completed. The insurer should be consulted before any new structures or building works or alterations or additions to existing buildings are carried out. Similarly the introduction of new or modified processes involving plant/machinery, processes or methods of storage, etc. should be referred to insurers at the earliest practicable stage.

20 Change of process or usage

The design stage should take into account foreseeable changes of process or use, which may affect fire protection measures.

Early notification of proposed changes of process or use should be given to the fire authority, the Health and Safety Executive, the insurer, and other authorities as may be necessary.

21 Siting of buildings and plant

Apart from any conditions attached to the planning consent (Housing and Planning Act, see 4.6), the minimum distance that the building can be placed from the site boundary is governed by Building Regulations (see 4.5). The distance will depend on the size and use of the building and the amount of unprotected area in the side near the boundary. In general, there are no provisions for separation between buildings on the same site. Consideration needs to be given to whether these distances are sufficient when taking account of the proximity and nature of other buildings and outdoor storage, etc., within and beyond the boundary.

For some specific substances, HSE guidance notes or industry codes of practice are available, giving separation distances such as those from plant to site boundaries.

There are also general requirements in the Health and Safety at Work etc. Act 1974 relating to distances. See also E.2.3, E.10.9 and E.10.11.

The plant should be sited at a safe distance from occupied buildings, boundaries and other items of plant. Future expansion should also be considered so that adequate separation distance can be maintained at all times. The plant should be sited to obtain good natural ventilation, preferably outside in the open air on an impervious non-combustible base, with a spillage retention sill. If weather protection is needed, a “Dutch barn” type of structure with a roof and open sides is preferable. It is important to segregate storage of flammable solvents from the process plant and to provide safe access and means of escape for plant operators.

22 Design and compartmentation

22.1 General

There are four ways in which a fire can spread: direct burning, convection, radiation and conduction. Compartmentation, vertically and horizontally by means of suitable fire-resisting walls and floors, will do most to prevent spread of fire from its origin to other parts of the premises.

22.2 Size of compartments

Maximum sizes of compartments for England and Wales are given in E.4.15, issued in support of Building Regulations (A.4.1), together with the fire resistance of the elements of construction. In Scotland the requirements are given in the Building Standards (Scotland) Regulations (A.4.2). The sizes are linked with the type of occupancy which is a reflection of the type of fire load that can be expected within that occupancy group. To assess the size of compartment to be used, the degree of hazard, the importance and value of the processes enclosed should be taken into consideration. Compartments can be designed to include a number of intermediate floors.

22.3 Provision and construction of cavity barriers and fire stops

The presence of hidden cavities within the structure of a building can be the reason for a rapid fire spread, especially where the cavities are lined with combustible materials. The presence of combustible dusts and residues from the processes in the cavities will intensify the problem. It is essential to ensure that cavities are limited in size and do not communicate with other cavities in a manner that will nullify the effect of compartmentation. Similar reduction in the effect of compartmentation may be the result of poor design features at the joints between elements of construction (e.g. between external walls and edges of floors); in such cases the joints should be fire stopped.

Provisions for cavity barriers and fire stops are set out in guidance issued in support of the Building Regulations.

22.4 Openings and maintenance of integrity

Where openings in walls and floors exist, it is essential that the integrity of the compartment be maintained. Openings in fire-resisting walls, floors and hoistways should be protected by fire-resisting enclosures fitted with fire-resisting self-closing doors or shutters. Doors or shutters which are normally required to be open for day-to-day activities may be controlled by devices which cause them to close automatically in a fire emergency. Belt and roller conveyors present a special problem. The provision of fire doors may not be practicable but some protection should be provided where conveyors pass through a fire-resisting wall, e.g. by enclosing the conveyor in a short tunnel fitted with sprinklers or other protective equipment or by providing sprinkler protection at the points where the conveyors pass through (see clause 68).

Where pipes, ducts and cables pass through compartment walls and floors they should be fire stopped. Where these consist of combustible materials, consideration should be given to replacing the section passing through the wall or floor by metal sections having a melting point greater than 900 °C. Fire dampers may be used where the passage of air or gases is required (see clause 59). Packing blocks are commercially available for the passage of electric cables and wires through compartment walls.

22.5 Intermediate floors

An intermediate floor is one contained within a compartment that may or may not be fire resistant. It is essential that all floors are fire resistant and preferable that they are imperforate (except for protected openings).

If it is not practicable to provide imperforate floors, consideration should be given to the provision of catch trays under flammable liquid spill risks. Bunds surrounding flammable liquid processes on solid floors, or kerbs round openings, will also restrict the extent of spills, and in the event, spread of fire.

Imperforate floors should be constructed with falls to control the spread of flammable liquids, e.g. away from staircases.

22.6 External walls and exposure hazard

The external walls of a building can prevent fire spreading by radiation to adjacent buildings and process plant. Conversely, the external walls can provide protection from fires in adjacent buildings and plant. Hence, it is possible to plan a site layout so that one external wall can provide mutual protection to two adjacent buildings, etc. However, openings in the walls for windows and doors reduce the protection provided, but these can be compensated for by spacing the buildings or reducing the size of openings to reduce their effect.

22.7 Materials of construction

Non-combustible materials (see E.4.15) should be used throughout. However, some non-combustible materials may be unsuitable because of their incompatibility with certain processes. In such cases, class 0 combustible materials (see E.4.15) or materials of limited combustibility (see E.4.15) may be suitable. Consideration should be given to the possible effects of humidity and surface abrasions since some of these materials depend upon the surface coatings applied to them for achieving their fire performance.

22.8 Internal linings and ceilings

Internal linings of buildings are often the means by which fire is spread from one part to another.

Guidance on acceptable standards of resistance to surface spread of flame and internal linings is set out in documents issued in support of Building Regulations.

23 Principles of structural fire protection

23.1 General

The principles of structural fire protection as applied to buildings are well understood and documented (see E.4.6) but there is less information available relating to fire protection of unenclosed process plant. Such plant requires consideration in relation to the materials handled and their fire hazards. The subject of compartmentation is dealt with in clause 22. Structural elements, if subjected to a fire, may fail, thereby escalating the incident. Protection measures required by legislation are directed mainly to the safety of persons. To ensure preservation of property a higher standard of protection may be needed. See also E.11.8. It is emphasized that structural fire protection is intended to prevent collapse for a specified period of time and may not prevent damage in a serious fire.

23.2 Fire resistance

23.2.1 Fire resistance is the ability of a component or construction of a building to satisfy for a stated period of time the appropriate criteria specified in the relevant Part of BS 476.

Test results are expressed in terms of the time the elements will comply, as appropriate, with the requirements contained in the standard for loadbearing capacity, integrity and insulation. The elements of construction which can be tested in accordance with BS 476-20 to BS 476-24 include the following:

- a) walls and partitions (loadbearing and non-loadbearing);
- b) floors;
- c) flat roofs;
- d) columns;
- e) beams;
- f) ceiling membranes;
- g) glazed elements;
- h) doorsets and shutter assemblies;
- i) ventilation ducts.

It does not follow that a structure whose elements have a given fire resistance will survive for that time in an actual fire. An actual fire may be of differing severity to the exposure in standard tests, and it may be necessary to estimate the likely fire exposure and to relate this, as far as possible, to the exposure in the test. Also a combination of elements may not have the same fire resistance as the individual elements because of possible weaknesses or gaps at joints and because of the interaction of one element with another; the latter effect may reduce or enhance the fire resistance of the structure compared with that of its elements. For example, thermal expansion effects may cause stresses leading to reduced fire resistance, but effects arising from continuity of a structure may increase fire resistance.

23.2.2 According to the hazards involved and the importance of the plant, varying degrees of fire resistance may apply, for example:

- a) merely sufficient to allow the escape of persons and safe shutdown of plant;
- b) such as are required to minimize the risk of total collapse of a structure.

Certain buildings or structures (which in themselves, and by reason of their contents, are not fire hazards) may, because of their importance (e.g. control rooms) or because of hazards other than fire (e.g. toxicity), require to be designed and constructed to have a high degree of structural integrity so as not to be vulnerable to external fires.

23.3 Fire protection of steel structures

The degree of protection against the effects of fire required for main structural steelwork supporting members (including cross-bracing) depends upon the nature and duration of the fire to which they may be exposed. Such exposure may be from an adjacent fire or from a liquid pool fire around the base of the process plant structure. Assessments of these hazards will require consideration for each case (see **E.4.7** and **E.4.8**). Where liquid pool fires can be envisaged, structures should be fire-protected up to a height of twice the maximum pool diameter.

The performance of structural steel in fire depends upon the dimensions and mass of the steel section. The thickness of fire protection required for a given period of fire resistance depends upon the mass of steel and its surface area exposed to heating. In most cases, for an outdoor chemical plant, a fire resistance rating of 2 h (using the alternative (hydrocarbon curve) of BS 476-20) will be adequate. The limiting temperature of the structure at the end of this period should be taken as 500 °C.

A large number of materials are available for the protection of structures and for the construction of fire walls and doors; these materials fall into three basic categories.

- a) Inorganic coatings, which include reinforced concrete and the widely used lightweight concrete (vermiculite/cement mixes).
- b) Organic coatings, which come in a variety of forms, from intumescent paints and mastics, to ablative and subliming compounds. They all incorporate an ingredient or a series of ingredients which are activated by the application of heat, and by various reactions dissipate the heat input. A residual char is then formed to provide an insulating layer. Some of these compounds are unsuitable for external structures.
- c) Preformed panels of a proprietary monolithic construction, such as mineral fibre/cement compositions, vermiculite/cement boards, mineral wool slabs and high temperature insulation slabs. These are not generally recommended for outdoor use unless both the materials and method of fixing are particularly designed for a potentially wet environment where freeze/thaw cycling could occur.

Fire protection should meet the following important criteria.

- 1) It should limit the steelwork temperature for a reasonably long period (2 h or more) to not more than 500 °C (the strength of carbon steel falls away rapidly above this temperature) under the influence of a heat flux not exceeding about 100 kW/m², typical for an enveloping fire.
- 2) It should not fail suddenly, and should remain in place during the fire.
- 3) It should withstand the thermal shock and impingement of firefighting water from hoses and monitors.
- 4) It should be non-corrosive to the steelwork and be unaffected by environmental conditions.
- 5) It should be easy to apply without causing a hazard, undue mess or interference with adjacent plant.
- 6) It should be cost effective for the risks involved.

Vermiculite concrete is currently the most widely used fire protection material for structural steelwork and has proved satisfactory in both fire tests and actual plant fires. Steelwork to be fire-proofed should initially be protected by a compatible anti-corrosive coating.

Where encasement is used, two problems may arise.

- i) Water can encroach and cause damage by freezing and thawing, thus reducing fire protection.
- ii) Corrosion can occur under the encasement.

For these reasons, regular inspection and maintenance is required.

23.4 Fire venting systems

The spread of fire can be reduced by the provision of fire venting systems, the aim being to release hot products of combustion, thereby limiting damage and assisting firefighting operations. In some cases the escape of the occupants of the building may be made easier. Normal ventilation is unlikely to be sufficient to have a significant effect in a fire.

The principal forms of mechanical emergency ventilation are:

- a) automatically operating fire vents, best installed in the roof in conjunction with roof screens of a profiled roof shape to limit the lateral spread of hot gases;
- b) high capacity, high temperature fans (see also E.4.3, E.4.4 and E.4.5).

24 Means of escape in case of fire

24.1 General

Means of escape are defined as structural means whereby a safe route or routes is provided for persons to travel from any point in a building or structure to a place of safety. Lifts for general use, hoists, or other mechanical means are not acceptable as means of escape.

Chemical plant, whether in buildings or open structures or self-supporting, includes such a wide range of process hazards that specific recommendations would not be applicable to all cases. It is essential to provide a sufficient number of exits and escape routes. The distance to a place of safety should be as short as possible.

24.2 Building Regulations

The Building Regulations make specific requirements for means of escape in case of fire in certain buildings.

24.3 Fire certificates

24.3.1 General. Notwithstanding any requirements in obtaining building approval (enforced by Building Control Authorities), it will be necessary in respect of most premises considered by this code of practice to obtain a fire certificate under the Fire Precautions Act 1971 or under the Fire Certificates (Special Premises) Regulations 1976. See also section 2.

24.3.2 Fire Precautions Act: fire certificates. The Fire Precautions Act 1971 applies to buildings and structures comprising factory and office premises as defined in the Factories Act 1961 and the Offices, Shops and Railway Premises Act 1963 (except those which are in premises subject to the Fire Certificate (Special Premises) Regulations 1976). Any general fire precaution requirements for open spaces used in connection with premises subject to the Fire Precautions Act 1971 may be required under the Health and Safety at Work etc. Act 1974. See 4.1.

Guidance on the application of the Fire Precautions Act 1971 and the standard of provision of means of escape to meet the requirements of that Act is contained in Home Office Guides (E.11.1 to E.11.3).

24.3.3 Fire certificates (Special Premises) Regulations. Certain classes of premises which are specified in Schedule 1 of the Regulations require a certificate issued by the Health and Safety Executive.

The premises subject to the Regulations are essentially those where the processes are of such a nature and of such a scale that general fire precaution requirements are likely to be dictated by the process hazards, however high the standard of process hazard precautions.

A fire certificate under the “Special Premises” Regulations applies to all the land, buildings and plant within the curtilage, whereas Fire Precautions Act Fire Certificates are issued in respect of separate buildings on the site.

Guidance on general fire precautions relating to these Regulations, including means of escape, raising the alarm and firefighting, is given in an HSE Guidance Note (**E.10.4**).

24.4 Effect of population on means of escape

The total number of persons occupying a building is an important factor affecting escape arrangements. However, the comparatively low scale of manning usual in chemical plants may render other aspects of equal or greater importance.

There may often be additional persons on a plant who are dealing with, for example, construction of new plant, maintenance, etc., and provision for them will require consideration.

24.5 Effect of operations on means of escape

The operations occurring within a building or any other place will greatly influence the provision of means of escape. Two buildings of similar size and with the same number of employees can require greatly differing means of escape according to the use of each building.

Factors to be considered are the rapidity with which a fire might develop, the possible spread of flame, smoke or toxic gas, and the layout of plant or machinery which may restrict free movement in the area.

24.6 Means of escape from high structures

Provision of means of escape from tall free-standing plant structures presents exceptional difficulties and is a matter for discussion between the occupier and the authority responsible for enforcing the legislation. Each case will have to be decided according to its circumstances and the hazards involved.

Personnel engaged on high level open-mesh floors should be protected in such a way that their escape is not endangered by spillage from above or by fire below. It may be advisable to have solid floors on some escape routes.

Consideration should be given to the provision of more than one route of escape from tall free-standing plant structures to reduce to a minimum the possibility of persons being trapped by fire or toxic fumes. Account will have to be taken of the frequency of use by personnel involved with the process or for maintenance purposes.

Where two or more structures are grouped together, a second escape route should be arranged by bridging either the space between them or to an adjacent structure. Where bridging leads into a building, the access door should be self-closing and fire resisting and should open in the direction of travel.

24.7 Travel distances

On open plant structures with working places above ground level and with unprotected escape stairs, the time taken to descend to ground level should be assessed. For situations of similar risk the horizontal distance to the escape exit may need to be reduced for higher levels. However, such considerations will not apply where there are alternative simple and unobstructed routes at high level which will enable persons to get well clear of a fire before descending to ground level.

24.8 Obstructions and lighting

It is of utmost importance that all escape routes, internal and external, are kept free from obstructions and slippery substances or projections which might cause persons to trip, and also that they are adequately illuminated. It may be, under some circumstances, that emergency lighting will be necessary (see clause **25**). The lighting should provide a sufficient degree of illumination for persons to see their way to a place of safety.

24.9 Ladders

Fixed ladders may be provided as means of escape from plant structures provided the circumstances have been agreed with the certifying authority. Such ladders are not recommended for means of escape from buildings. Reference should be made to BS 4211 for details of construction, except that the distance between landings should not exceed 6 m, apart from special cases such as chimneys.

24.10 Signs and notices

Fire safety signs in accordance with BS 5499 should be used to indicate escape routes.

25 Lighting

It is recommended that emergency lighting be provided in all situations where failure of the power supply to the normal lighting would cause a serious risk. Such provision is required not only to enable persons to find and use exit routes, but also to allow plant operators to move about the plant to take whatever action may be necessary in the emergency.

Emergency lighting should be of suitable type for the particular environment concerned. See BS 5266-1, and **E.10.1** and **E.15.30** of this code.

26 Space heating

Appliances for space heating, together with associated equipment, may be responsible for outbreaks of fire and special consideration should be given to their type and location. Guidance on good practice will be found in various publications constituting the Chartered Institution of Building Services Guide.

Hazards may arise in many ways: the following examples are typical.

- a) The incorrect location, or the use of an unsuitable type of portable appliance to provide an improvised source of heating which may result from the installation of undersized heating equipment with the resulting need, in abnormally cold weather, to provide additional heating of a temporary nature.
- b) The misuse of heating appliances, e.g. actions such as the storage, or accidental or careless depositing of materials, in a manner which reduces the heat dissipation of appliances to an extent which permits a dangerously high temperature to develop locally.
- c) The installation of incorrect heating systems resulting in hazards due, for example, to incorrect or unsuitable location of fuel stocks, presence of flames and sparks, overheating and overpressure due to fault conditions.
- d) Faulty installations, e.g. insufficient clearance between the flue pipe and combustible elements of construction.
- e) Lack of maintenance, e.g. leakage of circulating heat transfer medium reacting with process materials.

27 Explosion relief in buildings

27.1 General

Processes in which there is a risk of explosion should preferably be located in the open air or in open-sided structures with minimum weather protection.

The need to exclude personnel while the plant is operating should also be assessed.

If there is a risk of an explosion within an enclosed building, the provision of explosion relief vents should be considered.

Any hazard which might be caused to neighbouring structures or personnel should be given due consideration when siting such buildings and arranging vents.

27.2 Location and size of vents

Vents should be placed as near as possible to the likely point of origin of an explosion. The required vent area may be provided by one vent or several vents but for a compartment with one large dimension or an irregularly shaped enclosure, it may be necessary to regard it as several separate compartments with sufficient venting area in each section.

Areas containing an explosion hazard should be segregated from other parts of the building by walls designed to limit the effects of an explosion. Interior walls of light construction should be avoided in explosion-hazard locations, as they are potential sources of missiles which may lead to injury to personnel, or of escalation of the incident.

The sizing of vents depends on the process and the type of structure and is not within the scope of this code (see E.8.2).

27.3 Types of vent

27.3.1 Openings. Unrestricted openings are the most effective vents. Louvres and roof openings with a weather shield may be regarded as partly restricted openings which afford weather protection and control unauthorized access.

27.3.2 Hinged panels. Hinged panels may be fitted in the walls or roof. Their inertia should be kept as low as possible by light construction and, for this reason, counterweights should not be used. They should be restrained so that they will not become missiles in an explosion and sited so as not to be a danger to persons who may be outside. Hinged panels should be arranged to latch open after primary operation and this is most conveniently achieved where the panels are bottom hinged. Regular inspection to check freedom of movement is required. Access doors should not be used as vents.

27.3.3 Blow-out panels. Blow-out panels fitted in the walls or roof should be so designed as, in the event of explosion, to minimize the missile effect and control the direction of discharge, and so create minimum hazard to adjacent plant and personnel.

27.3.4 Lifting roof. A roof, in whole or part, may be designed to lift at a predetermined (safe) pressure, and return to its rest position when the enclosure has been vented.

27.3.5 Windows. Windows in an enclosure/building can be included in the calculations for explosion relief. However, where double glazed units are employed, the failure pressure is higher than for a single pane. If windows are fitted, for explosion relief or for other reasons, they should be treated so as to be shatter resistant (laminated/shatter filmed/low flammability plastic panes) and the design should be generally as for blow-out panels. Regard should be taken in their siting in relation to any other combustible materials on the face of the building.

27.4 Wind and other effects. The effect of wind pressure and suction on hinged or blow-out panels, and the effect of snow loads on roof, should be taken into account.

28 Protection against lightning

BS 6651 should be consulted to determine the need for protection against lightning and how such protection may be provided.

29 Storage buildings for combustible or flammable materials

See also section 7.

When designing or selecting buildings or parts of buildings for the storage of combustible or flammable materials, the following are some of the more important aspects to be considered.

- a) Single-storey buildings having no basements are preferred, since they provide advantages for firefighting purposes and salvage operation.
- b) Adequate protection should be provided by distance or other means where the storage building or its contents could be exposed to external fire.
- c) Buildings used for the storage of materials constituting a fire risk should be of non-combustible construction, except in the case of small units which are reasonably safe by virtue of position relative to the site boundary and adjacent hazards. Reinforced concrete frames are preferable to unprotected steelwork. Where a building is constructed in steelwork, the main load-bearing members should be protected from fire by means of, for example, sprayed vermiculite concrete or sprayed mineral fibre, providing a fire resistance of at least 1 h duration. Buildings used for the storage of highly flammable or explosive materials are required to comply with the requirements of appropriate legislation (see 4.2, 4.3 and 4.4). See also E.10.11 and E.10.22.

d) Generally, openings in external walls are governed by the relationship of the building to the site boundary and to other buildings as laid down in the appropriate Building Regulations, but for certain constructional materials, additional, more onerous conditions may apply. Openings in division walls isolating the storage building from other activities should be equipped with approved fire doors having at least the same resistance rating as the walls (see 23.2.1 and E.7.2).

e) Where multi-storey buildings are used, floors should be designed to carry not only the stored material, but also loads which may be imposed due to firefighting water which may be absorbed by the material in storage. Where watertight floor construction is employed, drains or other suitable means should be provided to carry away safely the water used for firefighting purposes. Stairways and other vertical shafts should be enclosed or sealed off at each floor level, with construction having the same fire-resistance rating as the building.

f) Fire-resisting walls, fire doors and floors should be maintained in good repair at all times to ensure that any fire which may occur is contained as far as possible in the area of origin. Fire venting of the building may be applied as appropriate and as agreed with the fire authority (see 23.4).

g) Where dusty materials are stored, buildings should be designed to have smooth surfaces and due consideration should be given to the avoidance of ledges where flammable residues can accumulate (see 9.4).

h) For high risk areas, segregation into small units should apply; compartmentation may be appropriate (see clause 22).

i) Where heat sensitive materials are stored, particular attention should be paid to preventing heat build-up from the sun's rays or other sources. Windows and roof lights should be avoided, good ventilation provided and the roof area suitably thermally insulated.

j) Floors may need to be of special construction, e.g. non-sparking or antistatic. Due regard should be paid to the possibility of liquid spillage and means should be provided for its containment or removal to a safe place. Floor areas should be free of open drains to prevent the uncontrollable release of firefighting water or spilled product.

k) Bunds and raised thresholds to door openings, etc., of suitable fire-resisting and liquid tight construction should be provided around areas where flammable liquids are stored, or used where there is a possibility of fire being spread to other risk areas by the leakage of flammable liquid. The bund should produce a storage volume equivalent to 10 % more than the volume of the largest individual container stored. Where pipes pass through bund walls, special arrangements should be made to maintain the bund integrity.

l) Access routes to warehouses should take account of the requirements for emergency vehicles in addition to normal business traffic. Alternative approaches from the public road system should be available in the event of dense and potentially toxic smoke and fumes.

m) To reduce the risk from arson, warehouses not already located within a fenced factory should be protected by a security fence with minimum access, subject to l) above. Windows in the lower part of buildings should be avoided. External lighting coupled with intruder alarms should be considered. Reference to this is made in *Guidelines for safe warehousing of substances with hazardous characteristics*, published by the Chemical Industries Association (**E.2.6**), and a film is also available (**E.8.15**). Incident reports are available from the Health and Safety Executive (see **E.10.24** to **E.10.27**).

n) The use of lift trucks and other vehicles which may constitute a source of ignition should be suitably protected and strictly controlled. Advice is given in **E.10.15**.

Section 6. Storage and movement of materials

30 Introduction

30.1 Combustible materials not in process

Each storage requirement of combustible materials not in process, including siting, will need individual consideration, and the advice of experts, such as manufacturers, suppliers, fire authorities, Health and Safety Executive, Home Office and insurers, should be sought.

Special precautions are necessary when storing oxidizing agents and materials having unusual burning characteristics or which react violently with other substances. For such cases, appropriate literature and legislative requirements should be consulted. Storage arrangements should be made with the advice of a qualified person. As a general rule, the amounts of such commodities stored should be maintained as the absolute minimum level consistent with the economic and logistic conditions involved. When large amounts of certain substances are ignited they give rise to self-propagating chain explosions. The amount of such material stored in one place should be limited.

30.2 Fire loading

In a factory or plant, the fire loading of storage areas is often significantly higher than that elsewhere. Containers such as those made from corrugated cardboard, and pallets, which are combustible, offer a ready means for the spread of flame and the rapid development of a serious fire situation (see clause 10).

30.3 Legislation, certification and licensing

Many of the legal requirements listed in section 2 are applicable to storage; certification and licences are necessary. Legislation regarding labelling for identification of materials has also to be complied with. See **E.2.6** and **E.10.22**.

31 Principles of safe storage

31.1 General considerations

31.1.1 Introduction. Factors to be considered when selecting a storage area are covered in section 7. When materials to be stored may evolve flammable gases or vapours at or near ambient temperatures, an outdoor storage area should be selected.

Consideration should be given to possible interaction between different stored materials or between stored materials and fire extinguishing media (including water). See **E.2.6**, **E.8.11** and **E.10.22**.

31.1.2 Indoor storage. Materials likely to be affected by exposure to atmospheric conditions should generally be stored indoors within suitably located storerooms.

From a fire prevention point of view, indoor storage may be required to provide protection of the flammable contents from ignition from outside sources, and also to limit the spread of any fire outbreak that may occur (see **31.1.3**).

Where combustible solid materials in bulk are stored in a building, the building should be suitably sited, designed and equipped for the purpose.

31.1.3 Outdoor storage. "Outdoor storage" means locations outside any building or structure and includes storage under a weather shelter or canopy having not more than two sides enclosed. Tank storage is dealt with in clause **33**.

It is recognized that occasions do arise in industry where materials normally stored in buildings have to be accommodated outside as a temporary expedient (see **31.18**).

Owing to the diversity of material handled and stored, no general recommendations can be provided to cover all contingencies. However, the principles outlined will provide a basis for achieving adequate fire protection for outside storage. Recommendations concerning specific commodities which are considered to constitute special risks can be obtained from material suppliers or manufacturers and should be subject to consultation with either the Health and Safety Executive or the fire authority, as appropriate.

Mobile mechanical handling equipment should be suitable for the transport of the type of material stored and the terrain over which the equipment is to be used (see clause **34**).

31.2 Segregation

All storage locations should be separate with respect to each other and to their surroundings to avoid the spread of fire. The storage of packages and containers should be planned, both to limit the amount of material in each stack, and to provide a ready means of access of sufficient width for routine and emergency purposes.

Separate storage should be allocated to materials which are incompatible chemically or are unstable or which react adversely to normal firefighting means.

31.3 Transfer of flammable liquids and gases

Transfer of flammable liquids and gases should, wherever practicable, be by an enclosed system (see clause **38**).

Welded pipe runs are preferable, with facilities for isolation and drainage. Movement of these materials other than by a piping system should be specified with respect to:

- a) the procedure to be followed;
- b) the type of container/vehicle to be used;
- c) the routes to be followed.

For the use of vehicles for transfer see clause 34.

31.4 Minor storage of combustible materials

31.4.1 General. Although the fire loading of a minor store of fire-hazardous materials is much less than that of the bulk store, the probability of ignition may be greater.

31.4.2 Legislation and licensing. Some provisions of the legislation and licensing procedure listed in section 2 are equally applicable to bulk and minor storage.

31.4.3 Siting. The prevention of fire spread between plant and store should be a prime consideration when siting. Safeguards include the following:

- a) provision of a separate roofed enclosure for storage having a fire resistance commensurate with any external fire exposure hazard;
- b) avoidance of locations under windows or other openings for outdoor storage;
- c) avoidance of sites below overhanging roofs of combustible structure;
- d) avoidance of locations on, or adjacent to, main stairways or other vertical openings for indoor storage;
- e) avoidance of locations adjacent to sources of ignition.

The effect of a store fire upon plant and services should be considered and sites located below vessels, overhead power cables and piping systems should be avoided. A store should not be sited in a position where it is likely to endanger an escape route.

Wherever practicable, minor stores of highly flammable materials should be located outside the main building and provision made for transfer of materials by an appropriate means. The ventilation of a stores area located within a building often presents difficulties. Basements should not be used for storage of these materials.

31.5 Fire prevention in storage areas

The likelihood of fire is reduced by adopting the following measures.

- a) Preventing the access of unauthorized persons, e.g. by providing a security fence for bulk storage or a lockable steel bin or cupboard for smaller quantities.

b) Prohibiting the storage of materials other than those for which the facility is designed until consideration has been given to any hazard which may be introduced.

c) Strict control of all sources of ignition. In addition to the source of ignition covered by clause 7 the following aspects are particularly important in relation to warehouses.

- 1) Adequate separation of battery charging activities from flammable substances.
 - 2) Segregation of packing, wrapping and despatch areas.
 - 3) Careful control of shrink-wrapping operations.
 - 4) Segregation of processing activities such as sieving, filling, blending, reactions, etc., which could give rise to flammable vapours and dusts.
 - 5) Strict control of office or mess-room activities which could involve electrical devices, heat or open flame.
 - 6) Location and control of space-heating equipment.
 - 7) Provision of appropriate ventilation and drainage.
 - 8) Avoiding condensation in areas where materials sensitive to moisture are kept.
 - 9) Avoiding fire risk from grass and undergrowth.
- NOTE Chlorate-type weed killers should not be used.
- 10) Constructing storage racks, stillages, cupboards, etc. of non-combustible material.
 - 11) Performing constructional and maintenance work only on a permit-to-work basis (see clause 51).
 - 12) Displaying, conspicuously, appropriate cautionary notices which also give details regarding action in an emergency.
 - 13) Ensuring that material stored within a bund does not exceed the bund capacity (see 33.3.5).

31.6 Fire warning systems and fire protection

An audible form of fire warning system should be provided which should include means of communication from isolated storage areas.

A storage facility which presents a fire or explosion hazard requires a suitable form of protection.

31.7 Venting/pressure relief

31.7.1 Filling and emptying liquid storage equipment. Venting should be provided on bulk liquid storage equipment, whether refrigerated or otherwise, to avoid vessel rupture by excessive pressure/vacuum on filling and emptying (see **F.1.5**).

31.7.2 Emergency venting of atmospheric and low pressure storage tanks exposed to external fire hazard. Every such above-ground storage tank should have some form of construction or device that will relieve excessive internal pressure caused by exposure to fire.

In a vertical tank, the construction may take the form of a floating roof, a lifter roof, a weak roof-to-shell seam or other approved pressure-relieving construction.

Guidance on the sizing and arrangement of emergency venting will be found in **F.1.5**.

31.7.3 Relief of pressure storage. Relieving capacity for pressure storage should be calculated as for other process pressure vessels (see clause **43**).

Duplication of relief devices is desirable and may be mandatory.

For disposal of hazardous discharges from vents, see **43.3**.

31.8 Ignition

There are many possible causes of ignition (see clause **7**).

Storage areas should be classified according to fire risk (see section 11). Hazardous areas should be clearly marked as such and all practicable measures taken to avoid sources of ignition in those areas. These measures should include adoption of safe procedures for storage, material movement and maintenance (see section 10).

It is essential that storage areas containing flammable or combustible substances are designated "NO SMOKING" areas and that appropriate electrical equipment is used.

31.9 Location

Preference should be given to locations having:

- a) sufficient clear space from boundaries, plant buildings and other combustible storage which might constitute a fire exposure hazard;
- b) adequate clearance from highways and railways;
- c) good access by all-weather roads;
- d) no risk of flooding;
- e) absence of gradient variations likely to cause hazards;

f) good solid subsoil, suitable for supporting all anticipated loads;

g) no underground piping or drains which may constitute a hazard;

h) no overhead electric power cables;

i) adequate means to prevent access of unauthorized persons;

j) sufficient area to provide safe segregation for the stored material;

k) adequate water supply, with hydrants suitably located to give overall protection (see clauses **14** and **70**).

31.10 Change of use

Buildings and storage areas should be re-examined if at any time there is a significant change in the nature of the material stored. See **32.1**.

31.11 Access

All-weather roads, kept clear of obstruction and snow, should be provided for firefighting and general safety purposes.

Good access should be provided both outside and inside storage buildings (see clause **13**) to facilitate easy manoeuvring of all portable and transportable fire appliances required to give full cover to the risk involved, and to enable removal of stored material quickly and safely in the event of fire. It is important that gangways are not obstructed by temporary marshalling of materials in transit and that ready access is maintained to all important switchgear and main service controls.

31.12 Heating

Heating, if required, should be of a type which will not introduce a source of ignition. Braziers, portable heaters or open fires should not be used in storage areas where combustible or flammable materials are stored (see clause **26**).

31.13 Ventilation

Adequate natural or mechanical ventilation, as appropriate to the risk, should be provided in all storage areas.

Many oxidizing agents, and substances which react with water to liberate heat and flammable gases, require special climatic conditions demanding ventilation, cooling and in some cases dehumidification.

31.14 Drainage

Suitable steps should be taken by the use of traps, separators, neutralizing pits or effluent treatment plant, to prevent flammable or toxic materials entering drainage systems of any public authority. In this context, where flammable materials are stored in large quantities, due consideration should be given to the need or otherwise to incorporate emergency drainage systems. These should be designed to drain off firefighting water which may contain flammable, combustible or toxic materials to a safe location. Drainage systems will need individual consideration, including the fire and corrosion resistant materials involved. The advice of the appropriate authorities should be sought (see also clause 15).

31.15 Lighting

Adequate artificial lighting should be provided to illuminate essential operating facilities, and to allow good supervision over all parts of the storage area (see E.10.1).

31.16 Housekeeping (see also 50.3)

Good housekeeping is of paramount importance. The premises, indoors and outdoors, should be maintained at all times in a neat and orderly condition. Combustible wastes should be kept down to a minimum, stored in closed non-combustible containers and safely disposed of at frequent intervals. Empty flammable liquid or gas containers should not be stored indoors (see clause 35) and should be kept separately from full or part full containers.

Facilities for the storage of employees clothing should not be in the storage building unless a separate room with adequate fire separation is provided.

Vegetation likely to constitute a fire risk should be cut short within 6 m of any storage building containing flammable or combustible materials, but attention is drawn to the increased fire hazard associated with the use of certain chemical weed killers (see 31.5).

Sawdust or other combustible materials should not be used for soaking up leakages or spillages of flammable liquids. Dry sand or absorbent particles of inert mineral material should be used.

Waste products, empty containers and residues should be stored in an isolated section of the storage compound allocated for the purpose. Those of a highly flammable or toxic nature should be held in closed, non-combustible, suitably marked containers and safely disposed of at frequent intervals (see clause 35).

31.17 Identification by labelling

Materials should be clearly identified by labels or other similar means.

Requirements for labelling some materials are given in legislation (see for example A.5.2).

31.18 Temporary outdoor storage

Decisions to adopt temporary outdoor storage for materials normally stored indoors should be made only by a responsible and knowledgeable person, noting that in no sense are lower standards acceptable for temporary outdoor storage than for permanent arrangements. Every effort should be made to ensure that the fire safety of the storage compound is not jeopardized and that such materials are transferred at the earliest opportunity to an appropriate indoor storage area.

32 General storage

32.1 Storage layout and stacking

32.1.1 Outdoor storage layout and stacking. A preliminary survey of any storage location should be carried out before allowing stacks of material to be built up on open ground. This survey is to ensure that the ground will be stable under all weather conditions and that no damage will be caused to underground pipes or cables.

The possibility of fire affecting overhead power lines or pipelines should be considered (see E.11.9). Similarly, where mechanical aids are used for stacking, overhead hazards should be recognized and suitable precautions taken.

Very large concentrations of combustible or flammable materials in a single unit should be avoided. Areas should be marked by stakes or similar means to give clear indication of the extent of individual stacks and also to identify clearly access ways and aisles. Stacking and layout of outdoor storage areas should take into account the flammable and toxic nature of the materials being stored.

Sufficient clearance should be provided between individual stacks or piles to reduce the possibility of fire spread in the event of fire; alternatively, stacks may be segregated by fire-resistant partition walls.

Stored materials should be arranged to ensure that aisles and cross-aisles are wholly and easily accessible for firefighting purposes and for means of escape. Aisles with "dead-ends" should be avoided (see clause 24).

Combustible materials require aisles related to the height of the pile. As a rough guide, the width of the aisles should equal the height of the pile and be not less than 3 m.

Fire hazard may be reduced by categorizing materials in fire risk classifications (see clauses 17 and 66) and arranging storage so that highly combustible and incompatible materials are, as far as is practicable, separated by inter-spacing with non-combustible materials.

Pallets and stillages may contribute to fires and should preferably be constructed of non-combustible materials.

Buildings in outside storage areas should be located with as much clear space as possible between them and the commodities being stored.

In the case of open bulk storage, careful consideration should be given to the possibility of spontaneous ignition, e.g. the effect of damp, pressure and heat. If this condition is expected, thermometers should be inserted to enable the internal temperature to be observed and preventative measures taken as outlined in 31.13.

32.1.2 Indoor storage layout and stacking. All commodities should be stored, handled and piled with due consideration of their fire characteristics. Subdivision of material concentrations is a fundamental requirement of good storage and a prerequisite to any stacking procedure. Good access should be maintained at all times by the provision of adequate gangways at fire breaks within a building since, in the event of an outbreak occurring, the whole of the compartment at risk.

Special consideration, appropriate to the individual circumstances, should be given to fire protection in pallets, silos and similar mechanized storage systems.

Stacking should be arranged with the object of minimizing the spread of fire and be conducive to any salvage operations. High fire hazard materials (see clause 17) should be separated from the main bulk of storage by appropriate fire walls and fire doors. Commodities that may be hazardous if combined with others should be stored and separated so that they cannot come into contact with each other. Consideration should be given to reducing the fire hazards by carefully selecting materials in fire grade classifications and arranging the storage area so that highly combustible materials are, as far as is practicable, separated and maintained in small unit piles by interspacing with less hazardous or non-combustible commodities.

It should be borne in mind that the rate and development of a fire is usually increased more than proportionally by increase in stack height of the flammable stored items.

Stacking should be arranged so as to provide stability even under fire conditions and the strength of racking, etc. should reflect this. In considering this point, due regard should be paid to the combustibility of the wrappings, surface dust and bindings. Storage piles should be kept as narrow as practicable, consistent with acceptable operating conditions, in order to facilitate firefighting operations.

Combustible materials should not be stored or piled near main building columns which are not protected or inherently fire-resistant. Periodic inspection of fire-resistant cladding of columns should be undertaken. Due regard should be paid to the effect of stored materials on the operation and effectiveness of built-in firefighting systems. As an example, stacking should be arranged so as to provide at least 1 m clearance under sprinkler deflectors in order to reduce the possible obstruction of water distribution.

Materials that are susceptible to water damage should be arranged at least 100 mm from the floor on suitable pallets or other means. Some materials expand considerably when wetted and in such cases, to avoid the possibility of structural damage, materials should not be stored closer than 1 m to outside walls. However, for small buildings (less than 9 m in width) this dimension can be conveniently reduced.

Adequate clearance should be maintained around fire doors to ensure proper and effective operation. A clearance of 0.6 m should be maintained around the path of travel of fire doors unless they are otherwise suitably protected by barricades. Combustible materials should not be stored within 2 m of any fire door opening or fire-resisting shutters.

32.2 Storage of flammable liquids in small containers and drums

32.2.1 Introduction. General recommendations are given in E.10.11.

Storage outdoors, or in special buildings suitably separated from plant and other hazards is preferred to storage in plant or buildings used also for other purposes.

Small containers of flammable materials should be carefully stacked. Cylindrical drums laid on their sides should be well chocked to prevent collapse of the pile. Periodic inspection should be made and any leaking container attended to.

Containers should be stored within a closely defined area on a concrete pad or other impervious surface. The surface should be sloped to prevent spillage remaining under containers and any such spillage should either be retained by low sills constructed around the storage area or drained to a safe place.