

PUBLISHED DOCUMENT

Guidance on directives, regulations and standards related to prevention of fire and explosion in the process industries

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Foreword

This Published Document was published by BSI. It was prepared under the authority of Technical Committee FSH/23, *Fire precautions in industrial and chemical plant*. A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

The standards and draft standards listed or referenced in this Published Document were current at 1 September 2005.

Similarly, the regulations listed or referenced in this Published Document should not be regarded as exhaustive and up to date. It is the duty of all employers, self-employed and employees to be aware of all work place health and safety regulations that apply to them

This Published Document is not to be regarded as a British Standard.

1 Scope

This Published Document discusses the European Union (EU) and United Kingdom (UK) legislation intended to minimize the risk of fire and explosion in the process industries. It provides a comprehensive guide to the standards, draft standards and other documents that contain the technical, practical and organizational information to ensure compliance with EU Directives and UK regulations. This legislation specifies a risk assessment approach to dealing with fire and explosion hazards, so the procedures adopted in performing a risk assessment are used in this document as a framework with which to guide the reader to the information required to prepare the assessment.

The fire and explosion hazards covered in this code arise from use in the workplace of dangerous substances, as defined in the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) [1], and combustible substances that do not fall under the DSEAR definition of Dangerous Substances but which are capable of burning and thus participating in a fire.

NOTE 1 Fire and explosion hazards fall into two types in the process industries; those associated with the use of dangerous substances and the operation of equipment in explosive atmospheres, and those associated with chemical reaction hazards and uncontrolled exothermic reactions and decompositions. This Published Document concentrates on the first of these fire and explosion hazards. The second, although part of DSEAR [1], is not the subject of standards, but needs to be considered in the overall risk assessment. Although such topics are not comprehensively covered in this code, some further reading is listed in the bibliography.

This Published Document is not applicable to the offshore industry or to the mining industry.

It is not applicable to oxidizing substances or preparations, or to substances that are used or manufactured solely for their explosive properties.

NOTE 2 Some further reading on such substances and preparations is listed in the bibliography.

NOTE 3 This Published Document refers only to standards or other types of document that are published by recognized standards bodies. Some fire and explosion hazards, chemical reaction hazards, for example, are not the subject of standards, but need to be considered in the overall risk assessment. Although such topics are not comprehensively covered in this code some further reading is listed in the bibliography.

2 Terms and definitions

For the purposes of this Published Document, the terms and definitions given in BS 4422, BS 4727-2, BS EN 1127-1, BS EN 13237, BS EN ISO 13943 and IEC 61241-0 and the following apply.

2.1 quenching distance

minimum distance between two parallel plates through which a flame can propagate

2.2 flashpoint

minimum temperature at which, under specified test conditions, a liquid gives off sufficient combustible gas or vapour to ignite momentarily on application of an effective ignition source

- 2.3 hazard**
something with the potential to cause harm
- 2.4 risk**
likelihood that harm will occur
- 2.5 safety**
freedom from unacceptable risk of harm

3 Fire and explosion safety

3.1 General

Fire and explosion hazards arise in the workplace wherever dangerous substances and combustible substances are stored, transported, processed or otherwise used. Fires and explosions can be very destructive of lives and property, and legal requirements are imposed on employers for ensuring the safety of workers and others by minimizing the risk of fires and explosions occurring.

This chapter is an overview of the European Union (EU) Directives and United Kingdom (UK) regulations.

3.2 Legal background: UK regulations and European Directives

3.2.1 EU directives

The legal requirements for dealing with fire and explosion hazards are embodied in both EU and UK regulations. Many of the UK regulations are an implementation into UK law of a series of “New Approach” directives from the EU. These directives are intended to facilitate the creation of a single European market by establishing common safety standards for many types of product together with a system of CE marking. CE marking is an indication that a product meets relevant requirements. The “New Approach” is that the directives set out general requirements while the specific detail for conforming to these requirements is described in European harmonized standards.

Some “New Approach” directives give general health and safety principles for the workplace and general requirements for management of health and safety. Others describe, in general terms, product law applicable to the design and construction of items, such as machinery and equipment intended for use where there is a risk of fire and explosion. These are known as product directives.

There are three types of product directive:

- basic directives, which apply to all manufacturers of products and address trade, enforcement, liability and other issues;
- generic directives, which address a specific range or group of products, one example being products that may generate radio frequency emissions; and
- product-specific directives, which apply to products where extreme hazards exist, such as with machinery.

Sometimes the involvement of an EU Notified Body might be mandatory in demonstrating conformity with these Directives, but this is not always so. Product-specific directives take precedence over all other Directives.

Product-specific directives set out a number of “essential requirements” in terms of design, production and documentation. One example of these is the Essential Health and Safety Requirements (EHSRs). The “essential requirements” have to be met by the manufacturer if a product is to be sold in the EU.

The manufacturer’s obligations for demonstrating conformity with the requirements of the Directives include a conformity assessment to determine whether a product does conform, CE marking of the product to demonstrate that the essential requirements have been met, an EC declaration of conformity and written attestation of conformity (if relevant), along with arrangements for holding in a secure place the EC declaration of conformity together with the technical documentation.

The route by which conformity can be demonstrated depends on such factors as the degree of hazard that the product itself presents and the hazards likely to arise from the location of its use. In some instances self-certification is allowed, but if the risk of a hazardous event is high, certification of the product by an independent third party might be required.

Member states of the EU have designated a number of organizations that are accredited to carry out this certification. These organizations are known as “notified bodies” and, when necessary, these conduct an examination to establish that a product meets the requirements of the Directives, including quality aspects of the production process, and that a CE mark can be affixed. The Notified Body issues a certificate prior to the CE Marking. A product might fall under more than one directive, and a CE mark is affixed only when the requirements of all the pertinent directives are met.

The relevant directive explains whether the involvement of a notified body is mandatory for conformity testing of a product.

The European Commission has published a guide to the implementation of “New Approach” Directives [2]. The DTI has published a guide to the product directives: *“Product standards: Keeping your product on the market”* [3].

3.2.2 Harmonized standards

The detailed technical and organizational means for ensuring compliance with the essential requirements of EU directives are not published in the directives themselves. There are, however, several ways of complying with the essential requirements:

- through specified European harmonized standards;
- in the absence of relevant specified European harmonized standards, through national standards; and
- through, for health and safety, the Essential Health and Safety Requirements.

The first of these is the easiest – fidelity to a published document, the technical content of which has been agreed throughout the EU will mean straightforward acceptance that compliance with the EHSRs has been achieved. The third is the most difficult because compliance then has to be demonstrated without the support of an agreed technical basis. The use of standards to show compliance is not, however, mandatory. In most cases, compliance can be demonstrated by other means.

There are three types of harmonized standard, which have been classified by the Machinery Directive [4] as Types A, B and C.

- Type-A standards give a description of general principles and deal with the basic methodology and philosophy of approaches to meeting the general requirements of the directives;
- Type-B standards deal with one safety aspect or one type of safety device that can be used across a wide range of machinery or equipment; and
- Type-C standards give detailed safety requirements applicable to one specific item of equipment and machinery or one class of equipment and machinery.

Some harmonized standards put forward mandatory requirements, especially those that support the product directives; others are not mandatory but describe “relevant good practice”.

European harmonized standards are identified by EN numbers and have currency throughout the EU. They are issued by the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). CENELEC and the International Electrotechnical Commission (IEC) have reached an agreement on parallel voting that means a standard generated by the IEC is voted as both an IEC and CENELEC standard and becomes a harmonized standard. IEC standards are published as ENs using their IEC reference numbers.

Agreed harmonized standards are published in the Official Journal of the European Communities (OJEC) and issued as national standards. Conformity with the standards allows a presumption of conformity with the relevant requirements of the Directive.

In the United Kingdom, the British Standards Institution (BSI) publishes standards under BS EN and BS IEC numbers. The BSI convenes a series of “shadow” committees that match the European standard committees subject for subject and are able to put forward UK experts as members of the European committees, comment on draft standards and agree UK acceptance, or otherwise, of the final version.

General terms and definitions concerning standardization and related activities are given in BS EN 45020.

Overall, the “New Approach” Directives impose important duties on employers, and some of them are important where there is a risk of a fire and explosion. The harmonized standards are intended to help fulfil these duties.

3.2.3 UK Regulations

In the United Kingdom, the basis of health and safety law is the Health and Safety at Work etc. Act 1974 [5]. The Act is supplemented by Regulations, which are approved by Parliament and impose legally binding obligations.

Approved Codes of Practice (ACOP) give advice on how to comply with the law by offering examples of good practice as illustrations of the law's requirements. An employer in breach of health and safety law and proved not to have followed the requirements of the appropriate ACOP can be found at fault unless it is demonstrated that they have used alternative means to comply with the law.

Guidance is published to help employers to understand the law, to assist in complying with the law and to offer technical advice. It is not compulsory to follow guidance, but an employer who does will normally be doing enough to comply with the law.

The regulations under the Health and Safety at Work Act [5], together with European directives, specify a risk assessment approach to minimizing the risk of fire and explosion. In the UK, the completion of this process means that measures have been identified that when implemented will ensure that the risk is As Low As is Reasonably Practicable (ALARP). ALARP means that the degree of risk is balanced against other factors, such as difficulty, time and cost, which render further measures to avoid or reduce the risk excessive. ALARP applies specifically in UK health and safety law and is not a concept found in European Directives, or in product law, where requirements tend to be mandatory.

The legal requirements set out in the European Directives, UK Regulations and associated ACOPs relevant to fire and explosion safety are given in Annex A.

4 General risk assessment

4.1 General

It is a legal requirement of health and safety law in Europe and the UK that whenever and wherever there is any potential hazard a risk assessment has to be performed.

A risk assessment is a formal consideration of the hazards associated with the workplace and the activities undertaken in order to identify situations that could cause harm to people and to introduce any measures necessary to eliminate risk or reduce it to an acceptably low level.

For any risk assessment a five step approach is suggested:

- identify the hazard;
- identify who may be affected and their location in the workplace;
- evaluate the risks arising from the hazard, considering the adequacy of existing precautions and what further controls may be necessary;
- record the findings and the details of actions taken and communicate these to the workforce; and
- continually review and revise.

General guidance on carrying out a risk assessment can be found in the Health and Safety Executive publications:

- *Five steps to risk assessment* [6];
- *Five steps to risk assessment; case studies* [7]; and
- *A guide to risk assessment requirements* [8].

A logical and structured approach to risk assessment methodology for all key areas of occupational health and safety is set out in *EP 515: HaSARD Manager. Risk Assessment Software* [9].

BS IEC 61882 gives guidance on Hazard and Operability (HAZOP) studies, a structured and systematic technique for examining a defined system to identify potential hazards and potential operability problems. An important benefit of HAZOP studies is that the resulting knowledge is of great assistance in determining appropriate remedial measures.

Once a hazard has been identified then the risk has to be estimated. A judgement is then made as to whether the risk is acceptable and what course of action should be taken to deal with it. The acceptability of a risk is often difficult to determine, but decisions might be made easier where a number of proposed courses of action can be considered. An estimation of the risk associated with each course of action can then be balanced against the practical consequences in terms of fitness for purpose of the items or materials involved, cost factors, etc. to arrive at an acceptable solution. All appropriate scenarios need to be addressed.

4.2 Risk assessments for fire and explosion

Fires and explosions are a potential hazard when the risk arises of an ignition source coming into contact with flammable substances that can produce either or both of these hazards. Flammable gas, vapour, mist or dust dispersed in air can produce an explosive atmosphere, which, if a sufficiently energetic ignition source is present, might ignite to produce an explosion. A flammable solid or a liquid can decompose or vaporize to produce flammable gases or vapours that might ignite to produce a fire.

A range of UK legislation implementing EU Directives requires a fire and explosion risk assessment to be performed. The aim of this risk assessment is to identify potential fire and explosion hazards in the workplace, estimate the risk of a fire or explosion occurring, and set out those measures necessary to minimize this risk, along with those measures that deal with any residual risk and limit to an acceptable level the effects of a fire and explosion should one or both occur.

Explosions can often be followed by fires, and, by the same token, a fire may lead to an explosion. It is important, therefore, that a fire and explosion risk assessment be carried out as a single exercise that considers all the fire and explosion hazards that can arise.

The assessment must identify all substances that can take part in a fire and explosion, and these are as follows.

- Dangerous substances, as defined by the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) [1], which have the potential for fire and explosion and require fire and explosion prevention and protection precautions. These particular fire precautions are often referred to as Process Fire Precautions (PFP) and are required in addition to General Fire Precautions (GFP).
- Other combustible substances, defined in this document as substances that do not fall under the DSEAR definition of Dangerous Substances but that are capable of burning and thus participating in a fire and require General Fire Precautions (GFP).

NOTE 1 In relation to compliance with DSEAR [1], Process Fire Precautions (PFP) are taken in addition to the General Fire Precautions (GFP). PFP are special precautions taken in respect of a work activity in order to prevent or reduce the likelihood of a fire or explosion occurring, or to limit its intensity. GFP are those basic measures taken to ensure people's safety in the event of a fire, e.g. general measures to prevent fire, means of escape, provision of fire extinguishers, fire detection and alarms, staff training, etc.

NOTE 2 Combustible substances forming part of the fabric of a building are covered by the Building Regulations [22, 27, 29].

4.3 Risk assessments for dangerous substances

4.3.1 General

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [1] implement the European ATEX 137 (or User) Directive [10] in the United Kingdom and set out UK law for the management of fire and explosion risks arising from the use or presence of dangerous substances in the workplace. The definition of “dangerous substances” given in DSEAR [1] is given in **B.2**.

Dangerous substances include oxidizing substances and flammable gases, flammable liquids and mists, flammable dusts and some flammable solids. Dangerous substances also include materials with explosive properties which are not used for their explosive properties.

Where a dangerous substance is present at a workplace, DSEAR [1] requires the employer to make a “suitable and sufficient assessment” of the risks to employees arising from that dangerous substance and to eliminate or reduce the risk, as far as is reasonably practicable, by replacing the dangerous substance with a substance or process which either eliminates or reduces the risk.

The risk assessment procedure specified by DSEAR [1], which follows the five step approach, includes consideration of:

- a) the hazardous properties of individual substances and the hazardous properties of substances when used in combination and the circumstances of the work;
- b) the likelihood that an explosive atmosphere will occur and its persistence;
- c) the likelihood that ignition sources will be present and become active and effective; and
- d) the scale of the anticipated effects of a fire or an explosion.

Where it is not reasonably practicable to eliminate or reduce the risk arising from the presence of a dangerous substance, DSEAR [1] requires the employer, “so far as is reasonably practicable, to apply measures, consistent with the risk assessment and appropriate to the nature of the activity or operation,” to (in order of priority):

- a) reduce the quantity of dangerous substances to a minimum;
- b) avoid or minimize the release of a dangerous substance;
- c) control the release of a dangerous substance at source;
- d) prevent the formation of an explosive atmosphere, including the application of appropriate ventilation;
- e) ensure that any release of a dangerous substance which might give rise to risk is suitably collected, safely contained, removed to a safe place, or otherwise rendered safe;
- f) avoid ignition sources;
- g) reduce to a minimum of the number of employees exposed;
- h) avoid propagation of fire or explosion;
- i) provide fire and explosion protection methods; and
- j) provide suitable personal protective equipment.

The employer is required to regularly review the risk assessment and make any revisions that are found to be necessary.

Before a workplace containing places classified as hazardous is used for the first time, the employer has to ensure that its overall fire and explosion safety is verified by a competent person, as defined in DSEAR [1].

The risk assessment required by the User Directive [10] takes the form of an explosion protection document(s). Although DSEAR [1] does not require specifically the production of an explosion protection document, the key requirement is still that risks from dangerous substances are assessed, controlled and recorded.

4.3.2 Integrated explosion safety

When dealing with the explosion aspects of the DSEAR [1] risk assessment, the principle of integrated explosion safety set out in the User Directive [10] should be applied. Through integrated explosion safety, the explosion hazard is dealt with using a mixture of explosion prevention measures and, if the explosion risk cannot entirely be avoided, explosion protection techniques.

Thus, when an explosion hazard has been identified, the risk is minimized by:

- firstly, if possible, preventing the formation of explosive atmospheres;
- secondly, preventing the ignition of any explosive atmospheres that might occur; and
- finally, either halting immediately any explosion that might occur or limiting the range of flames and pressures to a sufficient level of safety.

The integrated approach to explosion safety is evident in BS EN 1127-1, which specifies methods for the identification and assessment of hazardous situations, including the basic elements of risk assessment, and the design and construction of measures for ensuring safety.

NOTE Two European standards are in preparation that describe the principles for risk assessment of equipment and protective systems intended for use in potentially explosive atmospheres, as introduced in BS EN 1127-1.

Though produced for offshore production installations, BS EN ISO 17776 and BS EN 13702 (both parts) contain useful information on the identification of explosion (and fire) hazards and the assessment and management of risk.

Table 1 lists the requirements of integrated explosion safety along with the explosion prevention and protection measures that satisfy each requirement. Listed in the fourth column of the table are the ignition and explosion characteristics for which test information is needed in order to apply a particular measure, and details are given in the Annexes listed in the third column.

Such test data are obtained under specified conditions. It is important that these reflect the conditions in the plant.

Table 1 Application of ignition and explosion characteristics to explosion prevention and protection techniques

Essential health and safety requirement	Explosion prevention/ protection technique	Annex	Ignition and/or explosion characteristic
Avoidance of explosive atmospheres	Substitution of dangerous substances	Annex B	Flammability Flash point
	Limitation of concentration	Annexes C, D and E	Explosion range Explosion limits
	Inerting	Annex E	Limiting oxygen concentration
Elimination of ignition sources	Selection of appropriate equipment for use in hazardous areas	Annexes F and G	Minimum ignition energy Minimum ignition temperature (dusts) Auto-ignition temperature (gases) Layer ignition temperature (dusts) Decomposition temperature Spontaneous ignition temperature Impact sensitivity
Limitation of explosion effects	Explosion containment	Annex H	Maximum explosion pressure Maximum rate of pressure rise
	Explosion suppression	Annex H	Maximum explosion pressure Maximum rate of pressure rise
	Explosion venting	Annex H	Maximum explosion pressure Maximum rate of pressure rise
	Explosion isolation	Annex H	Maximum experimental safe gap Minimum ignition energy Minimum ignition temperature (dusts) Flame speed

4.3.3 Integrated explosion safety: Stage 1 – avoidance of explosive atmospheres

4.3.3.1 Identification of dangerous substances

Wherever gases, vapours, mists, liquids, powders and dusts are handled, stored or otherwise used in process industries, the explosion hazard has to be addressed and the dangerous substances identified. The identification of dangerous substances is discussed in Annex B.

A substance purchased from a supplier should come with a material safety data sheet (MSDS) containing information on the flammability and ignitability of the substance and the precautions that should be taken. However, when a substance is produced in the workplace, or the MSDS does not contain the appropriate information, the fire or explosion potential of the substance should be determined by tests.

The fire or explosion potential of liquids is determined on the basis of the flashpoint, as described in **B.3**.

A high percentage of dusts used in the powder processing and powder handling industries fall within the DSEAR [1] definition of a dangerous substance, and tests are available for identifying these dusts (see **B.4**).

4.3.3.2 Hazardous areas classification

When dangerous substances are present and explosive atmospheres can occur, DSEAR [1] requires that areas of the workplace are classified as hazardous or non-hazardous, and that, additionally, hazardous areas are separated into zones.

Zoning is based essentially on the frequency, extent and persistence of the potentially explosive atmosphere and leads to an estimation of the position and the size of each zone. The definitions of hazardous zones given in DSEAR [1] appear in Annex C.

Explosive atmospheres in the workplace can be the result of leaks of a dangerous substance or an unavoidable consequence of an action, such as spray coating. Potentially explosive atmospheres can also occur inside process plant handling dangerous substances, so the zoning of internal volumes of such plant is also required.

4.3.3.3 Limiting the extent of hazardous areas

It is incumbent upon the employer to minimize the extent of any hazardous areas and to eliminate them entirely if at all possible. DSEAR [1] recommends that, if possible, a dangerous substance should be replaced by an alternative that either eliminates or reduces the risk. If the use of a dangerous substance cannot be avoided the amount present should be kept to the minimum practicable.

Dangerous substances should be kept in suitable containers and any spills of liquids should be prevented from spreading. A requirement of DSEAR [1] is that, where containers and pipes used at work for dangerous substances are not marked in accordance with the legislation listed in Schedule 5 to these regulations, the employer is to ensure that the contents of those containers and pipes, together with the nature of those contents and any associated hazards, are clearly identifiable.

Dangerous substances should be stored well away from other processes or general storage areas and perhaps separated by a suitable physical barrier. For gases and vapours, other practical measures include detection of potentially explosive atmospheres, alarm procedures and appropriate ventilation. Dusts tend to settle out and so housekeeping measures have to be taken to minimize any accumulations in the workplace. Guidance on minimizing the extent and duration of explosive atmospheres in the workplace is given in Annex D.

Inside process plant, explosive atmospheres can be avoided by limiting either the concentration of the dangerous substance or the concentration of oxygen. Certain explosion characteristics of the dangerous substance are required if these techniques are to be applied. The standard tests and the implications of the test results for avoidance of explosive atmospheres inside process plant are given in Annex E.

4.3.4 Integrated explosion safety: Stage 2 – elimination of ignition sources

BS EN 1127-1 and the “*Approved Code of Practice and Guidance on Control and Mitigation Measures*” [11] issued under DSEAR [1] list potential ignition sources.

Ignitions due to electrical discharges and hot surfaces are discussed in Annex F, along with the test methods for measuring the ease of ignition of dangerous substances by such ignition sources. These ignition sources have special importance when electrical or mechanical equipment is chosen for use in hazardous areas. Other potential ignition sources covered in standards are also discussed in Annex F.

Once the ignition potential of the dangerous substance and the hazardous area classification are known, the appropriate explosion-protected electrical and mechanical equipment for the potentially explosive atmosphere can be chosen (see Annex G).

4.3.5 Integrated explosion safety: Stage 3 – limiting the consequences of an explosion: explosion protection

DSEAR [1] requires that when there is a residual risk of explosion, one or more of the methods of explosion protection – venting, suppression, containment and isolation – have to be applied.

If the protection methods are to be applied effectively, it is essential that the maximum explosion pressure and the maximum rate of pressure rise of the dangerous substance making up the potentially explosive atmosphere are known.

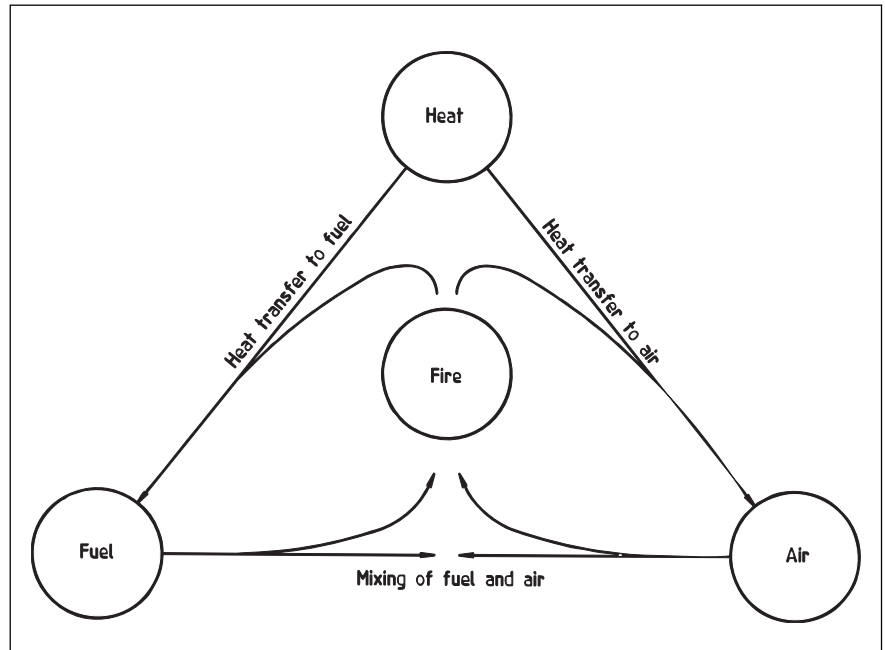
The explosion protection concepts and the test methods for measuring the explosibility characteristics of dangerous substances are described in Annex H.

4.3.6 Risk assessment for process related fires

When dealing with the fire aspects of a DSEAR [1] risk assessment, Process Fire Precautions (PFP) relevant to those combustible materials defined by DSEAR as Dangerous Substances are to be considered.

The three prerequisites for a fire are a combustible material (i.e. the fuel), an ignition source and the presence of oxygen, as pictured in the “Fire Triangle” in Figure 1.

Figure 1 The fire triangle



A fire begins when an ignition source comes into contact with a combustible material. Flammable gases and vapours, either present as the combustible material or evolved from a liquid or solid by the action of the ignition source, are then capable of being ignited. Whether the consequence of this is a fully-fledged fire depends on the igniting ability of the ignition source with reference to the ignition properties of the combustible substance and whether sufficient flammable gases and vapours are present or can be produced.

Smouldering fires only occur with materials that are and remain as a solid. Such fires propagate either across the surface or within the body of the solid material and can do so at very low oxygen concentrations. The smoke produced in smouldering fires might itself be flammable and, when confined, could lead to explosions. Smouldering fires might proceed to a flaming phase and, if large areas of material have been pre-heated during smouldering, the fire spread might be very rapid when flaming occurs.

Flammable liquids and vapours are a significant potential hazard because they can travel a relatively long distance.

The circumstances in which flammable substances are handled, stored, transported and ultimately discarded have to be considered. The type of work in which these substances are involved, including activities such as maintenance, where there is potential for a high level of risk, have also to be assessed.

Ignition sources in the workplace are many, including naked flames and hot surfaces, and their causes are varied. It is essential that potential ignition sources be identified [11].

The degree of ventilation is important to the rate at which a fire is supplied with oxygen. In high ventilation conditions, a fire grows rapidly and reaches high temperatures, and the controlling factor is the amount of fuel available. In low ventilation conditions, the fire is controlled by the amount of air available and fire temperatures are lower; combustion is not as efficient and fire duration is relatively longer. In addition to the air, oxygen can be present as part of the workplace activities; for instance, stored in cylinders. When the concentration of oxygen is high, the combustion rate can be fast and very high temperatures can be reached in a fire or explosion.

When fire hazards have been identified, measures have to be taken to ensure that the rate of spread of a fire is limited as much as is possible. The amount of combustible material in an area should be kept to a minimum or, if possible, replaced by non-combustible substitutes or materials of reduced combustibility. Combustible materials that are dangerous substances as defined under DSEAR [1] should be stored in fire-resistant stores, and waste materials that contain dangerous substances should be stored safely and disposed of properly.

4.3.7 Fire and explosion hazards in process equipment

Machinery and equipment used in process plant can give rise to fire and explosion hazards. Standards are available that deal with the avoidance of these hazards for particular types of machinery and equipment. These standards are described in Annex I.

4.3.8 Assessment of the toxic hazard of fire effluents

Toxic hazard assessment is that part of the risk assessment required by DSEAR [1] in which the toxic effects of inhaled fire effluent on those exposed are evaluated. Fire effluents are composed of combustion products and other substances given off by the burning material.

The term “toxic potency” is a specific technical term in fire science. It is the measure of the amount of toxicant that elicits a specific toxic effect. This, though, is only one of the factors that determine the toxic hazard posed in any given fire scenario. The composition of the fire effluent from a given material is not an inherent property of that material, but is critically dependent on the conditions under which that material is burnt.

BS 7899-1 proposes seven steps for the assessment of risks arising from the toxic gases, smoke and heat produced in a fire. Although BS 7899-1 provides guidance on the factors to be considered when assessing the risk to life and health presented by fires in buildings, its general approach is also applicable to Process Fire Precautions (PFP) (see 4.4.6).

BS 7899-1 and BS 7899-2 partially replace DD 180, which gives guidance on measures for reducing the probability of toxic combustion products being formed in significant quantities during a fire.

The toxicity of the combustion products produced by substances involved in a fire is an important aspect of fire testing. It is often the inhalation of toxic products that leads to death of personnel rather than the effects of heat and flame. Testing methods for the toxicity of combustion products are described in Annex J.

Large fires can have a substantial environmental impact, and this must not be forgotten in a fire risk assessment. Guidance given in BS 7982 is applicable to certain plastics storage sites. In addition to providing information and guidance on the burning of plastics and the environmental impact zones following a major fire, this standard lists and briefly reviews the relevant legislation, regulations and guidelines that apply to such situations. It should be noted that the Control of Major Accident Hazards Regulations (COMAH) [12] do not apply directly to plastics since plastics are not considered to be dangerous substances *per se*. It is possible, however, that burning plastics might release potentially dangerous substances and the application of COMAH [12] represents a cautious approach in such cases.

4.3.9 Escape and emergency lighting

The requirement for escape lighting is determined under general fire precautions to indicate clearly and unambiguously the escape routes, to allow safe movement towards and through the exits provided, and to ensure that fire alarm call points and fire fighting equipment provided along escape routes can be readily located. However, emergency lighting and standby power supplies may be required to enable safe shutdown of the process or plant. The requirement for these should be determined as part of the DSEAR [1] assessment.

Standards for emergency lighting and luminaires are listed in Annex K.

4.3.10 Safety signs

In both General Fire Precautions and Process Fire Precautions safety signs are used to give information for dealing with certain emergencies, including the identification of escape routes and the location of fire equipment. The minimum requirements for safety and/or health signs at work are set out in the Safety Signs Directive [13], which ensures that occupants, regardless of language, can understand safety messages indicated by signs. The Safety Signs Directive is implemented in UK law by the Health and Safety (Signs and Signals) Regulations 1996 [14], which set out minimum requirements for safety signs, including signs indicating escape routes.

It is essential that safety signs contain a graphical symbol; a visually perceptible figure used to transmit information independently of language. Consistency in the design of graphical symbols for use in a particular situation or in similar situations is important, as is comprehensibility. Standards for these symbols and safety signing generally are listed in Annex L.

4.3.11 Personal protective equipment (PPE)

Personal protective equipment is defined as all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him or her against one or more risks to his or her health and safety wherever there are risks that cannot be controlled in other ways. Personal protective equipment is the final recourse in protection measures against fire and explosion hazards. Collective methods should always be instituted first.

With regard to fire and explosion risks, a DSEAR [1] risk assessment might conclude that personal protective equipment is a necessary part of the overall safety precautions. The risk assessment might also indicate which types of PPE are suitable in terms of the hazard identified and the job to be done. Under the Personal Protective Equipment at Work (PPEW) Regulations 1992 [15], which implement European Directive 89/656/EEC [16], an employer is required to inform the users of PPE why it is needed and to provide instruction and training as to when and how PPEW is to be used, kept safely, repaired, replaced and maintained. Users have also to be made aware of the limitations of the PPEW provisions.

The DTI has published a Guidance Note on the UK Personal Protective Equipment 2002 Regulations [17,18], which regulate the placing on the market and supply of personal protective equipment by manufacturers.

BS 7971-2 gives guidance on conducting a risk assessment on situations where protective clothing and equipment has to be selected. This standard highlights the importance of identifying those with responsibility for decision-making and the factors to be taken into account in decision-making. Guidance is also given on establishing systems for the maintenance, storage, preparation, and issuing of protective clothing and equipment, and the segregation, decontamination, cleaning, inspection and eventual disposal of used clothing and equipment.

Although BS 7971-2 is concerned with protective clothing for violent situations, rather than for process hazards, it contains a risk assessment procedure that has general applicability, and provides a useful division of the selection process for personal protective clothing and equipment into six stages:

Stage 1. Determining what the protective clothing and equipment needs to do. Listing of the foreseeable hazards and risk levels identified in the risk assessment of the situations in which the protective clothing and equipment might be used. Determination of what the protective clothing and equipment is required to do with respect to each hazard.

Stage 2. Collecting information about the protective clothing and equipment available. Investigation of the protective clothing and equipment available and its claimed performance against the hazards identified at stage 1. Consideration of the problems inherent in the use of the protective clothing and equipment.

Stage 3. User trials. Conducting trials to assess the compatibility and the ergonomic performance of protective clothing and equipment and validation of the performance of the combinations of protective clothing and equipment.

Stage 4. Establishing procedures. Establishment and documentation of procedures for the storage, issue and maintenance of, and record keeping for, the protective clothing and equipment. Establishment of training needs with respect to the management of the protective clothing and equipment. Provision and monitoring of the training.

Stage 5. Introduction of the protective clothing and equipment. Prioritization of the supply of protective clothing and equipment, and organization of the training of operatives to use it as it is introduced.

Stage 6. Continuous evaluation. Establishment and operation of procedures to:

- a) monitor the training of operatives in the use of the protective clothing and equipment;
- b) monitor the performance of the protective clothing and equipment in training and in operational use;
- c) determine whether the protective clothing and equipment is achieving the reduction in risk required;
- d) consider whether operational restrictions are necessary;
- e) determine whether the decisions reached were correct and remain correct in the light of current circumstances;
- f) consider whether new intelligence or technological developments should be taken into immediate account; and
- g) provide information for continuing risk assessment.

General requirements for ergonomics, ageing, sizing, marking and manufacturer's information for protective clothing are specified by BS EN 340. Standards for specific types of PPE are listed in Annex M.

4.4 Risk assessment for other combustible substances

4.4.1 General

Dangerous substances, as defined by DSEAR [1], are not the only materials that can be involved in a workplace fire. Fire hazards also arise from the presence of other combustible substances, including those used in the construction of buildings.

General Fire Precautions (GFP) are those basic measures taken to ensure people's safety in the event of a fire, e.g. general measures to prevent fire, means of escape, provision of fire extinguishers, fire detection and alarms, staff training, etc.

Listed below are the three basic types or stages of fires and fire hazard conditions.

- a) *Smouldering/non-flaming.* This can involve self-sustaining smouldering or pyrolysis from externally applied heat radiation.
- b) *Well ventilated flaming.* This usually represents the early stages of a flaming fire where the fire size is small in relation to the size of the compartment. The type and disposition of the fuel determines the rate of fire growth.
- c) *Less well ventilated flaming.* This is where the rate of fire growth is determined by the amount of ventilation and usually occurs in the later stage of a flaming fire, consisting of either a small, vitiated fire in a poorly ventilated compartment or a fully developed/post-flashover, vitiated fire in a large or open compartment.

Fires are classified by BS EN 2 as:

- Class A: fires involving solid materials, usually of an organic nature, in which combustion normally takes place with the formation of glowing embers;
- Class B: fires involving liquids or liquefiable solids;
- Class C: fires involving gases;
- Class D: fires involving metals; and
- Class F: fires involving cooking oils and fats.

For any fire in an occupied structure, the survival of occupants is determined by the outcome of two parallel processes: the developing life threat from the fire and the process by which occupants escape. Fire safety design should be aimed at preventing occupants from coming into contact with heat and toxic smoke.

The main fire processes leading to risk usually involve ignition, growth of fire, developed burning, the release of smoke and toxic gases, oxygen depletion and heat. The point in any fire when a victim becomes incapacitated or dies depends strongly upon the growth curve of the fire, which determines the dose of toxic products to which a potential victim is exposed, as well as the toxic potency of the products, which in turn determines whether the dose delivered will cause incapacitation or death. The point in time where an incapacitating or lethal dose of products has been inhaled is also critical.

The rate of growth and spread of the fire and its production of life-threatening toxic products, smoke obscuration and heat depend broadly upon the interaction between the properties of the materials that can ignite and burn and the characteristics of the fire environment.

The development of a fire risk within a building and the extent to which the occupants are at risk depend on the design and use of the building and various human factors. There is a considerable degree of interaction between these factors and the fire process factors.

Fire risk assessment is the discipline of predicting the expected degree of human harm or loss of property resulting from a fire. A comprehensive description of the technical background for risk assessment is given in BS EN 60695-1-1.

4.4.2 The five-step approach to fire risk assessment

4.4.2.1 General

The fire risk assessment given in the Regulatory Reform (Fire Safety) Order 2005 [19] involves the five steps discussed in 4.4.2.2 to 4.4.2.6, and is common to that taken in DSEAR [1]. A similar set of regulations will become available for Scotland and Northern Ireland.

4.4.2.2 Step 1: Identification of potential fire hazards in the workplace

Anything that can burn is a potential fire hazard, including materials of construction. Standard tests on combustible materials can provide information on such aspects of the fire hazard as:

- a) ignitability;
- b) combustibility;
- c) softening and melting;
- d) surface spread of flame;
- e) rate of heat release;
- f) rate of smoke or gas release;
- g) toxicity of combustion products;
- h) fire resistance;
- i) flame penetration; and
- j) smoke or gas penetration.

4.4.2.3 Step 2: Identification of those at risk and their location.

The locations of everyone in the workplace, including visitors, at risk if a fire occurs have to be known. Only then can the necessary measures for detection of the fire, for warnings to those at risk and for means of escape be assessed. Evacuation of people to a safe place is more important than extinguishing any fire.

4.4.2.4 Step 3: Evaluation of the risks and the adequacy of existing fire precautions

Each area of the workplace should be classified as high, medium or low risk, depending on the circumstances.

A high risk is typified by:

- the storage and use of highly flammable or explosive materials;
- a lack of fire-resisting separation;
- openings through which fire, heat and smoke can spread;
- long and complicated escape routes;
- large areas of flammable or smoke-producing areas on walls or ceilings;
- workshops where highly flammable materials are used;
- areas where naked flames are present or excessive heat is produced;
- large kitchens in canteens;
- refuse chambers and waste disposal areas;
- storage of foamed plastics or upholstered furniture;
- workers in isolated places, such as roof spaces and service tunnels; and
- the presence of large numbers of people relative to the size of the premises or a low level of assistance available in an emergency.

A medium risk is typified by:

- the likelihood of a confined fire or one that will spread slowly and thus allow people to reach safety;
- a small number of people who can easily escape without assistance; and
- an effective automatic fire-extinguishing system, suppression or containment system that reduces the risk classification from high to medium.

NOTE "Medium" is often colloquially referred to as "normal".

A low risk is typified by:

- a minimal risk to people's lives;
- a low risk of a fire occurring; and
- negligible potential for fire, heat and smoke spread.

Other factors that need to be assessed are the provision of fire detection and fire warning equipment, effective means of escape, the capabilities of the fire fighting arrangements, including their maintenance and testing, and the fire safety training of employees.

If the risk assessment shows it to be necessary, a plan for improvements to the fire precautions should be drawn up and implemented.

4.4.2.5 Step 4: Recording of the findings of Steps 1 to 3 and the actions taken

Where there are five or more employees, the employer is required to record the significant findings of the risk assessment, including the measures that have or are to be taken. Sufficient information has to be given to show that the workplace and work processes are designed, operated and maintained with due regard for safety and that, in accordance with the Provision and Use of Work Equipment Regulations 1998 [20], adequate arrangements have been made for the safe use of work equipment. An emergency plan to be implemented in the event of a fire has to be prepared, including a suitable and easy means of contacting the emergency services. Employees have to be instructed and trained in fire precautions and carrying out the plan. Individuals might need to be nominated to undertake any special roles, and employees have to be consulted about such nominations and about proposals for improving the fire precautions generally. To whom and when fire training has been given has also to be recorded in the logbook.

4.4.2.6 Step 5: Reviewing and revising the assessment when necessary

It is good practice to conduct regular reviews of the risk assessment. When circumstances change, for instance modifications to a process or use of new substances, the risk assessment should be revised.

4.4.3 Identification of combustible substances: fire hazard testing

Identification of the materials that might contribute to the fire hazard is a key stage in the risk assessment. Many solid materials, including construction products, burn.

The design of fire safety measures and their success depends strongly on how and at what rate fire is able to spread once it is initiated. Minimizing the heat release potential of a room's contents and materials of construction slows the rate of spread of fire prior to the flashover point, at which the whole room becomes involved. It is also important that the potential for the spread of fire to other parts of the building or to the outside is minimized.

The fire behaviour properties of combustible materials have to be determined either from information provided by the suppliers or from tests (Approved Document B to the Building Regulations 2000 [21,22] makes reference to the results of fire tests in its recommendations). Tests are available that measure such characteristics as ignitibility, flame spread and resistance to fire, all of which aid in quantifying the risks from a fire. Such information is only an indication of potential hazard, however, since fire behaviour in practice depends on such factors as the location of the combustible material, the configuration of the room(s) in which it is stored or used or otherwise present, and the degree of ventilation.

Correctly designed and performed fire tests can contribute valuable input data for the calculations and procedures that are part of fire engineering. Fire tests presume a particular fire scenario and it is important that test results are not used in circumstances where the test fire scenario is not applicable. Thus, the limitations of this fire scenario should be set out.

BS 6336 is an important standard for anyone concerned with fire hazard assessment or fire risk assessment. This outlines the general process of a fire hazard assessment, including the acceptability or otherwise of a fire hazard or risk and the control measures required to bring it within the limits of acceptability. It gives general information on the behaviour of fires, fire safety engineering, the assessment of fire hazard and risk, and criteria for the choice of fire tests.

NOTE Standards use the terms "fire hazard assessment" and "fire risk assessment". Although these terms can have different meanings, they are often used interchangeably.

Guidance on the use of inter-laboratory (round robin) tests for determining whether standard test methods produce repeatable and reproducible results is given in BS ISO 5725 (all parts).

Tests normally deal with only a simple representation of one aspect of the potential fire hazard and cannot alone provide any direct guidance on the behaviour of a real fire or the implications for safety in fire. A test may, however, be used for comparative purposes or to ensure the existence of a certain quality of performance considered as having a bearing on fire performance generally.

Tests for the reaction to fire and resistance to fire of building materials and structures, especially the tests in BS 476 which are often called up in product specifications for building components, and the implications of their results, are discussed in Annex N.

Following the adoption of the European system for classification and test methods, BS 476 is to be replaced by European harmonized standards. These new standards fall into two areas that concern reaction to fire and resistance to fire and are also discussed in Annex N.

The toxicity of the combustion products produced by substances involved in a fire is an important aspect of fire testing (see 4.4.6). It is often the inhalation of toxic products that leads to death of personnel rather than the effects of heat and flame. Testing methods for the toxicity of combustion products are described in Annex J.

Annexes J and N should be read together.

Standards giving advice and guidance on the fire resistance requirements of construction materials and building elements, and which often make reference to the testing standards described in Annexes J and N, are listed in Annex O.

4.4.4 Fire safety design

When fire hazards have been identified, measures have to be taken to ensure that the rate of spread of a fire is limited as much as is possible. The amount of combustible substances in an area should be kept to a minimum or, if possible, replaced by non-combustible substitutes. Combustible substances should be stored in fire-resistant stores, and waste materials that contain combustible substances should be stored safely and disposed of properly. The rate of fire spread across materials of construction should be restricted by, for example, the application of fire-resistant treatments or coverings.

Recommendations for the design of fire safety measures for premises are given in the various parts of BS 5588. These, together with other standards relating to fire precautions in buildings, are discussed in Annex P.

4.4.5 Fire safety engineering

In most of the existing building regulations, ignitability, flame spread, burning rate, smoke production and toxic-species production are controlled by what are known as reaction-to-fire and flammability classifications. These are, to a great extent, empirical and based on product performance in a specific small-scale test.

A more modern approach for prescriptive regulations is to establish a classification scheme based on small-scale tests in such a fashion that relative performance in one or more full-scale fire scenarios is replicated. If the tests are sufficiently representative of real fire scenarios, the classification system becomes more reliable than those based on performance in small-scale tests alone.

For most buildings the prescriptive recommendations on design given in BS 5588 (discussed in Annex P) might be found to be adequate, but a fire safety engineering approach that takes into account the total fire safety package could in some cases be the only viable means of achieving a satisfactory standard of fire safety in some large and complex buildings.

There are three types of fire safety engineering:

Equivalency – the equivalent level of safety to that prescribed in a code;

Deterministic – the worst credible case and safety factors;

Probabilistic – reducing the probability of an unwanted event occurring.

An introduction to fire safety engineering is given in BSI specialist handbook, *BIP 2007: Basic Guide to Fire Engineering*, 2003 [23].

The primary standards on fire safety engineering are listed in Annex Q.

4.4.6 Assessment of the toxic hazard of fire effluents

The assessment of the toxic hazard arising from fire effluents is relevant where a fire safety engineering approach is undertaken. In this the toxic effects of inhaled fire effluent on those exposed are evaluated. Fire effluents are composed of combustion products and other substances given off by the burning material.

The term toxic potency is a specific technical term in fire science. It is the measure of the amount of toxicant that elicits a specific toxic effect. This, though, is only one of the factors that determine the toxic hazard posed in any given fire scenario. The composition of the fire effluent from a given material is not an inherent property of that material, but is critically dependent on the conditions under which that material is burnt.

BS 7899-1 proposes seven steps for the assessment of risks arising from the toxic gases, smoke and heat produced in a fire.

- Step 1: Identify and define the circumstances with regard to the structure and function of the building for which the assessment is being carried out, and identify possible fire scenarios that could occur in the building;
- Step 2: Assess the probability of the occurrence of each of the scenarios identified in Step 1;
- Step 3: Describe the growth of the fire, the probability of which was identified in Steps 1 and 2, from ignition to full development; quantifying the hazard throughout the building over the passage of time in terms of the concentrations of effluents and heat;
- Step 4: Quantify the hazardous effects of exposure to effluent and heat, and estimate the time to incapacitation and death (BS 7899-2 gives the methods for the calculation of times to incapacitation and death);
- Step 5: Estimate the maximum time required for all occupants of the building to be evacuated or to reach a safe refuge;
- Step 6: Compare the time to incapacitation and death with the maximum time required for escape to determine whether action is necessary to protect occupants of the building from the particular fire scenario in question;

- Step 7: Review and report the results and, if the outcome is unsatisfactory, consider changing the design parameters and repeating the analysis.

BS 7899-1 and BS 7899-2 partially replace DD 180, which gives guidance on measures for reducing the probability of toxic combustion products being formed in significant quantities during a fire.

The toxicity of the combustion products produced by substances involved in a fire is an important aspect of fire testing. It is often the inhalation of toxic products that leads to death of personnel rather than the effects of heat and flame. Testing methods for the toxicity of combustion products are described in Annex J.

4.4.7 Fire detection and warning

Fires have to be detected as quickly as possible and the alarm given before escape for personnel becomes impossible. The function of a fire detection system is to detect fire at the earliest practicable moment, and to give signals and indications so that appropriate action can be taken. The function of a fire alarm system is to give audible and/or visible signals to occupants of the building who might be at risk from a fire. Fire detection and fire alarm functions may be combined in a single system.

Fire detection and alarm systems include systems that range from those comprising only one or two manual call points and sounders to complex networked systems that incorporate a large number of automatic fire detectors, manual call points and sounders, connected to numerous inter-communicating control and indicating panels. Also included are systems that are capable of providing signals to initiate the operation of other fire protection systems and equipment (such as fire extinguishing systems, smoke control systems or automatic door release equipment) or safety measures (such as shut down of air handling systems, closing of oil or gas valves, or grounding of lifts).

BS EN 54-1 to BS EN 54-12 specify requirements, test methods and performance criteria against which the effectiveness and reliability of the component parts of fire detection and fire alarm systems can be assessed.

BS EN 54-13 specifies requirements for compatibility and connectability assessment of system components that conform either to the requirements of BS EN 54 or to a manufacturer's specification where BS EN 54 does not apply. These include requirements:

- for the integrity of the fire detection and fire alarm system when connected to other systems;
- related to compatibility and connectability assessment methods;
- tests for the system components;
- for ensuring that components are compatible/connectable;
- related to performance.

It does not, however, specify the manner in which the system is designed, installed and used in any particular application.

NOTE BS EN 54-14 (presently 96/542172 DC) and BS EN 54-15 (presently DD CEN/TS 54-14:2004) are in preparation.

BS EN 54 applies to fire detection and fire alarm systems for buildings, but it may also be used as a basis for the assessment of components of systems for other purposes, although additional testing might be required. This series of standards does not cover the requirements for self-contained smoke alarms.

Recommendations and requirements for the planning, design, construction, commissioning and maintenance of fire detection and alarm systems are given/specified in BS 5839, which is discussed in Annex R.

BS EN 13478 provides requirements and recommendations for the integration of fire detection and alarm system into machinery.

4.4.8 Means of escape: escape routes

4.4.8.1 General

An important part of the fire risk assessment is to identify everyone who is at risk and their location. The list of those at risk should include not only works personnel but also any visitors to the workplace. If a fire occurs everyone has to be able to reach safety, and this is a more important consideration than extinguishing the fire.

It is important to know in which directions and at what rates fire, heat and smoke are likely to travel in the specific areas where fire can occur. The major principle in designing means of escape from fires is that people should not pass from an area of low fire risk through an area of high fire risk before they reach a safe area. Escape routes should present no impediment to movement, either by a narrowing of the passageways or by obstructions, and have to be clearly signposted, well lit and, as far as is practicable, kept free of fire effluents. An evaluation of evacuation times is an important aspect of the evacuation assessment.

When a fire occurs it is important that personnel know what to do, so an emergency plan might need to be drawn up and personnel trained in the performance of the instructions of the plan.

Escape routes in buildings often pass along staircases. Stairs intended to provide a means of escape in the event of fire are governed by the Building Regulations, and the following documents should be consulted: Approved Documents B and K to The Building Regulations (England and Wales) [21,24], Technical Standards E and S to The Building (Scotland) Regulations [25,26,27] and Technical Booklets E and H to The Building Regulations (Northern Ireland) [28,29,30].

Complementing the requirements of BS 5588-5, BS 5395-1, BS 5395-2 and BS 5395-3 give recommendations for the design and construction of stairs, ladders, platforms, companion-ways and walkways (including those not covered by BS EN ISO 14122, which concerns permanent means of access to machinery) which touch upon fire protection and means of escape.

Doors can be designed to prevent the passage of fire and to resist explosions, but should not impede passage along an escape route. Standards for fire- and explosion-resistant doors and their controls are listed in Annex S.

4.4.8.2 Escape and emergency lighting

Escape lighting is required to indicate clearly and unambiguously the escape routes, to allow safe movement towards and through the exits provided, and to ensure that fire alarm call points and fire fighting equipment provided along escape routes can be readily located. This safe movement depends upon the level of illumination and the visibility of hazards, changes of level and changes of direction.

The time for which escape lighting has to operate is longer than the absolute minimum time required to evacuate the premises under ideal conditions.

Furthermore, particularly in larger premises, emergency lighting that is to remain in operation after the evacuation of the building has been substantially completed might be in order, for example, to enable an adequate search of the premises to be carried out easily and quickly.

Standards for emergency lighting and luminaires are listed in Annex K.

4.4.8.3 Safety signing

Safety signs are used to provide information on the actions to be taken to prevent or reduce the risk of accidents, to warn of hazards and to give information for dealing with certain emergencies, including the identification of escape routes and the location of fire equipment. The minimum requirements for safety and/or health signs at work are set out in the Safety Signs Directive [13], which ensures that occupants, regardless of language, can understand safety messages indicated by signs. The Safety Signs Directive is implemented in UK law by the Health and Safety (Signs and Signals) Regulations 1996 [14], which set out minimum requirements for safety signs, including signs indicating escape routes.

It is essential that safety signs contain a graphical symbol; a visually perceptible figure used to transmit information independently of language. Consistency in the design of graphical symbols for use in a particular situation or in similar situations is important, as is comprehensibility. Standards for these symbols and safety signing generally are listed in Annex L.

4.4.9 Smoke and heat clearance

4.4.9.1 General

A fire can generate large quantities of combustion products, specifically hot gases carrying smoke particles and containing toxic or noxious products and irritants. Measures have to be taken to allow unimpeded escape from a fire.

4.4.9.2 Ventilation

Ventilation by natural or mechanical means can be used to limit the spread of combustion products that could otherwise hinder or prevent escape and restrict or prevent effective rescue and fire-fighting by the fire brigade. It must be borne in mind, however, that ventilation systems and ductwork can be responsible for accelerating the initial spread of fire and causing the rapid dispersion of smoke and decomposition products.

NOTE Rainwater entering through ventilation systems and coming into contact with water sensitive materials or processes can present a hazard.

The requirements for ventilation in the event of fire might, on occasion, be incompatible with those for normal ventilation. In most cases, larger flows of air or gases have to be allowed for in directions sometimes different from those required for normal ventilation. Air circulation systems can be designed to extract smoke in the event of a fire, to assist in the fire fighting operations and to introduce fresh air to pressurize escape routes.

Smoke and heat exhaust ventilators can be used in a system of safety equipment to perform a positive role in a fire emergency. Such systems create a smoke-free layer above a floor and can improve conditions sufficiently to allow the safe escape and/or rescue of people and to permit a fire to be fought while still in its early stages.

Ventilation systems for smoke removal also serve simultaneously to exhaust hot gases released by a fire in the developing stage and delay and/or prevent flashover, thereby preventing full development of the fire as well as reducing thermal effects on structural components during a fire.

Standards for smoke and heat exhaust ventilators and their components are listed in Annex T.

4.4.10 Fire fighting equipment

A key factor to be considered in the fire risk assessment is the availability of fire fighting equipment.

All premises should be provided with fire fighting equipment appropriate to the class of fires likely to be encountered. Sufficient equipment should be provided for the use of employees, and training should be given on its use. Fire fighting equipment should be correctly maintained and, if necessary, repaired, so that it is in working order at all times.

Fire extinguishing systems usually, though not invariably, comprise a series of standardized approved components, though individual systems are nevertheless designed to meet the application in hand. This is a matter for designer and manufacturer of each system.

Annex U lists standards for various types of fire-fighting equipment, but not the techniques of fire-fighting. For instance, the dangers associated with fire-fighting water run-off are not covered, although some documents that discuss this aspect of fire-fighting are listed in the further reading section of the bibliography.

Fire-fighting equipment is not used for explosion suppression measures or for dilution of explosive atmospheres.

Information on extinguishing systems is given in BIP 2003: *Fire Extinguishing Systems. A guide to the types, application and considerations* [31].

BS EN 13478 provides advice to integrate fire detection and fire fighting in the machinery. This is a B-type harmonized standard and should be applied for the safe design of machinery. It covers the essential safety requirements of the Machinery Directive [4], Annex I, item 1.5.6, for fire protection.

Annex A **European directives and United Kingdom regulations**

A.1 **General health and safety in the workplace**

The basis of European Health and Safety legislation is the Framework Directive [32]. This sets out employers' duties in regard to any hazard in the workplace. Employers' obligations are to ensure the safety and health of the workforce by taking measures to prevent occupational risks.

A risk assessment approach is laid down for identifying potential hazards and establishing a series of measures that combine prevention of risks and protection of the workforce against risks that cannot be avoided.

An important part of an employer's duties is to consult with, and instruct, inform and train, the workforce concerning potential risks.

The necessary means and organization to implement safety measures have to be provided, and personnel competent to deal with the risks appointed. Collective protective measures should always be given priority over individual protective measures.

The Framework Directive is implemented in UK law by the Management of Health and Safety at Work Regulations 1999 (The Management Regulations) [33], which are supported by an HSE Approved Code of Practice [34], and the Health and Safety (Consultation with Employees) Regulations 1996 (Consultation with Employees regulations) [35].

Other applicable UK regulations are:

- The Safety Representatives and Safety Committee Regulations 1977 [36], and
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 [37].

NOTE BS 8800, OHSAS 18001, OHSAS 18002 and HB 10180 [38] give guidance on safety management systems and are useful to employers who are setting up safety management systems.

The Health and Safety Executive has published a guidance document, "Workplace health, safety and welfare: A short guide for managers" [39]. Further information is given in "Workplace health, safety and welfare, The Workplace (Health, Safety and Welfare) Regulations 1992, Approved Code of Practice and Guidance" [40].

A.2 **Fire safety requirements in the workplace**

Every employer has to implement fire fighting and evacuation procedures adequate to the scale of any emergency that the risk assessment has indicated might occur. These emergency procedures have to be made known to the internal and the external accident emergency services.

General Fire Precautions are set out in the EU Workplace Directive [41], which lays down minimum requirements for safety and health at the workplace. These are implemented, in England and Wales, by the Regulatory Reform (Fire Safety) Order 2005 [19]. A similar set of regulations will become available for Scotland and Northern Ireland.

The Building Regulations 2000 for England and Wales, as amended [22], lay down minimum requirements to secure the health, safety and welfare of people in and around buildings. Part A requires that large buildings are sufficiently robust that an explosion does not cause excessive collapse. Part B of the Regulations considers five aspects of fire safety in the construction of buildings, which are considered in detail in one of the Approved Documents that supplement the Building Regulations: “*Approved document B: Fire safety*” [21].

This document gives practical guidance on meeting the functional requirements B1 to B5 of Schedule 1 to the Building Regulations:

- B1: covers satisfactory provision of fire alarm and a satisfactory standard of means of escape;
- B2: covers inhibition of fire spread over the internal linings of buildings;
- B3: covers the stability of buildings in the event of fire, sufficient fire separation within buildings and between adjoining buildings and inhibition of the unseen spread of fire and smoke;
- B4: covers resistance of the external walls and roofs to spread of fire over the external envelope, and restriction of spread of fire from one building to another; and
- B5: covers satisfactory access for fire appliances to buildings and the provision of facilities in buildings to assist fire fighters.

Approved Document B [21] provides guidance on the fire safety requirements for completed buildings. It does not address the risk of fire during construction work. This aspect is covered by The Construction (Health, Safety and Welfare) Regulations 1996 [42], which is supported by the HSE publications, “*Construction fire safety*” [43] and “*Fire safety in construction work*” [44].

Scotland and Northern Ireland have their own Building Regulations: the Building (Scotland) Regulations 2004 [27] and the Building Regulations (Northern Ireland) 2000 [30], respectively.

Fire precautions are required during all phases of construction work from initial installation, through any modifications and to demolition. These are enforced, depending on the situation, by a number of enforcement authorities, including the Fire Authority, the Health and Safety Executive and the Local Authority. Enforcement responsibilities depend on a variety of factors.

The Regulatory Reform (Fire Safety) Order 2005 [19] applies to the majority of workplaces.

An easy-to-read guide to a wide range of issues related to fire prevention, fire protection and fire safety management is provided by HB 10199 [45]. This includes recent changes to building regulations and associated guidance.

A number of guidance documents are being published in support of the Regulatory Reform (Fire Safety) Order 2005 [19]. These Fire Safety guides cover a range of premises with one applicable to offices and retail premises, and another to factories and warehouses.

A.3 Explosive atmospheres and dangerous substances

The ATEX 137 Directive [10], known as the User Directive, covers the duties that an employer has in minimizing the risk of an explosion in the workplace. This requires the employer to prepare an Explosion Protection Document(s) that includes identification of the explosion hazards, an evaluation of the explosion risks, and a description of the specific measures taken to safeguard the health and safety of the workers.

The User Directive is implemented in UK law by DSEAR [1].

DSEAR [1] sets out UK law for the management of fire and explosion risks arising from the use or presence of dangerous substances in the workplace. The dangerous substances include materials with explosive properties but not used for their explosive properties, oxidizing substances and flammable gases, flammable liquids and flammable dusts.

Although DSEAR [1] does not require specifically the production of an explosion protection document, the key requirement is still that risks from dangerous substances are assessed and controlled.

Several Approved Codes of Practice (ACOP) have been issued by the Health and Safety Executive to supplement DSEAR [1] and the Risk Assessment process.

- Approved Code of Practice and Guidance on Dangerous Substances and Explosive Atmospheres [46].
- Approved Code of Practice on Unloading petrol from Road Tankers [47].
- Approved Code of Practice and Guidance on Control and Mitigation Methods [48].
- Approved Code of Practice and Guidance on Storage of dangerous substances [49].
- Approved Code of Practice and Guidance on Design of Plant, Equipment and Workplaces [50].
- Approved Code of Practice and Guidance on safe maintenance, repair and cleaning procedures [51].

DSEAR [1] also implements in UK law those parts of the EU Chemical Agents Directive [52] which cover measures to prevent the occurrence of hazardous concentrations of flammable materials or hazardous quantities of chemically unstable substances, and to prevent or protect against the effects of fire and explosion.

The Chemical Agents Directive [52] covers the use or presence of hazardous chemical agents in the workplace, and, overall, the requirements are similar to those specified in the Framework Directive, but deal additionally with monitoring of exposure to chemical agents and the implementation of health surveillance procedures. An important consideration in a fire and explosion risk assessment is that toxic substances might be produced as combustion products.

When there is a danger of a large incident due to the presence of dangerous substances at a workplace, the site becomes subject to the requirements of the SEVESO II Directive [53], which imposes tighter controls than are normally applied in the workplace.

The SEVESO II Directive is implemented in UK law by the Control of Major Accident Hazards Regulations (COMAH) 1999 [12].

Sites that are designated as involving a “major hazard” risk on the basis of the flammable properties of the materials and the amounts present are subject to COMAH [12]. These regulations require that all measures necessary to prevent major accidents and to limit their extent, should they occur, be taken. A document setting out the policy with respect to the prevention of major accidents has to be prepared and stored, and the policy implemented. On-site and off-site emergency plans have to be drawn up. The dangerous substances to which DSEAR [1] applies also fall under the COMAH regulations [12].

The Institute for Systems Informatics and Safety publication guidelines on the accident prevention policy and safety management system required by the SEVESO II Directive [53].

UK Regulations applicable to major hazard sites are:

- The Dangerous Substances (Notification and Marking of Sites) Regulations 1990 [54];
- The Notification of Installations Handling Hazardous Substances (Amendment) Regulations 2002 (NIHHS) [55]; and
- The Planning (Hazardous Substances) Regulations 1992 [56], as amended by the Planning (Control of Major Accident Hazards) Regulations 1999 [57].

A.4 Supply, storage and disposal of dangerous substances and preparations

A.4.1 Classification, packaging and labelling

The requirements for classification, packaging and labelling of dangerous substances and preparations on supply are set out in European Directive 67/548/EEC [58].

The Chemicals (Hazard Information and Packaging for Supply) Regulations (CHIP) 2002 [59] require that suppliers of dangerous substances or preparations have to ensure that these are clearly marked and labelled, using accepted symbols, standard risk phrases indicating the type of hazard, and standard safety phrases indicating precautions to be taken by the user. Dangerous substances and preparations are classified into several categories and include those to which DSEAR [1] applies. CHIP [59] is supported by an Approved Classification and Labelling Guide [60].

Information on the properties of dangerous substances or preparations have to be provided for the recipient on an up-to-date safety data sheet. The content of material safety data sheets is laid down by European Directive 91/155/EEC [61] and CHIP [59].

A.4.2 Transport of dangerous substances

The transport of dangerous substances and preparations in the UK is governed by the following statutory regulations:

- The Carriage of Dangerous Goods and use of Transportable Pressure Equipment Regulations 2004 [62];
- The Merchant Shipping (Dangerous Goods and Marine Pollutants) Regulations 1990 [63]; and
- The Air Navigation (Dangerous Goods) Regulations 1994, as amended [64].

The following international treaties are also applicable:

- The United Nations (UN) Committee of Experts on the Transport of Dangerous Goods – UN Recommendations [65];
- Economic Commission for Europe Inland Transport Committee – European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) [66];
- Central Office of International Rail Transport – Regulations concerning the international carriage of dangerous goods by rail, within the terms of the Convention concerning International Carriage by Rail [67];
- The International Maritime Organization – International Maritime Dangerous Goods Code [68];
- The International Civil Aviation Organization – Technical Instructions for the Safe Transport of Dangerous Goods by Air [69]; and
- The International Air Transport Association – Dangerous Goods Regulations [70].

A.4.3 Storage of dangerous substances

Sites holding 25 tonnes or more of dangerous substances are required by the Dangerous Substances (Notification and Marking of Sites) Regulations 1990 [71] to be notified to the local fire authority and the enforcing authority (the Health and Safety Executive or local authority).

Sites already notified under the Planning (Hazardous Substances) Regulations 1992 [72] or COMAH [12] are exempt.

The Planning (Hazardous Substances) Regulations [72] cover facilities where controlled hazardous substances are stored, manufactured, processed, transferred or used.

The regulations issued under the Petroleum (Consolidation) Act (PCA) 1928 [73] formerly required a licence for the storage of significant quantities of petroleum spirit or mixtures containing petroleum spirit with a flash point of less than 21 °C. However, the need for licensing under this Act at most large scale storage sites has been removed following the introduction of the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) [1, 46]. In relation to the workplace, licensing under PCA is now only required at premises where petrol is stored and dispensed (as defined by DSEAR) into the fuel tank of a vehicle (which might be a ship, a boat or an aeroplane), fitted with an internal combustion engine. The PCA [73], and legislation derived from it, continues to apply at all domestic and other non-workplace premises that keep more than 15 litres of petroleum-spirit.

The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 [74], which previously set out the storage requirements for flammable liquids of low flash point, have been replaced by DSEAR [1]. Guidance on storage of these materials is given in the DSEAR ACoP *Storage of Dangerous Substances* [49].

A.4.4 Disposal of dangerous substances

The Special Waste Regulations 1996 [75] set down the law relating to consignment notes and coding for wastes from organic chemical processes and wastes from organic substances employed as solvents, among other substances. The hazardous properties of special waste are as defined in Schedule 2, Part II, to these regulations, and include explosive, oxidizing, highly flammable and flammable substances.

Anyone who produces, imports, carries, keeps, treats or disposes of special waste is subject to the Environmental Protection (Duty of Care) Regulations 1991 [76].

These regulations impose responsibilities on the producer or importer of waste to ensure that no offences are committed during the process of disposing of a waste and that the waste is disposed of in an appropriate manner. The legal requirements of the duty of care have to be met through contracts with waste management contractors.

A.5 Product legislation

A.5.1 General

A number of basic directives contain requirements for general product safety and liability in the event of a defective product, but there are others that apply specifically fire and explosion hazards.

A.5.2 Product legislation where fire and explosion hazards exist

A.5.2.1 Machinery and equipment

The legal requirements for ensuring the safety of machinery, including the avoidance of fire and explosion hazards, are set down in the Machinery Directive [4].

The Machinery Directive requires that any risk of accident throughout the foreseeable lifetime of the machinery, including the phases of assembly and dismantling, have to be eliminated, even when the risks arise from foreseeable abnormal situations.

The European Commission has published a guide to the implementation of the Machinery Directive [77], as has the DTI [78,79].

NOTE Requirements for the marking of machinery are specified in BS EN 61310-1 and BS EN 61310-2.

The Machinery Directive [4] is implemented in UK law by The Supply of Machinery (Safety) Regulations 1992, as amended [80], which require that machinery is designed and constructed to avoid all risk of fire or overheating and any risk of explosion posed by the machinery itself or by gases, liquids, dust, vapours or other substances produced or used by the machinery. The same precautions have to be taken if the manufacturer of the machinery foresees the use of the machinery in a potentially explosive atmosphere.

Items intended for use in potentially explosive atmospheres are identified by the symbol in Figure 2.

Figure 2 **ATEX logo indicating that equipment is suitable for use in explosive atmospheres**



The minimum safety and health requirements for the use of work equipment by workers at work are laid down in the Work Equipment Directive [81], which requires that all work equipment has to be appropriate for preventing the risk of explosion of the work equipment or of substances produced, used or stored in the work equipment.

The Work Equipment Directive [81] is implemented in UK law by the Provision and Use of Work Equipment Regulations (PUWER) 1998 [82].

The legal requirements for equipment and protective systems intended for use in potentially explosive atmospheres are given in ATEX 100A Equipment Directive [83]. Guidelines for this Directive have been issued by the European Commission [84] and the DTI [85].

The ATEX Equipment 100A Directive [83] is implemented in the UK by the Equipment and Protective Systems for Use in Potentially Explosive Atmospheres (EPS) Regulations, 1996, as amended [86].

These regulations also cover controlling devices and regulating devices intended for use outside the explosive atmosphere but required for, or contributing to, the safe functioning of equipment or protective systems with respect to the risk of explosions.

Both electrical and non-electrical (mechanical) equipment is covered by these regulations. The various ways of demonstrating conformity to the requirements of the Directive are prescribed. Not only has the product itself to conform to the essential health and safety requirements but so also has the production process.

Requirements for establishing and maintaining a quality system in accordance with the requirements of the ATEX Equipment 100A Directive [83] are specified in BS EN 13980.

A.5.2.2 Pressure equipment

When flammable liquids or gases are kept under pressure, failure of the containment might lead to a flammable pool or an explosive atmosphere with consequent dangers of fires and/or explosions. The essential requirements for the design and manufacture of “equipment subjected to high pressure” or “pressure equipment” are set out in the Pressure Equipment Directive (PED) [87].

The PED [87] assigns to equipment one of four risk categories, plus one category of sound engineering practice, depending on the amount of stored energy and the hazard presented by a contained fluid. The larger the volume and the higher the pressure, the greater the risk.

The PED [87] is implemented in UK law by the Pressure Equipment Regulations 1999 (PER) [88], as amended. The DTI has published a Guidance Note on these Regulations [89].

In order to classify pressure equipment into one of the four conformity assessment categories established in the PED [87] and PER [88], the type of equipment, the state of the fluid contents and the fluid group have to be known. The Group 1 fluids are fluids that would fall under the descriptions of dangerous substances in DSEAR [1].

Although the legal requirements for the safe design and construction of pressurized equipment are normally covered by the Pressure Equipment Regulations 1999 (PER) [88], as amended, there are some exceptions. In some cases where the PER do not apply, the design and manufacturing requirements of the equipment may be covered by the Pressure Systems Safety Regulations 2000 (PSSR) [90], as amended.

The installation and subsequent use of pressure equipment, including maintenance and examination, are normally covered by the PSSR [90] or, where PSSR does not apply, the more general provisions of the Provision and Use of Work Equipment Regulations 1998 [20].

PSSR [90] is complemented by an Approved Code of Practice published by the HSE [91].

Pressure equipment approved for the inland transport of equipment containing gas by road or rail is covered by the Transportable Pressure Equipment Directive (TPED) [92].

A.5.2.3 Construction products

Fire safety in buildings depends on the fire properties of the construction products. The essential requirements relating to “materials intended for construction” are set out in the Construction Products Directive (CPD) [93]. Materials intended for construction are defined in the Directive as those products that are manufactured to form a permanent part of structures.

This Directive regulates construction products but does not directly regulate construction works. In practice, though, it exercises through its requirements a tight control on the regulations that might be applied to construction practice and works. This is because the essential requirements of the CPD [93] do not refer to the construction products themselves but to the construction works in which the product will be incorporated. In other words, products must have such characteristics that the works in which they are to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy the essential requirements contained in the directive.

There are six essential requirements with which construction works have to conform, the second of which is "*Safety in case of fire*". The CPD [93] differs from other "New Approach" directives in that only European harmonized standards or European technical approvals (ETA) can provide proof of conformity with the essential requirements. Direct compliance with the essential requirements is not possible.

The European Commission has produced a number of Interpretative Documents that give concrete form to these essential requirements. The second of the Interpretative Documents, ID2 [94], identifies products or product families and characteristics relating to their satisfactory performance, and provides the basis for verification that the "*Safety in case of fire*" essential requirement has been satisfied. ID2 [94] is concerned with similar requirements to those in Approved Document B [21] of the Building Regulations for England and Wales [22].

The CPD [93] is implemented in UK law by the Construction Products Regulations 1991 [95].

Annex B Identification of dangerous substances

B.1 General

Classes of dangerous substances are listed in the United Nations Classification Recommendation on Transport of Dangerous Goods (see ADR [66]), and are listed in Table B.1.

Table B.1 UN Classification of Dangerous Substances

Class	Sub-class	Definition
1		Explosives
	1.1	Substances and articles which have a mass explosion hazard
	1.2	Substances and articles which have a projection hazard but not a mass explosion hazard
	1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard, but not a mass explosion hazard
	1.4	Substances and articles which present no significant hazard
	1.5	Very insensitive substances which have a mass explosion hazard
	1.6	Extremely insensitive articles which do not have a mass explosion hazard
2		Gases
	2.1	Flammable gases
	2.2	Non-flammable, non-toxic gases
	2.3	Toxic gases
3		Flammable liquids
4		Flammable solids
	4.1	Flammable solids
	4.2	Substances liable to spontaneous combustion
	4.3	Substances which in contact with water emit flammable gases
5		Oxidizing substances; organic peroxides
	5.1	Oxidizing substances
	5.2	Organic peroxides
6		Poisonous (=toxic) substances
	6.1	Toxic substances
	6.2	Infectious substances
7		Radioactive material
8		Corrosive substances
9		Miscellaneous dangerous substances

B.2 The DSEAR definition of dangerous substances

The definition of “dangerous substance” in the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) [1] is:

- a) a substance or preparation that meets the criteria in the *Approved Guide to the Classification and Labelling of Dangerous Substances and Dangerous Preparations* [96] for classification as a substance or preparation which is explosive, oxidizing, extremely flammable, highly flammable or flammable, whether or not that substance or preparation, is classified under the Chemicals (Hazard Information and Packaging for Supply) Regulations 2002 (CHIP) [59],
- b) a substance or preparation which, because of its physico-chemical or chemical properties and the way it is used or is present at the workplace, creates a risk, not being a substance or preparation falling within a),
- c) any dust, whether in the form of solid particles or fibrous materials or otherwise, that can form an explosive mixture with air or an explosive atmosphere, not being a substance or preparation falling within a) and b).

DSEAR [1] covers materials with explosive properties used in the workplace for reasons other than their explosive properties.

B.3 Flammable liquids

B.3.1 General

Explosive atmospheres of a vapour with air do not form above a flammable liquid unless the liquid is at or above the flashpoint. The flashpoint is relevant only when vapour alone is above the liquid surface. Mists, aerosols and foams of flammable liquids are formed by means other than evaporation and can ignite at temperatures below the flashpoint.

The flashpoint is used to classify flammable liquids and indicates the maximum temperature at which a liquid can safely be stored. It is used to:

- a) determine whether or not a flammable vapour exists in the ullage space of a vessel; and
- b) indicate whether the handling of the liquid falls within the scope of regulations for flammable liquids.

Classification of a substance or preparation according to the value of the flashpoint is given in the CHIP regulations [59]:

- Flammable liquids
Substances and preparations having a flashpoint equal to or greater than 21 °C and less than or equal to 55 °C supporting combustion.
- Highly flammable liquids
 - i) Substances and preparations that might become hot and finally catch fire in contact with air at ambient temperature without any input of energy. Substances that have a flashpoint lower than 55 °C and which remain liquid under pressure, where particular processing conditions, such as high pressure or high temperature, can create major accident hazards.
 - ii) Substances and preparations having a flashpoint lower than 21 °C and which are not extremely flammable.
- Extremely flammable gases and liquids
 - i) Liquid substances and preparations that have a flashpoint lower than 0 °C and the boiling point (or, in the case of a boiling range, the initial boiling point) of which at normal pressure is less than or equal to 35 °C.
 - ii) Gaseous substances and preparations that are flammable in contact with air at ambient temperature and pressure, whether or not kept in the gaseous or liquid state under pressure, excluding liquefied extremely flammable gases (including liquefied petroleum gas) and natural gas.
 - iii) Flammable liquid substances and preparations maintained at a temperature above their boiling point.

UK legislation that requires flashpoint information for its application includes:

- The Chemicals (Hazard Information and Packaging for Supply) Regulations 2002 (CHIP) [59];
- The Carriage of Dangerous Goods (Classification, Packaging and Labelling) and Use of Transportable Pressure Receptacles Regulations 1996 [97];
- The Notification of New Substances Regulations 1993 [98];
- The Dangerous Substances and Explosive Atmospheres Regulations, 2002 [1]; and
- The Control of Major Accident Hazards Regulations 1999 [99].

B.3.2 Measurement of the flashpoint

There are several standard tests for measuring flashpoints. The most appropriate test depends on the flammable liquid to be tested and its intended use. The flashpoint is not a fundamental property of a liquid, and when measurements are reported the test method has to be identified.

When flashpoint data are being used to assess the flammability of a vapour space a safety margin should be applied. Typical values of the safety margin are 4 – 9 °C.

“Closed cup” tests are designed to simulate the conditions in the ullage space of a tank. “Open cup” tests are designed to simulate conditions during handling of liquid and its use in the field.

Guidance on the appropriate method to be used and the interpretation of the measurements is given in:

- BS EN ISO 1516 (Method of test for petroleum and its products. Determination of flash/no flash. Closed cup equilibrium method);
- BS EN ISO 1523 (Method of test for petroleum and its products. Determination of flashpoint. Closed cup equilibrium method);
- BS EN ISO 2592 (Determination of flash and fire points. Cleveland open cup method);
- BS EN ISO 13736 (Petroleum products and other liquids. Determination of flashpoint. Abel closed cup method);
- BS EN ISO 2719 (Methods of test for petroleum and its products. Determination of flashpoint. Pensky-Martens closed cup method);
- BS EN ISO 3679 (Determination of flashpoint. Rapid equilibrium closed cup method);
- BS 3900-A8, BS 6664-1, ISO 1516 [Methods of test for paints. Tests on liquid paints (excluding chemical tests). Test for flash/no flash (closed cup equilibrium method)];
- BS 3900-A9, BS 6664-2, ISO 1523 [Methods of test for paints. Determination of flashpoint (closed cup equilibrium method)];
- BS EN ISO 3680 (Determination of flash/no flash. Rapid equilibrium closed cup method);
- BS 3900-A11 [Methods of test for paints. Tests on liquid paints (excluding chemical tests). Small scale test for combustibility];
- BS 2000-35 (Methods of test for petroleum and its products. Determination of open flash and fire point. Pensky-Martens method);
- ASTM E502-84 (Standard Test Method for Selection and Use of ASTM Standards for the Determination of Flash Point of Chemicals by Closed Cup Methods) [100];
- IP 170/75 (Flash point by the Abel apparatus) [101];
- IP 303/83 (Determination of closed flash point. Mini equilibrium method) [102];
- NFPA 30 (Flammable and Combustible Liquids Code) [103]; and
- ISO/TC 28, “Joint TC 28-TC 35 WG: Flashpoint methods. Technical Report: Guidance on the determination of flashpoints and the interpretation of results” (to be published) [104].

HSE Guidance Note CS24: “*The interpretation and use of flashpoint information*” [105] describes the purposes for which flashpoint measurements are carried out, and discusses the variety of tests available in standards and the interpretation of the measurements.

B.3.3 Interpretation of the measurements

Flashpoint determinations are described as equilibrium or non-equilibrium methods, depending on the way in which the temperature of the liquid is raised during the test. In some tests the temperature can be ramped slowly, with the igniting flame introduced at intervals until a flash is seen. The vapour space might then not be at the same temperature as the liquid and the vapour/air mixture might not be saturated. This type of test is a non-equilibrium method.

Alternatively, the temperature is stepped to a given value and sufficient time then allowed for the vapour space to reach essentially the same temperature as the liquid. This type of test is an equilibrium method. A third option is to use a method that employs a smaller sample of liquid and that can be performed more rapidly than the equilibrium methods. This type of test is a rapid equilibrium method.

Generally, the value of a flashpoint increases in the order equilibrium method < rapid equilibrium < non-equilibrium. Comparisons show that the Abel closed cup method usually gives the lowest flashpoints, with other methods giving slightly higher values to the extent shown in Table B.2.

Table B.2 Comparisons of flashpoints from different test methods [105]

Test apparatus	Open/closed	Average comparative range °C (all ranges are approximate)
Abel	Closed	–
Setaflash	Closed	0 to 6.9 higher
Tag	Closed	0.5 to 5 higher
Pensky-Martens	Closed	1.7 lower to 6 higher
Abel-Pensky	Closed	0.2 lower to 1.4 higher
Luchaire-Finances	Semi-open	5.1 to 15.6 higher
Tag	Open	6.4 to 16.1 higher
Cleveland	Open	11.7 to 26.1 higher

Some materials might, for various reasons, not inflame in a conventional flashpoint apparatus. The vapour's quenching distance may be large, and so a flame cannot begin to propagate. The vapour might burn, however, when the vessel is larger. Other materials give dense vapours that stay close to the liquid surface and are not ignited by the flame. Others have a narrow explosion range.

The flashpoint is not the lowest temperature at which the liquid evolves vapour. If a liquid is used relatively close to the flashpoint, say 5 to 10 °C below, it is possible that in practice ignition might occur at temperatures below the flashpoint.

In this case, the potential hazard might better be defined by the explosion limits or the temperature limit of flammability, the minimum temperature at which vapours in equilibrium with a liquid are sufficiently concentrated to form explosive mixtures in air at atmospheric pressure. A test for measuring the temperature limit of flammability is given in ASTM E-1232-02 [106]. This test was devised because there are some materials above which the atmosphere might be explosive even though a flashpoint cannot be measured. A spherical 5 litre glass vessel, as described in ASTM E-681-04 [107], is used as the test vessel. Its design improves the chances of propagation when the vapour concentration is low.

The temperature limit of flammability test can be used as part of a fire and explosion risk assessment, but it is not a replacement for flashpoint determinations applied for regulatory purposes.

NOTE Some solids may exhibit a flashpoint, either because the flashpoint is less than the melting point of the solid or the solid contains some residual solvent.

Continued heating of a liquid above the flash point temperature eventually leads to the “fire point”, which is defined as the minimum temperature at which vapour is produced at a sufficient rate to sustain combustion. The sustained flame usually lasts longer than four seconds. Standard tests for the measurement of the fire point are given in ASTM D1310-01 [108] and ASTM D4206-96 [109].

The flashpoint of a liquid is not the same as the auto-ignition temperature, and the two properties are unrelated. The flashpoint indicates the temperature at which the vapour can be ignited by an external source. The auto-ignition temperature reflects ignition without the input of additional energy. Table B.3 gives data from PD IEC 60079-20 that demonstrate the differences between the flashpoint and the auto-ignition temperature.

Table B.3 **Comparisons of flashpoint and auto-ignition temperatures**

Flammable Material	Flashpoint °C	Auto Ignition Temperature °C
Carbon disulfide	–30	95
Diethyl ether	–45	160
Toluene	14	535
Decane	46	201

B.4 Flammable dusts: Assessment of the fire and explosion hazard

B.4.1 General

Tests are available that assess the likelihood that a dust will contribute to a fire or generate an explosive atmosphere if dispersed in air. These tests do not measure any quantifiable characteristic but identify flammable dusts that might then require further testing as part of the risk assessment.

B.4.2 Burning behaviour of flammable dusts

The burning behaviour of a dust accumulation is measured in the Train Firing Test, the result of which allots a dust to a combustion class (CC) [110]. The combustion class is a measure of the ignitability of a dust layer and the intensity of burning.

This classification is based on the behaviour of a defined dust heap when subjected to a gas flame or hot platinum wire:

- CC1 No ignition; no self-sustained combustion,
- CC2 Short ignition and quick extinguishing; local combustion of short duration,
- CC3 Local burning or glowing without spreading; local sustained combustion but no propagation,
- CC4 Spreading of a glowing fire; propagation smouldering combustion,
- CC5 Spreading of an open fire; propagating open flame, and
- CC6 Explosible burning; explosive combustion.

B.4.3 Explosive atmospheres of dusts: identification of hazardous dusts

B.4.3.1 General

Although the vast majority of the dusts encountered in the powder handling industries are composed of a flammable material there are many factors, such as particle size, that have an effect on their ignitability and explosibility. It is usual to test a sample of dust from the process to assess whether it constitutes an explosion hazard.

A sequence of tests is accepted in the UK for identifying flammable dusts, but they are not described in a British standard.

B.4.3.2 Ambient conditions

To identify flammable dusts at atmospheric pressure and room temperature, a 1.2 litre vertical tube apparatus, similar to the Hartmann apparatus described in ASTM E789-95 [111], is used. In the UK, an open tube made of Pyrex is used.

A known quantity of dust is placed at the bottom of the tube in a specially designed receptacle and is then dispersed by a blast of air around an ignition source that is either a spark or a hot coil. The amount of dust is varied in a series of tests so that a wide range of potentially explosive dust concentrations in air representing a credible explosion range is produced.

If any of the dust dispersions ignites, the dust is classified as Group A: flammable; otherwise the dust is classified as Group B: non-flammable.

As in all tests for determining ignition and explosion characteristics of dusts, the dust sample should be consistent with the finest dust in the process, but if this is not known a sample passing a 63 μm sieve may be used. The sample has also to be consistent with the driest material in the process, but if this is not known the sample can be dried to constant weight at 50 °C under vacuum or 75 °C at atmospheric pressure.

This test is sufficient to classify the dust at normal temperatures and pressures. If, however, process temperatures are above normal room temperature, the test is not a sufficient guide to a dust's potential flammability. Dusts classified as Group B: non-flammable in the vertical tube test might be flammable at process temperatures.

B.4.3.3 Elevated temperature

The Godbert-Greenwald furnace can be used to test whether a Group B dust is flammable when the surroundings are at an elevated temperature. This apparatus is described in BS EN 50281-2-1.

This furnace test can be modified to provide a more realistic situation by positioning a localized ignition source – a continuous spark, for instance – inside the furnace tube. The air in the tube can be heated to the required temperature before the dust is dispersed. The likelihood of an ignition can then be tested at the process temperature. Accurate measurements of the temperature are necessary if the result is to be applied to known process conditions.

B.4.3.4 Alternative tests

The above sequence of tests and the Group A /Group B classification is rarely, if ever, used outside the UK. Elsewhere in Europe an alternative sequence of tests using a Modified Hartmann Apparatus (a 1.2 litre vertical tube with a hinged cover [112]) and either a 1 m³ vessel or a 20 litre sphere is usually performed [113].

This simple test is a useful screening procedure. The ignition source is either a continuous spark or a hot coil. The dust is identified as flammable at room conditions if either a visible flame is seen or the instrumentation indicates the hinged cover has opened.

If tests using the Modified Hartmann Apparatus give no indication that the dust is flammable, further tests are carried out in either the 1m³ vessel or the 20 litre sphere apparatus. These tests can be used without prior screening in the Modified Hartmann Apparatus.

Some models of the 20 litre sphere can be operated at elevated temperatures and pressures and so dust flammability can be assessed at conditions other than room conditions in this test.

For testing of atmospheres in which both flammable gases and dusts are present, expert advice should be sought.

Annex C Hazardous areas: Zoning procedures

C.1 General

Classification of hazardous areas into zones is based essentially on the frequency, extent and persistence of a potentially explosive atmosphere.

The definitions of the zones used in DSEAR [1] are:

Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Zone 1

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Zone 20

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously or for long periods or frequently.

Zone 21

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Under DSEAR [1], areas where there is a risk of an explosive atmosphere occurring have to be indicated, where necessary, by the sign in Figure 3.

Figure 3 Warning sign for areas where explosive atmospheres may occur

