BS 5908-2:2012

BSI Standards Publication

Fire and explosion precautions at premises handling flammable gases, liquids and dusts —

Part 2: Guide to applicable standards and regulations

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Publishing and copyright information

Published by BSI Standards Limited 2012

ISBN 978 0 580 77877 3

ICS 13.220.20; 71.020

The following BSI references relate to the work on this standard:
Committee reference EXL/23
Draft for comment 12/30258581 DC

Publication history

First published as PD 6686, March 2006
First published as BS 5908-2, December 2012

Amendments issued since publication

Date	Text affected

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 5908 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2012. It was prepared by Technical Committee EXL/23, *Explosion and fire precautions in industrial and chemical plant.* A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This Part of BS 5908 supersedes PD 6686:2006, which is withdrawn.

Relationship with other publications

This Part of BS 5908 is intended to be read in conjunction with BS 5908-1.

Information about this document

BS 5908-2 constitutes a full revision of what was the content of PD 6686:2006, *Guidance on directives, regulations and standards related to prevention of fire and explosion in the process industries*.

As a guide, this Part of BS 5908 takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

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

Compliance with a British Standard cannot confer immunity from legal obligations.

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1 Scope

This part of BS 5908 gives guidance on the legislation and standards applicable to onshore industrial premises that handle significant quantities of flammable gases, liquids or dusts. It identifies the different strands of legislation that apply to those who supply, transport, store, or use such materials, and those who supply plant and equipment for any of these activities, and provides a guide to relevant standards so that suppliers and users of products that create fire and explosion hazards can identify which might be relevant to their activities.

This part of BS 5908 does not cover offshore oil and gas production or coal or other mining activities, and only references legislation and standards relevant to the distribution and supply of natural gas where these are also relevant to other activities.

Legislation and standards relevant to the storage and use of liquid fuels and liquefied petroleum gas (LPG) are, however, covered, as in many cases these are also relevant to chemicals with similar hazards which are not specifically used as fuels.

The development of a hydrogen economy, with hydrogen either stored at very high pressure or in liquid form, is at an early stage of development, and this area is also out of scope of this British Standard.

NOTE There is, though, considerable activity within ISO in developing standards on hydrogen applications.

Chemical processes might create fire and explosion hazards that are different from those arising from the chemicals used in the process. The methods associated with assessing those hazards are not in general suitable for standardization as they are too specific to the individual process. The issue of chemical reaction hazards is considered in BS 5908-1.

Some flammable liquids used in pressurized systems, such as hydraulic oils, can form flammable mists from small leaks in hosing or pipework. This scenario is covered in the discussion of the legislation and standards applicable to this situation.

2 Terms and definitions

For the purposes of this British Standard the following terms and definitions apply.

NOTE Definitions are compiled for ATEX standards, except in respect of electrical equipment in BS EN 13237. For electrical equipment intended for use in potentially explosive atmospheres, definitions are provided in BS EN 60079-0. Some terms are set out in the ATEX Equipment Directive 94/9/EC [1].

2.1 equipment

machines, apparatus, fixed or mobile devices, control components and instrumentation thereof and detection, or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy or the processing of material, and which are capable of causing an explosion through their own potential sources of ignition

NOTE This definition effectively excludes items which have no power source or moving parts. The ATEX guidelines [2] give examples of "borderline cases" showing how this is intended to be applied. Hand-operated valves, tanks and hand tools are therefore not within scope.

2.2 explosive atmosphere
mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture

2.3 potentially explosive atmosphere
atmosphere which could become explosive due to local and operational conditions

NOTE These definitions exclude conditions commonly found in chemical plant, where the system operates under conditions well removed from normal atmospheric temperature and pressure, or the air is excluded and an inert atmosphere is present. The DSEAR Regulations [3, 4], however, require an assessment of the hazards from dangerous substances, in whatever form they might be present. This recognizes that not all explosion hazards can be avoided by correct selection of ATEX equipment. Moreover, it is not practical or necessary to expect manufacturers to design ATEX equipment to be safe under any possible conditions that may occur in a process plant.

2.4 protective systems
design units which are intended to halt incipient explosions immediately and/or to limit the effective range of explosion flames and explosion pressures

NOTE 1 Protective systems may be integrated into equipment or separately placed on the market for use as autonomous systems.

NOTE 2 This definition recognizes that the protective system, perhaps a flame arrester or explosion vent panel, could be made and sold by a manufacturer different from that which supplied the equipment requiring the system. It implies that it needs to be acceptable to sell equipment that is only safe if it is subsequently fitted by the user or installer with a protective system from another supplier.

3 Legislative background and the relationship with standards

3.1 Introduction

Fire and explosion hazards exist wherever dangerous substances or combustible substances are stored, transported, processed or used. Legal requirements are imposed on employers to ensure the safety of workers and others by minimizing the risk of fires and explosions.

Many sites in the chemical and energy sectors have comparatively few employees and are situated away from centres of population. Any fire or explosion might therefore have a low risk of causing death or injury at such sites, but employers still need to prevent incidents which can cause damage to equipment, loss of raw materials or products and, ultimately, a real threat to the viability of their businesses. Accordingly, any package of protective measures should address the risks to both people and property.

3.2 European legislation

Much European legislation is aimed at ensuring the effective operation of a single market. To achieve this, the legislation specifies what is meant by “safe” for a vast range of products: from the comparatively simple, like a fire extinguisher, to the most complex of machines, such as a rotary printing press employing highly flammable gravure inks. National governments can then be satisfied that any such products are safe and can be sold within their countries. The provisions of European Directives are implemented by national legislation in all European Union (EU) member states, e.g. statutory regulations in the UK.

The EU has developed worker protection legislation, which has as an objective, first, to ensure a reasonable minimum level of safety in the workplace, and, second, to prevent migration of manufacturing industry across the EU, to places where safety standards are poor. Again, these Directives have been implemented in the UK by statutory regulations.

3.3 UK legislation

Traditionally, fire safety legislation as it applied to those in control of buildings in the UK was seen as separate from health and safety, and was very fragmented. The EU influence drew no such distinction, and the current UK fire safety legislation [5, 6, 7, 8, 9] (see Clause **5**) essentially implements general EU health and safety legislation as it applies to fire hazards in a broad range of premises.

NOTE Almost all of this legislation has been separately implemented in Northern Ireland. Where necessary this can be obtained from the UK office of public sector information at www.opsi.gov.uk

Fire hazards are also covered by the Building Act and Regulations [10, 11, 12, 13, 14]. The provisions are not uniform across the UK, with differences between England and Wales, Scotland and Northern Ireland, but the equipment and products used in buildings are subject to EU single market legislation, so, for example, a fire door as a stand-alone item or a fire alarm sounder still has to conform to European regulations and standards.

3.4 Relationship between legislation and standards

It is impractical to write into legislation all the technical details that relate to safety and, to a large extent, this work has been taken up by standards making bodies, such as ISO, CEN/CENELEC and BSI.

It is also impractical for those in charge of premises in the process industries to check every detail of equipment they buy. For them, standards supply a route to ensuring that the equipment they procure is safe for the intended purpose. It is expected that this document will help users locate appropriate standards when purchasing equipment, and also when installing and operating it. It should also be useful to manufacturers of equipment, particularly where there are standards that supply different levels of technical detail or where there is no very specific standard that applies to their products.

4 European directives and harmonized standards

4.1 Introduction

European directives containing provisions relevant to fire and explosion safety of products include the Machinery Directive [15], the ATEX Equipment Directive [1], the Pressure Equipment Directive [16] and the Construction Products Directive [17]. These directives contain high-level requirements, and CEN/CENELEC have provided detailed technical standards for meeting these.

Normally, these European Standards are “harmonized”, which means formally adopted by the EU as meeting the requirements of the relevant directives. If a product meets the requirements of the applicable standard, there is an automatic presumption that it meets the corresponding directive. The official lists of harmonized standards are on the EU commission main website: http://ec.europa.eu/enterprise/mobile/topics/policies/european-standards/harmonised-standards-legislation/index_en.htm

Some products fall outside the scope of particular standards. In these cases, manufacturers have to work to the less specific requirements of the directives.

4.2 Conformity assessment

Conformity assessment is the system by which a manufacturer demonstrates that they have applied the applicable standard(s) in designing and manufacturing a product, giving the user confidence that the product meets the legal requirements. At its simplest, the manufacturer draws up a "declaration of conformity" which lists standards used in the design, and fixes a "CE mark" to the equipment, which is a legal claim of conformity to all the relevant directives. In support of this there has to be a technical file, collecting together all the relevant design details, supporting tests and records, but this is not routinely available to the customer.

For the equipment that creates the highest risks, the design, testing and quality assurance during manufacture require independent input from a specialist test house. These are designated by member states as being competent to make independent judgments as to whether a product conforms to the essential requirements of a directive(s), and are notified to the EU commission. They are then "notified bodies". Some are notified only for a single directive, others for more than one. There are different systems for ensuring adequate quality, depending on whether many identical products are made (series manufacture) or the products are made in very small numbers so that each individual unit can be fully tested.

Under ATEX [1] (see **4.4**), an additional process not applicable to other directives is in place for products with an intermediate level of risk. Here, a technical file is lodged with a notified body prior to products being sold, but the notified body is not responsible for its contents.

4.3 Machinery Directive [15]

The Machinery Directive [15] is implemented in the UK by the Supply of Machinery (Safety) Regulations 2008 [18]. The definition of machinery is very broad and includes essentially anything that has moving parts and a source of power. In respect of fire and explosion hazards, the Machinery Directive [15] requirements are very simple: "machines must be designed to avoid any risk of fire, overheating or explosions caused by the substances produced or used by the machine". Depending on the hazards, some machines might also require built-in fire extinguishing systems.

A very large number of standards are needed to cover the requirements for all types of machinery covered by this Directive, and, in order to achieve a consistent format, these have been written at three levels.

- Type A standards describe general principles and deal with basic methodology and philosophy. There are comparatively few Type A standards, the most important example being BS EN ISO 12100.
- Type B standards deal with one safety aspect, or one type of safety device. These can be used across a wide range of machinery, and are normally cross-referenced in Type C standards. Type B standards particularly relevant to fire and explosion hazards are BS EN 1127-1 and BS EN 13478.
- A Type C standard specifies detailed safety requirements for one type of machine, or group of machines, normally covering all the relevant aspects from the Directive.

The manufacturer of machinery is generally responsible for ensuring their product meets the safety requirements. This is achieved by drawing up a technical file, which is not normally supplied to the customer, applying the CE mark to the machine itself, and a declaration of conformity, which has to be passed to the customer.

4.4 ATEX Equipment Directive [1]

4.4.1 Equipment covered by the Directive

The ATEX Equipment Directive [1] applies to equipment and protective systems intended for use in potentially explosive atmospheres, and is implemented in the UK by the Equipment and Protective Systems for Use in Potentially Explosive Atmospheres Regulations [19, 20]. The Directive [1] covers a large range of specially-designed electrical equipment, for which standards have been developed over the last 50 years, mechanical equipment that creates a potential ignition source, where no standards existed before 1994, and the items of equipment that comprise one of various types of protective system, using the techniques outlined in BS EN 1127-1. These include flame arrestors, explosion vent panels, explosion suppression systems and explosion isolation devices, as used in dust-handling plants (see **6.9**).

Many ATEX products are also machines, and in these cases the more specific requirements of ATEX are taken to demonstrate conformity with the high-level requirements of the Machinery Directive [15].

The ATEX Equipment Directive [1] introduced a comparatively complex system of conformity assessment, with products categorized according to intended use.

- Category 1: products intended for use where the risk of explosion is highest require independent (third party) conformity assessment by a notified body.
- Category 2: electrical products intended for use where a medium level of risk exists also have to be assessed by a notified body. Mechanical equipment does not require independent assessment, but a technical file has to be lodged with a notified body.
- Category 3: products used where there is a low risk of explosion do not require the involvement of a notified body, and the manufacturer issues their own declaration of conformity.

In each case ATEX equipment has to be provided with the CE mark, the mark of explosion protection (see Figure 1), and a declaration of conformity supplied to the customer.

Explosion protective systems are not subdivided into categories, and all require independent certification by a notified body.

Figure 1 **Mark of explosion protection**

In addition, as many aspects of explosion protection require some measurement of material properties, many test methods for such properties have been adopted as European standards. Prior to ATEX [1], the electrical equipment standards published by the IEC also required test methods for materials, and these have been published as IEC standards (see **6.7**).

For electrical goods intended for use in potentially explosive atmospheres that are sold outside the European market, an international scheme of independent conformity assessment, known as the IEC Ex scheme, has been established. Adoption by a manufacturer is voluntary, but the scheme is steadily increasing. Standards for electrical equipment intended for use in potentially explosive atmospheres are now almost all international in origin, adopted as European standards and harmonized by the EU Commission.

Standards for ATEX mechanical equipment have been written over the last ten years at European level, and harmonized. These are now being transferred to the international level, and will in due course appear as parts of ISO 80079.

4.4.2 Protective systems

The ATEX Directive [1] also covers protective systems, some of which, like explosion vent panels, are clearly products that can be tested in their own right, while others, like suppression systems, are sold as an "add on" package for other equipment, or a section of a process. The former are subject to mandatory independent conformity assessment, similar to Category 1 equipment (see **4.4.1**). The standard for suppression systems, BS EN 14373, cannot give the individual design checks for every application, and only indicates how parts of a suppression system can be separately assessed and sets out common design tools.

4.5 Construction Products Directive [17]

The definition of a construction product includes anything intended for permanent incorporation into a building or structure, but not a complete building. The Construction Products Directive (CPD) [17] sets out essential performance requirements under six broad headings, one of which is safety in case of fire.

It has proved a slow process to harmonize standards for many aspects of construction products, and the process is incomplete. Alongside formal European standards, European Technical Approvals are issued by independent test houses (notified bodies), and many British Standards remain current.

Because the CPD [17] has proved difficult to implement, it has been repealed by the Construction Products Regulation (305/2011) [21]. This has a transition period up to July 2013, but it sets out the conditions for CE marking which demonstrates that construction products have been assessed against a harmonized European standard and can be accepted onto the market anywhere in the European Economic Area (EEA). One of the consequences is that a wider range of products will be CE-marked in future. The Regulation is directly applicable to the UK, and does not therefore need to be implemented by national statutory regulations.

Relevant areas covered by harmonized standards include components for fire detection and fire alarm systems (BS EN 54), space heating equipment (BS EN 416 and BS EN 777), fixed firefighting systems (BS EN 12094), smoke and heat control systems (BS EN 12101), sprinkler systems (BS EN 12259) and tank overfill prevention devices (BS EN 13616).

Alongside harmonized standards, there are Eurocodes which set out common design principles for various structures, but allow individual countries to incorporate their own values of particular parameters. Of relevance is BS EN 1991-4, which gives recommendations for the protection of silos from dust explosions.

4.6 Pressure Equipment Directive [16]

Many flammable products are stored or processed in closed systems that operate at pressures above atmospheric. The Pressure Equipment Directive [16] applies to systems operating at pressures above 0.5 bar, and related safety accessories, with some complex exemptions. The system of conformity assessment is graded according to the risk, in this case operating pressure and size or volume of the equipment and the intended contents. The Directive is implemented in the UK by the Pressure Equipment Regulations [22].

Many fire extinguishers are covered by this Directive.

5 UK legislation

5.1 Health and safety

The Health and Safety at Work etc. Act 1974 [23] sets out the general responsibilities of employers, employees and those who supply products and substances used at work. It also established the Health and Safety Executive (HSE) to enforce its requirements. In Northern Ireland the equivalent requirements are found in the Health and Safety at Work (Northern Ireland) Order 1978 [24].

The explicit requirement for a risk assessment of work activities is set out in the Management of Health and Safety at Work Regulations 1999 [25] (and the Management of Health and Safety at Work (Northern Ireland) Regulations 2000 [26]), which implement the EU Framework Directive [27]. The Framework Directive [27] makes no distinction between fire and any other type of workplace hazard, and includes requirements for the evacuation of premises and contact with emergency services that were traditionally enforced in the UK by the fire services.

Fire hazards controlled by "process fire precautions" are enforced by the HSE. These are largely covered by DSEAR [3, 4] (see **5.3**).

5.2 Fire safety legislation [5, 6, 7, 8, 9]

In England and Wales, the Regulatory Reform (Fire Safety) Order [5] implements in part the requirements of the Framework Directive [27] and requires a risk assessment to be carried out by the employer (and others deemed the "responsible person") to determine the necessary preventive and protective measures to safeguard people from fire. However, the assessment has to cover not only employees, but all who might be lawfully present on the premises. In many situations the main risk is not just to employees. The equivalent legislation elsewhere in the UK is the Fire (Scotland) Act 2005 [6], the Fire Safety (Scotland) Regulations 2006 [7], the Fire Safety (Northern Ireland) Regulations 2010 [8] and the Fire and Rescue Services (Northern Ireland) Order 2006 [9].

For industrial premises, this legislation applies not only to buildings, but also other places where there might be a fire hazard, e.g. from storage of high fire hazard products in a tank farm or open-air drum store.

Particular requirements relate to means of escape, fire alarm systems, provision of hand-held fire extinguishers, emergency lighting, provision of fire safety information, and training on the actions required in case of fire. Enforcement is by the fire services, with the following exceptions.

Premises	Enforcement body
Construction sites not part of some larger premises	HSE
Military premises	Ministry of Defence fire services
Other crown premises	Fire inspector appointed by the government or one of the devolved administrations

The fire safety legislation is referenced in BS 9999, a comprehensive code of practice for fire safety in the design, management and use of buildings. Much of this is targeted at premises very different from industrial buildings, where the numbers of people are low and no sleeping accommodation is provided, but it does include advice specifically relevant to means of escape from process plant buildings and open-air structures (Annex F), and hot work (Annex U). It does not, however, cover the circumstances in which flammable materials can give rise to a risk of explosion and the issues that surround the preparation of process plant ahead of hot work.

5.3 DSEAR [3, 4]

5.3.1 General

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [3] draw their requirements from two separate directives (Chemical Agents Directive [28] and ATEX 137 [29]), and in consequence contain provisions based on a risk assessment approach and others which are more prescriptive. These set minimum requirements, some of which are relatively specific, for the protection of workers from fire and explosion hazards arising from the presence of dangerous substances and potentially explosive atmospheres in the work place. For Northern Ireland the equivalent provisions are set out in the Dangerous Substances and Explosive Atmospheres Regulations (Northern Ireland) 2003 [4].

The employer is required to carry out an assessment of the risks arising from the presence of dangerous substances on site, and adopt measures to control those risks.

DSEAR [3, 4] requires control measures to be adopted in the following order of priority.

- Reduce the quantities of dangerous substances present.
- Avoid or minimize the release of a dangerous substance (D-S).
- Control any release of D-S at source.
- Prevention the formation of an explosive atmosphere.
- Collect and remove any D-S that is released.
- Avoid ignition sources.
- Segregate incompatible D-S.

Specific requirements of DSEAR [3, 4] include the following.

- Identification of any hazardous areas where explosive atmospheres might be present and their division into zones according to the probability that an explosive atmosphere is present (see **5.3.3**).

- Selection of equipment to be located within a hazardous area from the categories set out in the ATEX Directive [1] according to the following.

	Zone 0	Zone 1	Zone 2
Equipment category	1	1 or 2	1,2 or 3
Category number is followed by G, D or G,D for gas, dust or atmospheres containing both			

- Assessment of the explosion safety measures by a competent person before any new equipment or process is brought into use.
- Marking of access points into hazardous areas with an Ex sign where necessary.
- Marking of containers and pipes holding or carrying hazardous materials to indicate their contents.
- Provision of information and training to employees about the hazardous materials present in the workplace.
- Procedures to deal with accidents, incidents and emergencies arising from the presence of dangerous substances.

The HSE has published Approved Codes of Practice and Guidance to the Regulations, e.g. L133, L134, L135, L136, L137 and L138 [30, 31, 32, 33, 34, 35].

5.3.2 Explosion hazards

Fire hazards can occur where flammable gases, liquids or dusts are present, but explosion hazards might also occur and these need to be considered.

Explosions can be the consequence of:

a) heating of a closed container that is not provided with protection;

b) ignition of a gas/air, vapour/air or mist/air mixture inside a closed system;

c) ignition of a dense suspension of dust in air inside a closed system, usually requiring an internal means of creating and maintaining the dust cloud; and

d) a chemical reaction inside a closed system which generates large volumes of gas.

Explosions that occur outside an enclosed or semi-enclosed system are possible, but generally much larger quantities of materials are required, and not all flammable materials create this risk.

Closed containers take many forms, for example pressurized gas cylinders, sealed drums for flammable liquids, silos for storing powders, chemical process vessels, complete buildings, or rooms within a building and combustion plant. Systems do not have to be completely closed; risk arises from any sudden release of gas or energy that produces a rapid pressure rise causing the enclosure to fail.

Some explosion hazards can only be controlled by protecting the system from external fire (see **6.6**).

Dust explosions are controlled by special technical measures described in **6.7.5**.

Particular examples of protection against explosions in other process plant are given in **6.4.2**.

5.3.3 Hazardous areas

The development of equipment designed to be safe in the presence of an explosive atmosphere necessitates a methodology for determining what type of equipment is appropriate for particular locations.

The requirement for a hazardous area classification study long predates specific legislation, but the definitions of hazardous areas for gases, liquids and dusts are now set out in DSEAR [3, 4].

For gases and vapours:

- **Zone 0** is an area in which an explosive atmosphere is present for long periods, or frequently, e.g. above the liquid level of a container used for highly flammable liquids, or inside some enclosed processes.
- **Zone 1** is an area in which an explosive atmosphere can form in normal operation, e.g. where highly flammable liquids are poured from one container to another, or very close to the nozzle of a spray gun.
- **Zone 2** is an area in which explosive atmospheres are not likely to occur in normal operation and, if they do occur, persist for a short period only, e.g. where perhaps a spillage is possible, or controls on some item of equipment are faulty, provided in both cases that the problem is detected reasonably promptly.

For dusts:

- **Zone 20** is an area in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously for long periods or frequently. This is only likely to occur inside the containment system for the process, and might not apply where dust is stored for long periods but the activities which create a cloud occur only infrequently.
- **Zone 21** is an area in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally. This is normally inside the containment system for a dusty product, but could exist locally to a transfer point where dust is tipped in a system which is not completely enclosed from one container to another.
- **Zone 22** is an area in which an explosive atmosphere is not likely to occur in normal operation, but if it does occur persists for short periods only.

Layers, deposits and heaps of dust should be treated as any other source which can form an explosive atmosphere. Effectively, this requires assessment of the risk that a dust layer that might exist regularly can be raised into a cloud that is dense enough to create an explosion risk.

BS EN 60079-10-1 sets out a methodology for assigning hazardous areas where gases and vapours are present, and BS EN 60079-10-2 does the same for dusts. These standards offer relatively high-level guidance, and more detailed codes for particular industries are discussed in BS 5908-1.

5.3.4 Self-heating

DSEAR [3, 4] also covers the fire hazards that arise due to spontaneous combustion of materials, i.e. where there is no external source of ignition. This occurs with certain materials when they are either stored for long periods in bulk, such as in a silo or large store, or used in smaller quantities but at relatively high temperatures. BS EN 15188 details the material test method and how the test results can be applied to full-scale scenarios on the site to enable safe storage and operating parameters to be set, e.g. safe ambient temperatures, volumes and storage times. The requirement to assess the risks from self-heating also falls under the fire safety legislation [5, 6, 7, 8, 9] (see also **6.4.2**).

Materials liable to undergo self-heating that require transport need to be tested under the *Recommendations on the Transport of Dangerous Goods: Model Regulations* (Volumes 1 and 2) [36]. Substances liable to self-heating are classed as Division 4.2 substances and different packing groups apply depending on the test results of the material that restrict the package volumes that can be used (see also **6.3**).

5.3.5 Personal protective equipment

Personal protective equipment of many kinds is used to protect individuals from exposure to chemicals, by direct contact or inhalation. Clothing has been developed that provides some protection from fire, either because it is non-combustible, difficult to ignite, not prone to absorb liquids, or provides some degree of thermal insulation. This is commonly used by firefighters, but is not generally required by those working with flammable chemicals, and its adoption is the last of the protective measures listed in DSEAR [3, 4].

Clothing for protection against spatter (small splashes of molten metal), short contact time with flame, radiant heat from arc, and electrical shock by short-term, accidental contact with live electrical conductors in normal conditions of welding and allied processes is specified in BS EN ISO 11611. Such clothing might also be of benefit where grinding of metals is regularly carried out.

See **6.7.3** for antistatic PPE.

5.4 Provision and Use of Work Equipment Regulations 1998 [37]

The Provision and Use of Work Equipment Regulations [37] impose a general obligation on employers to provide equipment for use at work that is fit for the intended purpose, properly maintained and, where necessary, periodically inspected.

A specific requirement of these Regulations is that the equipment has to conform to the requirements of any applicable product directive. This, however, is not applicable retrospectively, so that old machines, pressure vessels or ATEX equipment can be used indefinitely, provided they are "fit for purpose".

5.5 Health and Safety (Safety Signs and Signals) Regulations 1996 [38]

The identification of fire exits, location of fire equipment, places of assembly and other information needed to help ensure safety in case of fire are specified by the fire safety legislation [5, 6, 7, 8, 9]. DSEAR [3, 4] extends these by specifying the use of an Ex sign to mark hazardous areas, where this is necessary, and the distinctive marking of pipelines carrying hazardous products (e.g. gas or a flammable liquid). Provisions for signs and their designs are set out in the Health and Safety (Safety Signs and Signals) Regulations 1996 [38]. More detailed recommendations for their use are given in the various parts of BS 5499. Requirements for the actual signs, including performance and durability, are specified in ISO 17398, BS ISO 7010 and ISO 3864-4.

6 Assessment of fire and explosion hazards

6.1 Locations of special fire hazard

Any risk assessment under DSEAR [3, 4] or the fire safety legislation [5, 6, 7, 8, 9] should identify places of special fire hazard. This term, however, is defined in a rather restricted way in *Approved Document B to the Buildings Regulations for England and Wales* [39] as "oil-filled transformer or switch gear rooms, boiler rooms, storage space for fuel or other highly flammable substances, and rooms housing a fixed internal combustion engine". The Northern Ireland equivalent to Approved Document B is issued by the Northern Ireland Department of Finance and Personal as Technical Booklet E [13] supporting the Building Regulations (Northern Ireland) 2012 [14]. This includes in the definition of a place with a special fire hazard laboratories, technical rooms with open heat sources and stores for chemicals. The Scottish definition of a place with a special fire risk, given in Section 2 of the Scottish Technical Standards [40] in support of the Building (Scotland) Regulations 2004 [12], includes also paint spray booths and rooms where other flammable liquid is used.

For places in which chemicals are used or stored and which have a range of hazards, this concept needs to be extended. In such sites, often the first material ignited is not one of the chemicals, but rather packaging, waste materials or an item of equipment that has overheated. If the fire then threatens stored chemical products the risk to individuals can rise quickly. Toxic products could be released, closed containers or process equipment can release flammable liquids or gases, causing a sudden increase in fire size, or control might be lost over chemical processes.

Typical examples of places with high or special hazard include a location:

a) that has been classed as a hazardous area for the purposes of DSEAR [3, 4];

b) where a small fire could lead quickly to an explosion;

c) where fire could be expected to grow particularly quickly, so that the means of escape need to allow for this;

d) in which a process uses open flames or elevated temperatures, and the materials handled or present could ignite at these temperatures;

e) with a particularly high fire load; and

f) where a small fire could cause the escape of highly toxic products, the release into the environment of environmentally damaging chemicals, or bursting containers to be ejected from the site of the fire.

6.2 Toxic hazards of fire effluents

In most building fires, danger to the occupants arises primarily from the toxicity of carbon monoxide (CO) and hydrogen cyanide (HCN), and from irritating acid gases and smoke, which obscures escape routes and contains a reasonably predictable range of other toxic components. BS EN 60695-7 gives guidance on the factors which affect the toxic hazard from fires involving electrotechnical products, and provides information on methodologies for estimating and reducing the toxic hazard from fires. BS ISO 13344 provides a means for estimating the lethal toxic potency of the fire effluents produced from a material exposed to a physical fire model. BS 7899-1 and BS 7988-2 give guidance and recommendations for assessing hazards from smoke and its normal components.

Where chemicals and other dangerous products are stored in quantity, a wider range of hazards are created by a fire, and BS 7899 becomes difficult to apply. Some chemicals are volatile and toxic, and create an immediate danger if released by fire. Less volatile chemicals might be dispersed in the convection currents from a fire. Other materials decompose to produce different toxic products. Very often, the burning material comprises more than one chemical product so that a very large number of chemicals can be detected in the smoke. The complexity of this problem means there is very little published information to help with the assessment of risks from chemical products released by a fire into the air and the wider environment.

In addition, chemicals might be released into the ground or nearby water courses as the result of a fire. The risks might then be mainly to the environment, rather than people nearby.

6.3 Classification of chemicals with fire hazards

The Dangerous Substances Directive [41] and the Dangerous Preparations Directive [42] specify the classification, labelling, packaging and supply of information for chemicals and chemical preparations.

These directives are to be superseded by the European REACH Regulation [43], which come fully into force in 2015. The test methods used for classification under REACH [43] are listed in European Regulation 440/2008 [44], which in turn cross-references various standards.

Separate legislation drawn up by the UN (*Recommendations on the Transport of Dangerous Goods: Model Regulations* [36] and the Globally Harmonized System of Classification and Labelling of Goods [45]) applies to the international transport of dangerous goods. Consequently, many chemical businesses have had to classify and mark their products separately for transport and supply. These rules use a system of classification that is separate and different from the supply legislation. This too requires test methods for both the materials and containers. Test methods for the materials are not published as standards, but are provided in the UN manual of test and criteria published by the UNECE (see http://www.unece.org/trans/danger/publi/manual/rev5/manrev5-files_e.html).

The transport of dangerous goods by road, rail, sea or air requires the use of approved packaging. Test methods for most types of packaging of dangerous goods are set out in ISO 16104, and ISO 16467 for intermediate bulks containers (IBCs).

With test methods for material properties published separately for international transport and European supply, in support of ATEX requirements and IEC standards for electrical equipment, care has to be taken when using tabulated data to ensure that the source is understood. Generally, the results are sensitive to both the apparatus used and the test protocol.

6.4 Determining the characteristics of materials

6.4.1 Gases, liquids and vapours

6.4.1.1 Safety data sheets

Suppliers of hazardous materials, including flammable liquids, are required to provide safety data sheets containing information specified by the Chemicals (Hazard Information and Packaging for Supply) Regulations (CHIP) 2002 [46] and European Directive 91/155/EEC [47].

This includes methods for fighting fires (suitable media and any special hazards, such as reaction with water), melting point, boiling point, flash point, explosive limits, auto-ignition temperature, solubility in water, and packaging requirements for transport and gas group (relevant to ATEX equipment specifications).

Gas and vapour explosion limits may be determined by the methods specified in BS EN 1839, while BS EN 15967 specifies a test method for measuring the maximum explosion pressure and maximum rate of pressure rise (though the values in practice are very strongly dependent on the geometry and size of the system and so have limited application).

BS EN 14756 sets out a method of determining the limiting oxygen content, the maximum concentration of oxygen in a mixture at which an explosion cannot occur at any fuel concentration.

A test for the auto-ignition temperature of a flammable gas or vapour is set out in BS EN 14522. The values in practical applications depend strongly on the scale of the equipment, whether the vapour is inside a closed vessel, or makes contact with an external hot surface, the contact time, and other factors.

The lower and upper explosion points (LEP/UEP) of a flammable liquid can be determined in accordance with BS EN 15794. The LEP is typically lower than the closed cup flash point (see **6.4.1.2**).

Methods for determining the auto-ignition temperature and assigning a gas group are given in BS EN 60079-20-1, along with tabulated values for a large range of products.

6.4.1.2 Flash points

The flash point is the lowest temperature at which a substance gives off sufficient vapours to form a flammable mixture with air on contact with a flame or spark. The lower a liquid's flash point, the greater the risk of fire. There are numerous flash point tests, which are categorized as "closed cup", i.e. inside a container, or "open cup" (near the surface of the liquid) and are further divided into isothermal tests and tests using steadily increasing temperatures (equilibrium and non equilibrium methods). Isothermal tests take far longer to complete. Examples include:

- BS EN ISO 13736: Abel closed cup;
- BS EN ISO 3679: rapid equilibrium closed cup method;
- BS EN ISO 2592: Cleveland open cup;
- BS EN ISO 2719: Pensky-Martens closed cup.

The flash point in isolation gives limited information about the hazards of handling different products, where these contain only a small proportion of volatile flammable solvent (such as paints or adhesives), or chemically degrade on prolonged storage at elevated temperatures (e.g. bitumen), or where evaporation of trace amounts of water may mask a flash point that is well above 100 °C.

6.4.2 Dusts

Many dusts, such as sawdust, foodstuffs and agricultural products, are not classed as dangerous for transport or supply, and fall outside the regulations discussed in **6.3**. Nevertheless, an explosion can occur if a dust cloud is ignited.

Test methods for dusts have been developed over many years, and are now largely provided by European standards, such as:

- BS EN 13821: Determination of minimum ignition energy;
- BS EN 14034-1: Determination of the maximum explosion pressure (pmax);

- BS EN 14034-2: Determination of maximum rate of explosion pressure rise (dP/dt);

  NOTE Parts 1 and 2 are to be merged.

- BS EN 14034-3: Determination of lower explosion limit;
- BS EN 14034-4: Determination of limiting oxygen concentration.

The test for determining spontaneous ignition behaviour set out in BS EN 15188 involves loosely filling mesh wire baskets of varying volumes with dust samples. These are heated in an oven at constant temperature. By repeating the tests at different oven temperatures, the onset temperature for self-heating at much larger scale storage can be estimated. A similar test is described in the REACH Regulation [44] A16, *Self ignition temperature for flammable solids*. This uses a single sample size and a ramped oven temperature to provide what is in effect a screening test for self heating substances.

BS EN 50281-2-1 specifies a hot plate test using a 5 mm thick dust layer held at a constant temperature. The test is repeated at different temperatures until ignition or decomposition occurs. The standard recognizes the value of testing other layer thicknesses as the layer thickness effects the ignition temperature. In addition, this standard also specifies the test method for measuring the ignition temperature of a dust cloud in contact with a hot surface using the Godbert Greenwald apparatus.

6.4.3 Flammable solids

The hazards associated with some types of high fire risk solids are recognized by the classification systems for transport of dangerous goods, but are also included in the classification system under REACH [43].

These include materials that:

a) self-ignite from contact with air at ambient temperature;

b) spread burning across a horizontal surface at a high rate;

c) evolve flammable gases when in contact with water;

d) self-heat, leading to combustion over an extended time when kept in bulk;

e) ignite readily through friction.

A general difficulty with the classification tests used for flammable solids is that the ease of ignition, rate of burning and hence the fire hazard depends strongly on the physical form of the product.

For example, many products manufactured as true explosives burn quickly, but not explosively, if spread as a thin layer and then ignited. Foamed plastics burn far more rapidly than the same material cast into a block.

If the fire hazards of flammable solids need to be assessed, it is often necessary to devise non-standard tests for such materials, which mimic the conditions in which they are to be stored or used. The HSE’s third scale room/corridor test for assessing the fire hazard associated with materials stored in bulk in warehouses is given in HSE Contract Research Report, *The use of small scale fire test data for the hazard assessment of bulk materials* [48].

Many solid materials used in buildings are required to be fire tested to meet the requirements of the UK Building Regulations. The appropriate national and European tests for different building components are specified in guidance supporting the Building Regulations, such as Approved Document B for England and Wales [39].

6.5 Loss of containment

NOTE Liquids can be released by either failure of the tank itself or by overfilling.

6.5.1 Detection of leaks

Leak detection systems initiate a visual or audible alarm, or automatic shutdown, when a leak of gas or liquid is detected. Such equipment could be exposed to an explosive atmosphere, and might need to be assessed as ATEX equipment in respect of ignition hazards, or it might be a protective system under ATEX [1].

BS EN 13160 specifies requirements for the following classes of leak detection systems.

- Class I: Detect a leak above or below the liquid level in a double-skin system. They are inherently safe and detect a leak before any liquid can enter the environment (i.e. pressure or vacuum systems).
- Class II: Detect a leak above or below the liquid level in a double-skin system with the possibility of the leak detection liquid leaking into the environment (i.e. liquid monitoring system).
- Class III: Detect a leak below the liquid level in a tank or in a pipework system, using liquid and/or vapour sensors located in leakage containment or interstitial space.
- Class IV: Detect, to specific levels of probability, specified rates of change of tank contents (i. e. leakages into or out of the tank), with a strong possibility that product will enter the environment in the event of a leak.
- Class IV A: Dynamic leak detection systems also indicate leaks in the connected pipework.
- Class IV B: Static tank gauge leak detection systems or statistical quiet period leak detection systems only indicate leaks from a tank.
- Class V: Detect liquid loss in tanks or pipes below the liquid level, with product entering the environment before the leak is detected (i.e. sensors in monitoring wells).

Release of fuel oil from high-pressure pipework is a common risk in marine engine rooms, and equipment is available to detect any oil mist that is formed. BS ISO 16437 specifies requirements for such oil mist detectors.

BS EN 1593 describes methods for detecting leaks by bubble emission.

6.5.2 Overfill protection

Loss of containment is also possible by overfilling tanks.

BS EN 13922 specifies requirements for overfill prevention systems for tanks for the transport of dangerous goods.

6.6 Controlling hazards

6.6.1 Explosive atmospheres inside process plant

Many types of process plant are designed to avoid the formation of a substantial volume of explosive atmosphere inside, thereby excluding the possibility of certain types of explosion.

Where this is not possible, some standards set out the necessary precautions.

Safety requirements for dryers and ovens, in which flammable solvents are released, are specified by BS EN 1539. These are often associated with batch or continuous coating processes, like printing or spray painting.

Thermal oxidizers are often associated with processes that evaporate large quantities of solvents of the types covered in BS EN 1539. Thermal oxidizers are effectively a form of combustion process with special features, and the relevant standard is BS EN 12753.

BS EN 12921-3 specifies requirements for machines using flammable solvents to clean or pretreat industrial items.

Documents about grain processing machines, including grinding machines, have been written for the Machinery Directive [15], but none have become harmonized ATEX standards. BS EN 14958 specifies requirements, including measures against fire and explosion hazards, for machinery for grinding and processing flour, and contains some informative recommendations for evaluating and controlling explosion hazards.

6.6.2 Inerting

Many chemical processes and storage facilities operate in fully enclosed plant, in which the risk of fire or explosion can be prevented by displacement of oxygen by an inert gas to a concentration below which no explosion can occur. Complete displacement of oxygen is not normally necessary. BS EN 14034-4 specifies a test method for determining the limiting oxygen concentration of dust clouds in a closed vessel under defined initial conditions of pressure and temperature. The level at which oxygen content needs to be maintained to prevent an explosion depends in part on the inert gas used, most commonly nitrogen or carbon dioxide.

Guidance on various methods of inerting is provided in PD CEN/TR 15281.

6.7 Ignition sources

6.7.1 Identification of potential sources

Any assessment of the risk of fire or explosion needs to consider all potential sources of ignition. Some hazards arise from particular products, the equipment, and sources of external energy, while others occur because flammable material is present as a fuel. Some exist continuously, while others regularly but intermittently and still others only very infrequently, but all need to be evaluated and controlled.

BS EN 1127-1 provides a list of possible sources, which may form the starting point for an assessment.

- Hot surfaces.
- Flames and hot gases (including hot particles).
- Mechanically-generated sparks.
- Electrical apparatus.
- Stray electric currents, including cathodic corrosion protection systems.
- Static electricity.
- Lightning.
- Radio frequency waves (sparks induced by absorbed radiation).
- Electromagnetic radiation (hot surfaces created by absorbed radiation).
- Ionizing radiation.
- Ultrasonic energy.
- Adiabatic compression.
- Exothermic reactions, including self-heating products.

6.7.2 Electrical equipment gases and vapours

BS EN 60079-0 specifies a large range of general requirements for electrical equipment for use in potentially explosive atmospheres. It also explains the system of temperature rating and different technical methods of making such equipment, described as protection concepts. The IEC now adopts a system of explosion protection levels, which parallel but differ from the classification in the ATEX Equipment Directive [1] (see Table 1).

Table 1 **Explosion protection categories: IEC and ATEX**

IEC equipment protection level	ATEX category
Ga	1G
Gb	2G
Gc	3G
Da	1D
Db	2D
Dc	3D

The IEC marking scheme has extended the equipment group set out in the ATEX Directive [1]. ATEX recognizes only two equipment groups, group I for mining equipment and group II for above ground applications. IEC describes equipment designed for dust explosive atmospheres as group III. The dust equipment is further subdivided into groups IIIA, IIIB and IIIC to allow for dust with different ignition hazards.

Since much equipment sold in Europe is also manufactured, certified and marked to the IEC scheme, many items of electrical equipment carry both sets of marking.

The following are the recognized protection concepts.

- Flameproof “d” (BS EN 60079-1).
- Pressurized enclosure “p” (BS EN 60079-2).
- Powder filling “q” (BS EN 60079-5).
- Increased safety “e” (BS EN 60079-7).
- Intrinsic safety “ia” and “ib” (BS EN 60079-11).
- Type “n” (limited to ATEX category 3, explosion protection level Gc) (BS EN 60079-15).
- Encapsulation “m” (BS EN 60079-18).

In addition, BS EN 60079-14 specifies the design, selection and installation of electrical equipment in hazardous areas associated with explosive atmospheres, and BS EN 60079-19 covers repair of EX equipment.

6.7.3 Electrostatic ignition hazards

Static electricity can be generated in many types of process equipment. The characteristics of the charging mechanism, the risks that are present and the precautions required depend on whether the flammable material is present as a gas, liquid, vapour or dust. If sufficient charge accumulates, and suddenly discharges where a flammable atmosphere is present, it could cause ignition. Some materials are more sensitive than others to small sparks, and the precautions required depend in part on the minimum ignition energy of the flammable substance. Dusts in general are less sensitive than vapours or gases to ignition, but some types of solid explosives are among the most sensitive products handled commercially.

The precautions required to control the risks depend in part on the equipment manufacturer, but also on the user. TR 50404 takes a broad look across the topic, highlighting the different ways in which a static discharge can occur, and how different mechanisms produce sparks of greater or smaller energy, and hence have a different potential to cause ignition. It gives recommendations to both equipment manufacturers and users. These do not cover the high risks associated with some sensitive explosive materials, or the risks in manufacture of electronic devices that can be destroyed by static discharges.

Requirements for the construction, testing and marking of electrical equipment and Ex components intended for use in explosive atmospheres are specified in BS EN 60079-0. Requirements for avoiding electrostatic charges in mechanical equipment are specified in BS EN 13463-1. These relate to the maximum area of non-conductive surface on relevant equipment.

Antistatic footwear is often recommended, but this term is not defined. To prevent ignition risks from static, dissipative properties as described in BS EN 61340-4-3 are required. Dissipative footwear should be combined with suitable flooring. BS EN 61340-4-1 specifies tests for laboratory measurements on new samples of floor coverings and installed floors, which demonstrate whether an operator wearing dissipative footwear could become sufficiently charged to generate an incendive discharge.

Flexible intermediate bulks containers (FIBC) or "big bags" are widely used for the storage and transport of bulk powders or granular products. Where the product in a bag creates a risk of static formation, or where the bag is to be filled or emptied in a hazardous area, antistatic bags are required. BS EN 61340-4-4 specifies procedures for evaluating the ignition risk presented by electrostatic discharges from FIBC to flammable or explosive environments. It covers four grades of bag, which offer different levels of protection when used in a hazardous area.

Requirements for drive belts used in power transmission systems, including a test for electrical resistance, are specified in BS 3790, with further requirements in BS EN 13463-5.

Requirements for antistatic properties of belts used in belt conveyors are specified in BS EN 12882.

6.7.4 Electrical equipment in dust atmospheres

European standards for electrical equipment for use in potentially explosive dust atmospheres have been renumbered as they have been converted to IEC documents. As they are revised, the new editions are being included in the IEC 60079 series. Consequently, the following list can be expected to change.

- BS EN 60079-0 specifies requirements for electrical equipment intended for use in explosive atmospheres, including explosive dust atmospheres.
- BS EN 61241-4 specifies requirements for electrical apparatus for use in combustible dust atmospheres with type of protection "pD".
- BS EN 61241-11 specifies requirements for electrical apparatus for use in combustible dust atmospheres with type of protection "iD".
- BS EN 61241-14 specifies requirements for the selection and installation of electrical apparatus for use in combustible dust atmospheres.
- BS EN 60079-31 specifies dust ignition protection by enclosure "t".

The BS EN 61241 series does not make use of the concept of explosion protection level, which is effectively a different terminology for the ATEX equipment categories. This is to change as the standards are revised.

6.7.5 Mechanical equipment

ATEX [1] brought in new legal requirements for mechanical equipment that creates an ignition risk, where this is intended to be used in a hazardous area. This makes sense given the statistics for sources of ignition in process equipment, but it also creates difficulties. Comparatively little mechanical equipment runs hot enough on the outside during normal operation to create an ignition risk, but a wide range of such equipment can generate hot surfaces very quickly in fault conditions.

Experiments show that mechanical sparks produced by repeated impact between a moving and a fixed part are actually remarkably inefficient as an ignition source, compared with electrical sparks, but they cannot be ignored. Dust explosions nearly always start inside the process, where there are very often moving parts capable of causing an ignition risk in fault conditions that cannot be entirely eliminated. It is not possible to make high-powered grinding plant free from the risk of creating an ignition risk, unless air is excluded.

The approach taken by the standards writers was to produce a single series of standards for gas, vapours and dusts for mining and non-mining applications. The basic standard, BS EN 13463-1, specifies not only a framework for the assessment of the risks, but also requirements for achieving ATEX category 3.

Further parts of BS EN 13463 specify requirements for ATEX category 2 equipment with protection concept letters similar to those used for electrical equipment. Of these, the most widely used are BS EN 13463-5, protection by constructional safety “c”; BS EN 13463-6, protection by control of ignition sources “b”; and BS EN 13463-8, protection by liquid immersion “k”.

Requirements for internal combustion engines intended for use in potentially explosive atmospheres are specified by BS EN 1834-1 (gases and vapours) and BS EN 1834-3 (dust atmospheres). Lift trucks, widely used in hazardous areas, are covered by the requirements of BS EN 1755. Requirements for fans intended to be used in potentially explosive atmospheres are specified in BS EN 14986.

Development of mechanical standards for specific types of equipment has been limited.

6.7.6 Other ignition sources

Lightning is a very powerful energy source, with the potential to damage buildings, equipment and control systems, as well as initiate fires. Tall structures are more vulnerable to lightning strikes, but many types of building and open-air plant require lightning protection. Lightning is one of the most common causes of fires on floating roof tanks. BS EN 62305-1 describes the general principles of lightning protection.

High-energy radio transmitters radiate significant amounts of power, and large metal structures, such as pipe runs in the open air, can act as aerials. Under particular circumstances, mainly where long wavelength radio transmitters are present, this can generate electrical potentials in the metalwork, creating the risk of a spark if something else at a different potential is brought close to the charged structure. A methodology for assessing such risk, and the necessary precautions for mitigating such risk, are described in BS 6656 and PD/CLC TR 50427.

Some types of ignition hazard may be eliminated by correct selection of equipment, but other sources of ignition require an understanding of the risks and control measures to be introduced by the site operator/user. A particular example is the control of ignition hazards from static electricity. Static can be formed wherever materials are moved, and the amount of charge that can collect, and the risk that this charge will form an incendive discharge, depend on whether the static can form and collect within gases, liquids, dusts or other solid surfaces

Detailed advice on the nature of the ignition hazard arising from static electricity, and how it can be controlled, is given in PD CLC/TR 50404. Precautions for controlling static that are implemented by the user, and not the supplier, of equipment include limitations on pumping speeds, and making earth connections between a vehicle or container before product transfer.

The Petroleum Spirit (Plastic Containers) Regulations 1982 [49] specify a maximum capacity for a container of 5 litres, to control the electrostatic ignition hazard, but without defining any performance tests.

Some products generate heat by reacting slowly with oxygen, or by the action of microorganisms. These processes can lead to self-ignition where there is sufficient bulk at extended storage times, or where the material is above ambient temperature when bulked. A method for determining self-ignition temperature for combustible dusts and granular materials is specified in BS EN 15188.

6.8 Control systems

Much modern process plant depends on automatic control systems to maintain temperature and pressures within its design range, and hence ensure the integrity of the containment system. Control systems may also control the sequence of a process, and so prevent unintended mixtures of air and fuel or other reactive compositions forming inside the process.

Modern programmable electronic control systems may provide not only the functionality for continuous control, but also the ability to initiate emergency actions.

BS EN 61511, written specifically for the process industries, describes the various stages of the lifecycle of a safety instrumented system, to ensure that such a system can be constructed to the required level of reliability, after a systematic analysis of what level of performance is required. BS EN 61511-1 specifies the framework, definitions, systems, hardware and software requirements for such systems, while BS EN 61511-2 gives guidelines for specification, design, installation, operation and maintenance .This standard uses the terminology of safety integrity levels to describe four different performance standards

Closely related, but applying to machines rather than process plant, BS ISO 13849 covers safety related parts of control systems for machines, and is not restricted to programmable electronic systems.

6.9 Explosion protection

In many types of dust-handling plant, the ignition hazards cannot be fully controlled and dust-air clouds form in normal operation. In such circumstances, the plant is normally provided with explosion protection features, such as:

a) dust explosion venting devices (ATEX equipment in their own right), for which requirements are specified in BS EN 14797 and BS EN 14491 (including the sizing of vents), and the gas explosion venting systems specified by BS EN 14994 (which also covers sizing);

b) explosion suppression systems, requirements for which are specified in BS EN 14373;

c) use of explosion pressure resistant and pressure shock resistant equipment. Design recommendations for pressure shock resistant equipment are specified in BS EN 14460. Such equipment can be distorted following an internal explosion but does not rupture. The design requirements of BS EN 14460 are limited to shapes covered by the standard for unfired pressure vessels (BS EN 13445). Alternatively, BS EN 14460 accepts that equipment may be rated for pressure shock resistance by using a pressure test or explosion test, but without giving guidelines on how such tests should be performed;

d) explosion isolation devices between different items of equipment in a dust-handling plant, requirements for different types of which are specified in BS EN 15089;

e) flameless venting devices used to protect enclosures from internal explosions arising from the rapid burning of suspended dust, vapour or gas contained within, where an explosion vent has to open into an area where people are present, or where there is a risk of disturbing dust deposits and creating a secondary explosion (BS EN 16009);

f) explosion diverters, requirements for which are specified in BS EN 16020, that reduce the risk of an explosion spreading through process plant, without providing the more positive isolation achieved with equipment conforming to BS EN 15089.

6.10 Fires in machinery and electrical equipment

Many types of machinery create a fire hazard, either from a machine itself or, more commonly, from the products that it processes. The starting point is an assessment of the risks to people, property and the environment, from a fire caused by the machine. BS EN 13478 is a type B machinery standard which sets out a framework for such a risk assessment. Where flammable gases, liquids or dusts are present, the risk of an explosion also has to be considered, and this might dominate the decision as to the appropriate precautions. The range of technical control measures can be grouped under the following headings.

- Pre-fire alarm systems.
- Fire alarm systems.
- Manual discharge extinguishing systems.
- Automatic discharge extinguishing systems.

Most machinery contains electrical equipment, and the design of this to minimize the fire risk is an important consideration that might not be explicitly recognized when machinery is selected. A series of test methods for analysing the fire hazard of electro-technical products is set out by BS EN 60695.

The test methods are of most relevance to manufacturers of electrical equipment, but users of the equipment, particularly where hazardous materials are handled, might find some of the following parts relevant to assessing the risks of installed equipment.

- BS EN 60695-1-10: general guidelines for assessing fire hazards;
- BS EN 60695-1-11: fire hazard assessment;
- DD/IEC TS 60695-1-20: general guidance on ignitability;
- DD/IEC TS 60695-6-2: smoke obscuration, summary and relevance of test methods;
- BS EN 60695-8-1: heat release general guidance.

6.11 Combustion plant

Combustion plants can burn gaseous, liquid or solid fuels. Each type of fuel has its own particular hazards, but an explosion risk always exists if there is excess fuel inside the combustion zone at the time the ignition source is provided.

Automatic gas burners are very widely used, with fully sequenced start-up and shutdown. Requirements for automatic gas burner control systems are specified in BS EN 298.

Automatic forced draft gas burners are covered in BS EN 676, while safety and control devices for gas burning equipment are specified in BS EN 13611.

Industrial thermoprocessing plant takes many forms, and requirements are specified in BS EN 746-1 and 746-2.

The other parts of BS EN 746 specify more generalized requirements for machinery that incorporates combustion processes, or operates at elevated temperatures.

Various types of oil burners are covered by:

- BS ISO 22968 (forced draught oil burners);
- BS EN ISO 23553-1 (shut-off devices for oil burners);
- BS EN 230 (automatic burner control systems for oil burners);
- BS EN 303 (heating boilers);
- BS EN 267 (automatic forced draught burners for liquid fuels).

6.12 Special atmosphere furnaces

Special atmosphere furnaces are items of processing equipment that operate at elevated temperatures, and potentially contain inside gas mixtures with flammable, toxic and inert components. Many of these are found in the metallurgical industries.

BS EN 746-3 specifies requirements for both the thermoprocessing equipment and the associated systems for generating the special gas atmospheres. Particular requirements relate to the purging systems required to ensure that the inside of the equipment never contains a large volume of gas mixture with a composition capable of exploding.

Other types of equipment are designed for controlled combustion, and at the highest temperatures (over 750 °C) this occurs safely without the need for a separate ignitor or pilot flame.

6.13 Pipework

Pipework used for conveying flammable liquids and gases is subject to a wide range of requirements designed to ensure a high degree of integrity. Different industries and applications have developed different design codes, and these in turn reference other sources for the materials used in manufacture, tolerances during manufacture, fabrication, testing and other factors.

BS EN 13480 specifies an overarching set of requirements, covering materials (BS EN 13480-2), design and calculation (BS EN 13480-3), fabrication and installation (BS EN 13480-4) and inspection and testing (BS EN 13480-5).

PD 8010-1 gives detailed recommendations and guidance on natural gas pipelines, including the selection of a particular route. PD 8010-3 expands on this methodology, providing a risk-based approach, underpinned by historic failure rate data, to establish safety distances around pipelines containing flammable substances.

A specific design code for gas pipework within buildings is provided in BS EN 1775, which is more appropriate than BS EN 13480 for this application, because it offers a simpler design basis where the range of hazards to be considered is more restricted.

6.14 Spray booths

Many coatings for corrosion protection or decorative purposes are applied by spray processes. Powder coating generates dust clouds deliberately. The overspray dust is collected and recovered, and this creates dust explosion risks in the recovery system. Safety requirements from spray booths are specified in BS EN 12981.

The application equipment uses high electrical potentials to create static charges and this generates potential ignition risks. BS EN 50177 covers static spray equipment, specifying requirements for three categories of equipment, depending on the potential discharge energy. Type A-P has the lowest potential discharge, type C-P the highest.

Similarly, flock processes apply short staple fibre to a substrate coated in adhesive, potentially creating a fire or explosion risk. BS EN 50223 specifies safety requirements for four categories of stationary electrostatic flock application equipment, according to the maximum discharge energy they can release. Type A-F has the lowest potential spark energy, while type D-F has the highest. Equipment selection needs to take account of any flammable vapour that might be present in the adhesive coating.

Safety requirements for spray booths applying organic liquid coatings are specified in BS EN 12215, while the application equipment is covered by the safety requirements of BS EN 50176.

6.15 Solids bulk handling equipment

Various types of conveying plant handling solids in granular and powder form create ignition risks, or are a potential direct source of fire. Where fine powders are handled, any fire could initiate an explosion.

Bucket elevators might generate dust clouds inside the casing, and can be potential sources of ignition due to friction or impact between static and moving parts. Where explosible powders are present, the risks are usually controlled by a combination of measures intended both to reduce the potential for sources of ignition to arise, but also explosion protection measures, normally venting or suppression. Work is ongoing to produce a CEN technical report on the state of the art for explosion protection for bucket elevators (no number assigned yet).

Belt conveyors are usually less completely enclosed, and do not generally create an explosion risk, but might generate high temperatures and a fire risk if a belt slips or supporting rollers become seized. Requirements for minimizing a range of hazards associated with belt conveyors handling explosible dusts, including fire and explosion, are specified in BS EN 620.

Other types of bulk handling equipment for solid materials are covered by the requirements of BS EN 618, which also specifies some requirements for controlling fire and explosion hazards.

Rotary valves are used to control the flow of powder products and separate powder from air flow in pneumatic conveying systems. They can act both as an explosion barrier to prevent the passage of pressure and flame, and also, if the control system is designed for this purpose, prevent the spread of burning particles through a system. Methods of test, and requirements for effective explosion isolation, are specified in BS EN 15089.

6.16 Battery charging

Many chemical process sites, and other sites with continuous process plant, require control systems and other safety-related equipment to have a very high degree of reliability and protection against the possible loss of mains power. This may be by diesel generators, but immediate protection against power interruption is by banks of lead acid batteries or nickel-cadmium (Ni-Cd) batteries that are permanently connected. These can evolve hydrogen during the charging process, particularly at the end of the process.

Similarly, many sites use lift trucks powered by lead acid batteries, and these need recharging regularly. Safety is achieved by a combination of good design of charging equipment, suitable operating procedures and good ventilation. Requirements for battery charging points, including ventilation, are specified in BS EN 50272. BS EN 50272-2 covers stationary batteries, while BS EN 50272-3 covers traction batteries.

6.17 Hydraulic systems and fluids

Many different types of liquids are used in hydraulic power systems. The risks from fire vary substantially depending on the application. Any release from a very high pressure system is liable to form a mist, which can be ignited by sparks or hot surfaces even though the liquid temperature is well below its flash point. Where a risk assessment indicates that a fire resistant fluid is required, reference may be made to the requirements and guidelines of BS ISO 7745.
PD CEN/TR 14489 gives guidance for the selection of fire-resistant fluids.
BS ISO 7745 classifies the different types of fire-resistant fluids according to their chemical nature (see Table 2). The standard gives advice on the characteristics of the different types of fluids, on issues relating to changing fluids and shelf life.

Table 2 **Classification of fire-resistant fluids**

Designation	Composition
HFAE	Oil in water emulsion
HFAS	Chemical solution in water
HFB	Water in oil emulsion
HFC	Polymer solution in water
HFDR	Water free phosphate esters
HFDU	Non-phosphate water free

6.18 Equipment for acetylene use

Acetylene is mainly used as a source of fuel where very high temperature flames are required, as in some types of welding and laboratory spectrometers. Acetylene shares with hydrogen a very low ignition energy, but a relatively high auto-ignition temperature. However, it also has explosive properties, and can decompose very violently in the absence of air. The risk of explosive decomposition is reduced when the gas pressure is low. Liquid acetylene is too dangerous to handle, so it is distributed in cylinders absorbed onto a porous mass containing small amounts of solvent.

Acetylene cylinders involved in fires are treated with extreme caution by the fire and rescue service due to their unstable nature, with the potential to explode producing projectiles. Often, a 200 m exclusion zone is imposed around a cylinder for 24 hours while the cylinder is cooled with water.

Special equipment is required for handling acetylene, and the requirements are set out in the following standards.

- BS EN ISO 14114 (manifold systems for welding).
- BS EN ISO 7291 (pressure regulators).

- BS EN ISO 5171 (pressure gauges).
- BS EN ISO 3821 (rubber hoses for welding).
- BS EN 1256 (hose assemblies).
- BS EN ISO 5172 (blowpipes).

6.19 Equipment for liquid petroleum gas (LPG) services

LPG is widely used for domestic heating and portable appliances, and as an automotive fuel. There are many standards for the design of the cylinders and equipment to be used for these applications, but they fall outside the scope of this standard. Industrial users who store or transfer larger quantities of material might, however, need to be aware of the standards relevant to the equipment and procedures used. These include the following.

- BS EN 1762 (rubber hoses for LPG and natural gas up to 25 bar).
- BS EN 12817 (inspection and requalification of LPG tanks up to 13 m^3).
- BS EN 12864 (low-pressure regulators for LPG service).
- BS EN 12252 (equipment for LPG road tankers).
- BS EN 13175 (specification and testing for LPG tanks valves and fittings).
- BS EN 13776 (filling and discharge procedures for LPG tankers).
- BS EN 14071 (ancillary equipment for use with pressure relief valves for LPG tanks).
- BS EN 14570 (equipment for LPG tanks).

7 Equipment for fire safety

7.1 Emergency lighting

Emergency lighting is a requirement in buildings which would be difficult to evacuate in the event of fire if the normal lighting failed. The structure of standards in this area is complex. Similarly to the situation with fire alarm systems, the actual fittings used in emergency lighting are specified in standards written in support of the Construction Products Directive [17], but their siting and installation are subject to national legislation and BS 5266-1, BS EN 1838, BS 5266-7 and BS EN 50172, BS 5266-8.

BS 5266-1 draws a distinction between lighting provided purely to allow safe escape from premises, and lighting which might be required to stay on for a more extended period. This could be particularly applicable to chemical plant, where some control room activities might need to be completed, to shut a process down after the fire alarm system indicates a fire in a part of the premises that does not cause an immediate threat to control room staff.

BS EN 50172 specifies high-level requirements for the provision of illumination for escape routes and safety signs, but much of the detail is given in BS 5266-1.

BS EN 60598-2-22 is the specification for luminaires for emergency lighting.

7.2 Alarm system components and systems

Recommendations for the design, installation, commissioning and maintenance of fire detection and fire alarm systems are provided in BS 5839-1, while PD 6531 provides responses to questions raised concerning BS 5839-1 and interpretations of specific aspects. The components to be used in such systems are specified by a European standard harmonized under the Construction Products Directive [17]. BS EN 54 comprises a general introduction (Part 1), and requirements and test methods for control and indicating equipment (Part 2), sounders (Part 3), power supplies (Part 4), heat detectors (Part 5), point smoke detectors (Part 7), flame detectors (Part 10), manual call points (Part 11), linear smoke detectors (Part 12), aspirating smoke detectors (Part 20) and visual alarm detectors (Part 23).

BS EN 54 does not specify requirements for equipment in hazardous areas or in process plant in which hazardous areas have been defined, but it is likely that components of the fire alarm system need to conform to the applicable parts of BS EN 60079.

Manually-operated electric fire alarm systems are required in all but the smallest industrial buildings, while automatic fire detection is provided if the need for this is identified by an analysis of the risks as part of a fire risk assessment. BS 5839-1 distinguishes between systems which only respond following manual operation (typically breaking glass call points), systems which include automatic fire detection for the purposes of life safety, and systems which include automatic fire detection for the purposes of property protection. These are described as category M, category L and category P systems respectively, and are subdivided as follows, depending on the extent of any automatic fire detection provided.

- Category L1 systems that provide coverage throughout the premises.
- Category L2 systems that, in addition to Category L3, cover defined rooms with specific hazards or where the occupants are particularly vulnerable.
- Category L3 systems that are specifically designed to protect an escape route from a fire and include detectors within rooms which adjoin escape routes.
- Category L4 systems that provide coverage of staircases, corridors and other circulation routes that form escape routes from the building.
- Category L5 systems provide detection for some specific fire safety objective.
- Category P1 systems provide coverage throughout all areas of a building.
- Category P2 systems provide coverage in defined parts of a building.

BS 5839-8 gives advice on design, installation, commissioning and maintenance of voice alarm systems, which could be relevant to some industrial buildings.

In the process industries, many buildings are characterized by low occupancy levels, with some areas that might be important for the safety of the process being effectively unoccupied for most of the time. In some cases, operators might need to take actions to shut a process down safely as a response to a fire alarm signal, and not simply evacuate the building. Fire warning systems may be integrated into building alarm systems provided for other purposes, for example a toxic gas alarm or a system to give warning of a major spillage of process materials. Before trying to apply BS 5839-1, the system designer needs to be clear as to:

a) the objectives the user has for the system;

b) any special conditions relating to the response to a fire warning from different locations;

c) whether the system is designed to link up to fixed fire suppression systems; and

d) whether the system will link other alarm systems, including open-air plant.

In the process industries, selection of the most suitable types of automatic fire detectors needs to be informed by the nature of the fuel, the ambient conditions (temperature, humidity or the presence of potentially corrosive vapours, flammable vapours or combustible or non-combustible dusts).

Powerful ventilation systems or strong convection currents produced by equipment that is intended to run hot influences the effectiveness of automatic smoke and heat detectors, and the designer of the fire alarm system needs to be provided with adequate information to understand how such air flows might alter the number and location of fire detector heads required.

Linear optical smoke detectors (beam detectors) have particular advantages in buildings with high ceilings, such as warehouses or process plant that is effectively open from ground floor up through multiple working levels to the roof.

Linear heat detectors are used to provide early detection of fire in cable racks, cable tunnels and similar locations.

Flame detectors for use within buildings are quite different from flame detectors that are used in combustion plant to prove that a flame is present. The tests described for flame detectors in BS EN 54-10 describe a response point test using a methane flame. Additional sensitivity tests use trays of heptane and methylated spirits to produce smoky and non-smokey flames. Flame detectors are subdivided by class, with the most sensitive, class 1, responding to flames at a range of up to 25 m.

Flame detectors can measure or detect radiation in the UV or IR range, or both in combination. Flame detectors might nevertheless be sensitive to lightning, welding work, electrical sparks and other radiation sources, and hence give false alarms. Reliable detection of flames in outdoor plant, without large numbers of false alarms, requires detectors that are specifically designed for this purpose.

7.3 Hand-held fire extinguishing equipment

Design requirements for hand-held fire extinguishers are specified in BS EN 3, with Parts 7, 8 and 9 applying to different types.

BS 5306-3 gives recommendations for the commissioning and maintenance of portable extinguishers, work that is normally left to specialist contractors.

BS 5306-8 gives recommendations for selection and installation. The provision of hand-held fire extinguishers relates largely to buildings, but on sites where quantities of flammable materials are held or used in the open air, or under partial shelter, additional extinguishers might be needed. Where chemicals are present that could create a fire that grows very rapidly, the selection of extinguishers should take account of this risk.

7.4 Mobile fire extinguishers

Mobile fire extinguishers are mounted on wheels. Individual units might contain up to 150 kg of powder or water or 50 kg of CO_2, allowing an individual to tackle a much larger fire than would be possible with a hand-held extinguisher. These are most likely to be appropriate where a significant pool fire from a release of flammable liquid is foreseeable, in a small bund, or around a tanker loading/unloading area. The design, type testing and inspection of mobile fire extinguishers with a total mass greater than 20 kg for powder, water and CO_2 extinguishers are specified in BS EN 1866-1.

7.5 Fire protection systems

7.5.1 General

All premises where flammable materials are handled are likely to require equipment and/or facilities to help prevent small fires growing out of control, and to ensure that the fire and rescue service or other trained fire fighters have the means to intervene effectively.

At the very simplest level, this could be hand-held fire extinguishers or fire blankets.

Mobile extinguishers are intended chiefly for use in open areas, typically in large storage facilities for flammable liquids.

Conventional buildings might have suppression systems, such as sprinklers, capable of controlling the growth of fires involving solid fuels, but these are much less likely to be suitable for fires in industrial process plant or chemical storage areas. Fixed automatic or manually-operated fire protection systems are available for many specialist applications, most commonly releasing a gaseous extinguishing agent. These can provide protection for a specific process or a single room.

Large-scale external fire risks, involving storage tanks, silos, pressure storage or, less frequently, process equipment can be provided with fixed water drench systems to provide cooling or fixed systems to apply foam to smother a fire. Wherever fire protection is provided for open-air situations, the risk that the system could be inoperable when needed, because water has frozen, should be considered.

In addition, most premises require an adequate supply of water for firefighting, and a network of hydrants, fire mains or rising mains, so that excessive lengths of hose are not required.

It is important to be clear about the intended purpose of the equipment provided. Many industrial premises have comparatively small numbers of people on site, who are always awake and familiar with the premises. As BS 9999 makes clear, these factors tend to reduce the risk to life. Good means of escape and a suitable fire warning system, together with the provision of hand-held fire extinguishers, supported by proper training, might be sufficient to achieve the life safety objectives of the fire safety legislation [5, 6, 7, 8, 9].

Building legislation [10, 11, 12, 13, 14] sets out requirements for facilities to assist the fire and rescue service, in terms of water supplies and access around buildings, but these take little or no account of special hazards.

The provision of almost any further fire protection is then driven almost entirely by the economic consequences of fire, in terms of direct loss of equipment and materials or the loss of business following a fire. Insurance companies might have an input to what is provided, but often the choice of fixed fire protection is left to the site owner.

In sites with particularly large inventories of flammable materials, subject to major hazards legislation, special fire protection might be required in order to limit the risk to people off site from fires or explosions, or the release of toxic materials. Any requirements under this legislation need to be assessed by the site occupier and agreed with the Health and Safety Executive and the Environment Agency, or the equivalent bodies in the devolved administrations.

Whatever protection is provided, staff on site have to understand its mode of operation, and be trained if they are expected to use the equipment or take particular actions other than simply escape from the source of fire.

Standards in this field reflect the drivers for the provision of equipment.

Design standards for hand-held, mobile and fixed equipment are largely written at the European or International level. This facilitates free trade, and particularly those who tender for the provision of systems across different countries. Fixed fire equipment is often seen as part of a building, and hence the standards are harmonized under the Construction Products Directive [17].

Some insurance companies, particularly in the United States, have a tradition of researching effective fire protection measures, and offering reduced premiums to those who fit systems that they have approved. They have developed detailed publically-available design codes and some of these cover situations not covered by standards. In addition, the American National Fire Protection Association publishes a wide range of codes and standards, some of which cover topics that are not covered by British, European and International standards.

Design standards for fire protection systems on open-air chemical plant come from a more diverse range of sources, in part from major oil companies and associated trade associations.

Finally, because technology moves forward, as new types of systems are developed, design requirements might be set out in technical specifications that are not full standards, but are intended to assist suppliers and purchasers of such systems to reach a common understanding.

Since the choice of what fixed fire protection is required, in which circumstances, is largely made on a site-by-site basis by individual companies, standards take the form of guidelines or codes of practice, which are not in general prescriptive. BS 5306-0 is the key standard for those responsible for selecting fixed fire protection from a range of available options. Where factory occupiers specify a standard as the basis for a purchase order, they need an understanding of any subdivisions or options that are set out in the standard, but the specifications for full design details are mainly of use to equipment suppliers.

7.5.2 Systems using water

BS 5306-0 gives recommendations for hose reels and foam inlets, including design, installation, testing and maintenance. Requirements for the hose reels themselves are specified in BS EN 671.

Requirements are specified, and guidance given, for the design, installation and maintenance of sprinkler systems in BS EN 12845, though many older systems are built to earlier British standards. The components used to make a system to BS EN 12845 are standardized in BS EN 12259. There are many categories of sprinkler design, particularly hazard class, which is a function of the fire load and potential for rapid fire growth, and whether the system is wet, dry or alternating. A dry system, for example, is needed for a building that is not heated, so that freezing temperatures are possible.

DD CEN/TS 14816 specifies requirements and gives recommendations for the design, installation and maintenance of fixed deluge water spray systems internal and external to buildings and industrial plant and other premises on land. Again, many earlier systems are installed to proprietary designs from individual suppliers.

Water drencher systems for pressure storage of LPG tanks are covered in UKLPG Code of Practice 1 [50].

Water mist systems are increasingly being used in a variety of different applications, extending their use away from their traditional use in confined spaces such as ship engine rooms. However, their general use on processing sites has till now been very limited, but will undoubtedly increase. There are currently no published standards, but the DD 8489 series published in 2011 covers the following areas: design and installation, test and requirements for flammable liquid fires, combustion turbines and machinery spaces, industrial oil cookers and low hazard occupancies.

BS 7273-3 and BS 7273-5 are two other codes of practice that detail the operation of fire protection measures and include watermist systems.

7.5.3 Foam systems

Foam systems work in various ways, but the most common action is by smothering a fire. As foam is applied to a burning surface, it spreads, providing cooling and excluding air. Complete coverage is needed to extinguish the fire. Properties that control the effectiveness include the stability of the foam where there are hot surfaces; drain time, before the foam has collapsed; the flow properties, to encourage rapid spread across the surfaces to be protected or extinguished; and, particularly where chemicals are present, the stability of the foam in the presence of those chemicals.

Foam systems are subdivided into low, medium and high expansion types and there are many variants on the systems that may be selected.

They may be used for protecting chemical process areas, storage areas including large tanks, fuel transfer areas, such as road tanker stances, or marine jetties and warehouses.

All such systems require a pumped supply of water and foam concentrate, a system for mixing these in the right proportions, a means for aspirating the mixture into a foam, and some means of delivering the foam to the area affected. Foam is used both for extinguishing fires, and for covering open areas of non-burning liquid surface to prevent fire spread. Medium and high expansion foams are used to fill volumes, rather than provide a layer of foam over a fire.

Often, foam systems are designed with a combination of fixed and movable equipment, so, for example, fixed pipework leading to foam pourers can be provided on a tank, but the pump, foam stocks and proportioner are brought to the location when needed. Where a fully fixed system is provided, it might be operated manually or automatically on detection of fire.

Low expansion foam is often the preferred option for extinguishing very large pool fires, such as bunds around tanks, or on the roof of a floating roof tank.

Where a fixed system is provided, its compatibility with foam fire extinguishing systems used by the incoming fire brigade needs to be considered.

BS EN 13565-2 specifies requirements for the design, testing, installation and maintenance of a complete foam fire extinguishing system, while BS EN 13565-1 specifies requirements for the components of such a system.

Different applications require different types of foam compound, and these are specified in BS EN 1568, together with test methods for the foams.

- Part 1: medium expansion foam for surface application to water-immiscible liquids.
- Part 2: high expansion foam concentrates for surface application to water-immiscible liquids.
- Part 3 low expansion foam concentrates for surface application to water-immiscible liquids.

- Part 4: low expansion foam concentrates for surface application to water-miscible liquids.

7.5.4 Powder systems

Powder systems are less widely used than gaseous extinguishing systems, largely because they create a significant clean-up problem after use. They can, though, provide extremely rapid extinction of flames from running liquid fires. They inhibit visibility, and should not be activated while people are in the area. They may be used with different types of powder for extinguishing fires involving gases, liquids and solids. Applications listed in BS 5306-0 include flammable liquid drum stores, engine test rooms and pumping stations.

The design requirements, together with recommendations for construction and maintenance, for a powder extinguishing system are given in BS EN 12416-2, while BS EN 12416-1 specifies requirements and test methods for components of such a system.

7.5.5 CO_2 systems

Carbon dioxide has been used for many years as a gaseous fire extinguishing agent, and the standards for this type of system have changed little in recent years.

The design requirements and recommendations for the provision of carbon dioxide fire extinguishing systems are contained in BS 5306-4. Concentrations of CO_2 in the range 35% to 50% v/v are typically needed for extinction. These may be designed as total flood, local application or, less commonly, manual hose reels. Total flood or local application systems may be manually controlled or automatic, with a facility to switch to manual. BS 5306-4 identifies coating machines, printing presses and fumes ducts as locations where local application systems might be appropriate. Total flood systems are suitable where a fire hazard is enclosed. These are used on both surface fires involving liquids, and deep seated fires in stocks of granular or powder materials.

Commonly, gaseous fire extinguishing systems covering a restricted area are linked to automatic fire detection and alarm systems for the whole building. Recommendations for this interface are given in BS 7273-1 for electrically-actuated systems, while BS 7273-2 covers systems that are mechanically activated.

7.5.6 Systems using other gaseous extinguishing agents

Following the withdrawal of halons 1211 and 1301, as a result of the Montreal Protocol on Substances that Deplete the Ozone Layer [51], a range of alternatives has been commercialized, with different degrees of success. Such systems have some common features, but each gaseous agent has a different design concentration and different operating pressures. Some are stored as liquids, others as gases under high pressure, for which larger cylinders are needed. The halon containing agents generate decomposition products, which might be corrosive or irritating, while those systems based on inert gases, e.g. nitrogen, argon and carbon dioxide blends, produce no decomposition products and act largely by reducing the oxygen available for a fire and reducing the temperature within the flames.

Broad design requirements are specified in BS EN 15004-1, with other parts giving details for the different individual extinguishing agents:

- Part 2: FK 5-1-12;
- Part 3 HCFC blend A;
- Part 4 HFC 125;
- Part 5 HFC 227ea;

- Part 6 HFC 23; and
- the inert gases: Part 7: IG 01; Part 8: IG 100; Part 9: IG 55 and Part 10: IG 541.

Extinguishant HFC 227ea typically requires a design concentration of 9% for fires involving liquids. For comparison, the blend of nitrogen, argon and carbon dioxide IG 541 requires up to 48% as a design concentration for fires involving liquids.

If a gaseous fixed firefighting system is required, the choice between halocarbon, inert gas and carbon dioxide systems is likely to depend on a balance of factors, including initial capital cost, maintenance costs, costs of refilling after use, the potential impact of decomposition products formed, and the space available for cylinders of extinguishant.

7.6 Water supplies, hydrants and equipment for use by the fire brigade

Equipment supplied within a private site needs to be compatible with equipment provided on public roads for use by the fire brigades. Within tall buildings, wet or dry risers, depending on the building height, might be required as specified in the Building Act and Regulations [10, 11, 12, 13, 14].

On large sites, where any part of the premises is remote from a fire hydrant or public road, a fire main, private fire mains and hydrants are likely to be needed. Dry mains are pressurized by the fire brigade from the public supply, while wet mains are served by fixed pumps provided on site. Two pumps are normally provided, each capable of delivering the full required flow rate. The quantities of water required depend on the facilities and materials on the site, and if the public supply is likely to be inadequate, fixed storage tanks might be required. BS 9990 gives recommendations specifically on the design of fire mains within large buildings, but the principles it sets out are relevant to the provision of fire mains across open areas of industrial premises. In all cases, consultation with the local fire authority is recommended.

Requirements for the national operational and health and safety requirements for conventional underground fire hydrants are specified in BS 750.

The different components of wet and dry risers inside a building are specified in BS 5041-1 and BS 5041-2, respectively. The locations for rising mains are set out in the Building Act and Regulations [10, 11, 12, 13, 14].

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