# Recommendations

RC12

for the prevention and control of dust explosions

FPA
Fire Protection Association

InFiReS

LOSS PREVENTION RECOMMENDATIONS

These recommendations are part of a series of insurer documents developed under the Insurers' Fire Research Strategy Funding Scheme (InFiReS) and published by the FPA. InFiReS membership comprises a group of UK insurers that actively support a number of expert working groups developing and promulgating best practice for the protection of property and business from loss due to fire and other risks. The technical expertise for the Recommendations is provided by the Technical Directorate of the FPA and experts from the Insurance Industry who together form the InFiReS Process Steering Group.

The aim of the FPA Series of Recommendations is to provide loss prevention guidance for industrial and commercial processes and systems. The series continues a long tradition of providing authoritative guidance on loss prevention issues started by the Fire Offices' Committee (FOC) of the British insurance industry over a hundred years ago and builds upon earlier publications from the LPC and the ABI.

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First published by
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Printed in Great Britain by O'Sullivan Printing Corporation 1.0/05.04

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## SCOPE

These recommendations apply to workplace situations and processes where explosible dusts and powders are likely to be present. Mines and quarries are not covered by this document.

## DEFINITIONS

Explosible dust: For the purpose of this document an explosible dust is a dust which, when suspended as a mixture with air, may explode on contact with an ignition source.

Explosible powder: For the purpose of this document an explosible powder is a powder which, when suspended as a mixture with air, may explode on contact with an ignition source.

A powder is considered as a finely divided material intended to be present.

A dust is considered as a finely divided material that arises as a by-product or waste that is not intended to be present.

## INTRODUCTION

Dusts produced by a wide variety of materials may be combustible and, under certain conditions, explosible. Similarly, fine powders may also be combustible and explosible. Explosible dusts can arise during the handling of materials, in processes such as milling, grinding, mixing and drying, in extraction systems and dust collectors. Powders are often part of a process or even the end product. For example, cornflour and food preparations based on it. Disturbance of a settled layer of dust or powder can also produce an explosible cloud. Materials that are combustible when in bulk form will almost certainly form explosible dusts or powders. However, some materials that are not normally combustible in bulk form may also produce combustible and explosible dusts and powders if the particle size is sufficiently small. For example a bar of aluminium metal is not readily ignited but aluminium powder is extremely flammable and explosible in confined spaces.

An explosion will only propagate through a cloud if the concentration of particles lies between certain limits. The lower of these limits may be as little as 10g/m$^3$ in air. More typically these limits will be 30g/m$^3$ to 60g/m$^3$ for particle sizes in the common region of 100 micrometres diameter. Sugar and caster sugar are typical of these particle sizes. Upper limits have been quoted in the region of 2000g/m$^3$ to 6000g/m$^3$ but practical measurement of these levels is difficult and the values should be used with caution. For all practical considerations, dust concentrations above the lower limit should be treated as potentially hazardous.

Explosive concentrations of dusts and powders do not arise in open areas of the workplace during normal working conditions but are usually confined to within factory plant. Thus the greatest risk is for a primary explosion to occur within the plant. There is also a risk from secondary explosions caused by the ignition of deposits and layers of dust or powders blown into clouds by the force of a primary explosion. Experience has shown that greater damage is often caused by secondary explosions. This document includes recommendations to reduce the risk of primary and secondary explosions.

Dust and powder explosions can cause injury and loss of life. In addition, such explosions and subsequent fires cause substantial damage to property and loss of production. Measures to prevent such explosions and restrict their effects are an essential part of modern risk management.

The life safety issues have been recognised in a European Directive[1]. In the UK this Directive is implemented through the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)[2]. These Regulations require that where a dangerous substance, such as an explosible dust or powder, is present or likely to be present a formal risk assessment should be carried out and that measures be implemented to mitigate against risks identified by such an assessment. Many of these measures are also relevant to property protection and will be described below.

Apart from the safety issues arising from exposiblity, dusts and powders often have health hazards associated with them and the exposure of employees and others to these hazards is controlled under health and safety legislation. The primary Regulations which do so are the Control of Substances Hazardous to Health (COSHH) Regulations 2002[3]. Guidance on occupational exposure limits is given in EH40[4].

## RECOMMENDATIONS

### 1 Risk assessment

1.1 *Statutory requirements*

The requirement for a risk assessment under DSEAR[2] means that an assessment of the risk to workers from explosion should be undertaken and mitigating action taken. DSEAR specifies items that must be included in the risk assessment process and specifies control and mitigating measures with an order of priority in which these must be addressed. These are reflected in sections 3 to 8 below.

1.2 It is recommended that when such an assessment is carried out the scope of the assessment be extended to include property and business protection issues.

### 2 Classification and labelling of zones in areas where exposible dusts may be present

2.1 Statutory requirements. The Dangerous Substances and Explosive Atmospheres Regulations 2000 (DSEAR)[2] require that places that are hazardous due to the presence of sufficient quantities of explosive atmosphere must be classified and labelled.

2.2 Clouds of combustible/explosive dusts (or powders) may constitute an explosive atmosphere and are subject to DSEAR.

2.3 Classification of hazardous places where the hazard arises from the presence of combustible/explosible dusts (or powders) is defined by DSEAR (Schedule 2). These are:

- Zone 20 – A place in which an explosive atmosphere in the form of a cloud of combustible dust (or powder) in air is present continuously, or for long periods of time or frequently.
- Zone 21 - A place in which an explosive atmosphere in the form of a cloud of combustible dust (or powder) in air is likely to occur occasionally in normal operation.
- Zone 22 - A place in which an explosive atmosphere in the form of a cloud of combustible

dust (or powder) in air is not likely to occur but, if it does, will be present for a short period only.

2.4 *Labelling*

**Figure 1. Ex symbol**

Where necessary areas classified as zones 20, 21 or 22 should be marked at their entrance points by the sign prescribed in Schedule 4 of DSEAR. See Fig. 1.

## 3 Substitution

3.1 Before a new process is designed or changes made to an existing process the use of alternative, less dangerous materials or procedures should be assessed. (It should be noted that it is a requirement of DSEAR that this is done 'so far as is reasonably practical'.)

For example, can a process using powder by replaced by one using pellets or paste?

3.2 Such an assessment is also recommended before significant investment is made in dust or powder handling systems and explosion control equipment.

If alternative materials or processed are not reasonably practical the following are recommended.

## 4 Dust control

4.1 New plant and modifications to existing plant should be designed to:

- reduce the escape of dust or powder from within the plant to a minimum.
- prevent the accumulation of dust or powder in dead spots where spontaneous ignition might occur.

4.2 Fully enclosed plant should be used wherever possible.

4.3 The quantity of material in use in production areas should be limited to daily requirements.

4.4 Good housekeeping is essential to prevent the accumulation of dust and powder layers. This will reduce the risk of secondary explosions. Manual cleaning using a suitable vacuum cleaner should be carried out on a daily basis at least. (A suitable vacuum cleaner is one designed for removing combustible dusts.)

4.5 Blowing down techniques should not be used.

4.6 Brushing and sweeping should be avoided if at all possible. Where these techniques are used to remove dust or powder deposits care should be taken to minimise the production of dust or powder clouds.

4.7 Washing down should also be considered as a cleaning method provided that the components of the dust or powder are compatible with water or other cleaning materials used.

4.8 Material collected during cleaning should be disposed of immediately outside the building in non-combustible, preferably metal, lidded containers.

4.9 It is recommended that the development of dust or powder deposits be regularly monitored. Any areas where build up is greater should be subject to more frequent cleaning.

4.10 To minimise the accumulation of dust or powder deposits, horizontal exposed surfaces should be eliminated wherever possible.

4.11 Where only partial plant enclosure can be achieved, local mechanical exhaust ventilation should be provided as close as possible to the points of particle emission. Particles should be conveyed via metal ducting to suitably sited collectors. The use of portable dust collectors designed and built for the purpose may be appropriate for exhaust ventilation of small items of plant.

4.12 Buildings housing dusty processes or plant should be provided with general exhaust ventilation by fans and ducting to collectors in order to reduce accumulations of dust or powder on surfaces. Generally dust or powder concentrations sufficient to produce an explosion risk are significantly higher than the occupational exposure limits (OEL) allowed under COSHH[3] and are also at levels where visibility would be significantly impaired. Thus it is not normally necessary to provide ventilation to control explosive limits as health requirements are far more stringent[4].

4.13 Fixed dust collectors should be suitably sited. That is, away from production plant and fixed sources of ignition (a clear space of at least 1 metre is recommended) and should, preferably, be outside.

4.14 Dust collection ductwork should, where possible, not penetrate fire compartment walls. If this is not possible the use of fire dampers should be considered to preserve the integrity of the compartment in the event of a fire. (See paragraph 4.16.)

4.15 Where external dust collection is in place and a risk assessment identifies the extraction duct as a possible route for fire spread into the plant, consideration should be given to installing a fire damper to prevent burn back. (See paragraph 4.16.)

4.16 The use of fire dampers in dust extraction ductwork should take into account the effects of

dust deposits on the damper operating mechanism. Specially designed dampers are required, any parts likely to be adversely affected by dust being mounted out of the airstream.

## 5 Elimination of ignition sources

5.1 Care must be taken to exclude all potential ignition sources. Some common ignition sources are:

- Open flames
- Welding and cutting
- Explosions from another source (secondary explosions)
- Heat and sparks caused by friction, impact or electrical equipment
- Static electricity
- Hot electrical components
- Hot surfaces
- Smouldering sources, such as cigarettes
- Spontaneous combustion

5.2 The possibility of spontaneous combustion of dust or powder residues should also be considered and any likelihood of this occurring should be eliminated.

5.3 Smoking should be prohibited in areas where explosible dusts and powders may be present.

5.4 A planned, preventive maintenance programme should be specified for all machinery and plant to minimise the possibility of overheated bearings and other potential ignition sources.

5.5 Suitable magnetic and/or pneumatic separators should be provided on the material inlet side of all machinery to prevent ingress of 'foreign' material and eliminate frictional sparking.

5.6 Gas and electrical welding and cutting, and the use of blowtorches should be restricted to designated areas such as workshops wherever possible. Where such work can only be carried out in hazardous areas a strict permit to work system such as a hot work permit scheme described in FPA RC7[5] should be used.

5.7 Measures should be taken to prevent the accumulation of static electricity and resultant discharges. (See section 7.)

5.8 Work is in hand, at the time of publishing, to develop European standards for the classification of non-electrical equipment for use in explosive atmospheres so that non-electrical equipment can be assigned to the categories required by DSEAR (see section 6.2). To date only BS EN 13463-1[6] has been published giving basic testing and assessment methods for equipment manufacturers to assign category 1, 2 or 3. Essentially non-electrical equipment built to good engineering standards and meeting the criteria described in 5.1 above would be expected to be suitable for category 2 or 3 use when assessed using this Standard.

## 6 Electrical installation

6.1 Wherever possible, electrical equipment should be located outside areas in which concentrations of explosible dust or powders may occur. When this is not achievable, electrical equipment in such areas should comply with the requirements of Schedule 3 of DSEAR and be selected according to the zone classifications described in 2.3 above.

6.2 Schedule 3 of DSEAR requires that electrical equipment used in areas in which concentrations of explosible dust or powders may occur should be selected as follows

- Zone 20 – category 1 equipment
- Zone 21 – category 1 or 2 equipment
- Zone 22 – category 1, 2 or 3 equipment

It should be possible to identify appropriate equipment from markings on the equipment. It is a statutory requirement for the manufacturer to mark equipment with details of its classification and the like. Equipment appropriate for use within the scope of this document will be designated Group II with either category D1, D2 or D3. D indicates suitability for use in dust/powder atmospheres.

(A designation G indicates protection for use in explosive gas atmospheres and is not appropriate for dust/powders. Marking with the designation M indicates a level of protection intended for use in mines and should only be found on Group I equipment.)

The categories of equipment are defined in Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996[7].

Advice on selection, installation and maintenance of certain types of protected equipment is given in BS EN 50281-1-2[8].

6.3 The installation in general should conform to the current Institution of Electrical Engineers' Wiring Regulations[9].

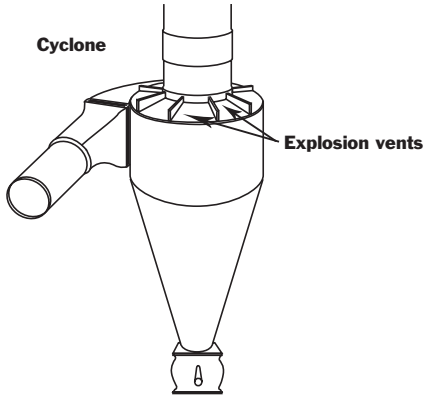
## 7 Static electricity

7.1 Casing, trunking, storage vessels and other items of plant, including plastic pipework, should be bonded and earthed to prevent the accumulation of electro static charges during the handling of dusts[10,11].

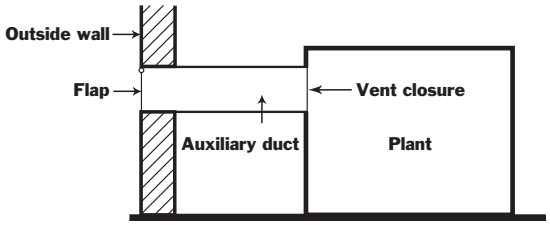
7.2 Where the risk assessment indicates it, people working in hazardous areas should be equipped with appropriate anti-static clothing.

7.3 Particular care is needed where manual dispensing of dusts and powders is required.

**Figure 2. Examples of venting**

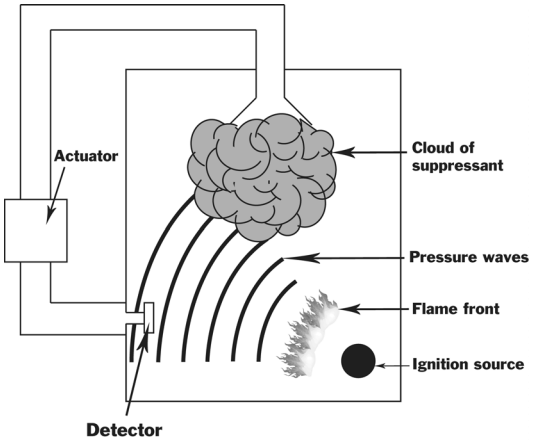



The disruptive effects of an explosion can be materially reduced by providing vents which open when an explosion occurs. They should be designed to open at a pressure well below that which would severely strain or distort the structure. The hot gases and other materials can then escape.



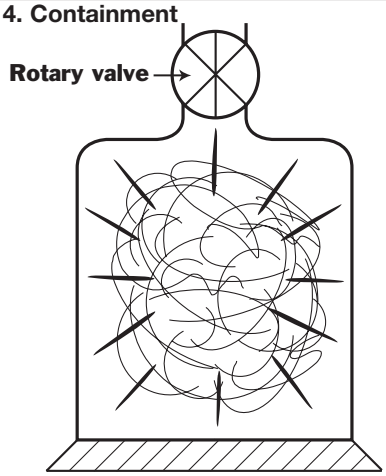

Vents should be as close as practicable to likely points of ignition. They should be placed so that they do not discharge burning material into workrooms or into places where a secondary explosion or injury to persons could result.

**Figure 3. Explosion suppression**



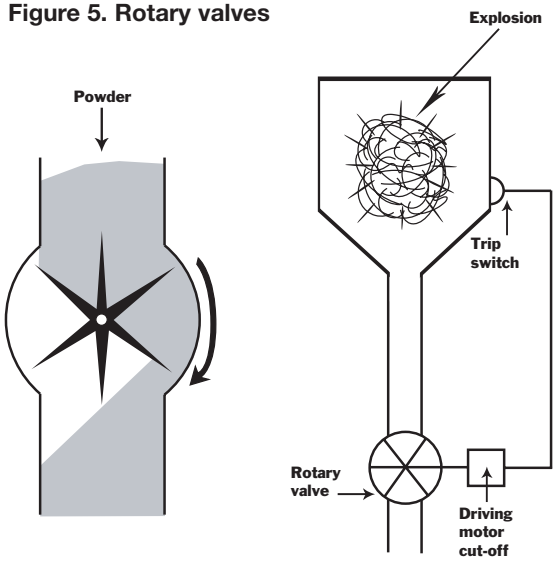

The very brief interval of time between first ignition and the attainment of peak pressure in an explosion can be utilised to suppress the explosion.
A quick-acting pressure switch can be installed which will respond to the initial and comparatively slow increase in pressure. The switch releases a chemical to suppress the explosion.

**Figure 4. Containment**




Pressures of 7bar may be generated in an explosion. Plant of certain types of operation, eg grinding and pneumatic conveying, can be made to withstand and contain dust explosions of this order.

**Figure 5. Rotary valves**




This valve consists of a number of vanes on a spindle rotated by a motor. The vanes are enclosed and just clear the casing. There is no direct passage between the inlet and outlet of the valve.
On rotation it allows the downward movement of powders but prevents the direct passage of an explosion flame front.
Burning particles could be carried through the rotating valve, however, and to lessen this risk a trip switch can be used to cut off the valve motor.

## 8 Control of explosions

### 8.1 *Venting*

8.1.1 Properly designed and located explosion vents should be provided on vessels and equipment to relieve the pressure resulting from an explosion and so prevent or reduce damage. Buildings may also require vents; windows, doors, skylights and sections of walls or roofs can sometimes be adapted to serve as explosion vents in buildings. Proprietary venting devices are available for both buildings and equipment. The required area of

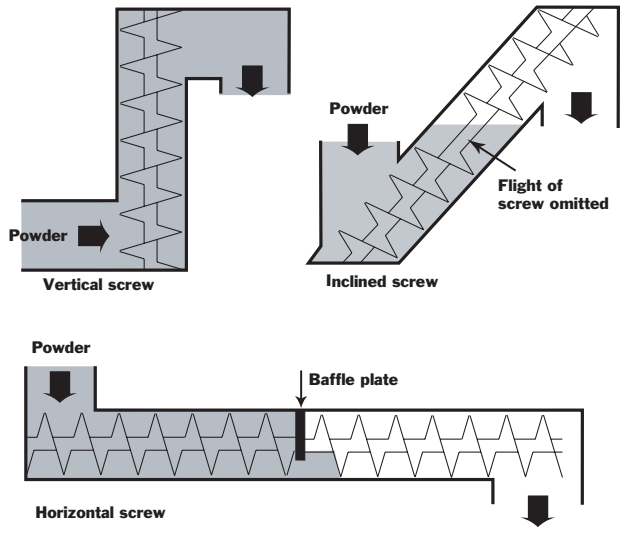



**Figure 6. Screw conveyor**

Vertical screw conveyors are a safe mechanical means for transporting powder upwards. The powder itself forms a compact plug which prevents the passage of an explosion.

An inclined screw conveyor from which one flight of the screw has been removed can be used to transport material. A plug of powder will seal the conveyor where the flight is missing and will remain in position even when feed to the lower end of the conveyor is discontinued.

Horizontal screw conveyors can also be used for transport of material but in addition to omitting a flight of the screw a baffle plate has to cover the upper part of the conveyor in order to effect a successful seal.

explosion vents depends on the expected intensity of an explosion, the strength of the structure, the type of vent closure and other factors.

8.1.2 Venting should be to a safe place, normally in the open air, taking into account the locations of people, domestic animals and property.

Venting to the open air is recommended unless the material being vented is toxic, radioactive, corrosive or similarly hazardous.

8.1.3 Where vent panels are in roofs or similar areas that may be susceptible to build up of snow, ice or other materials that could impair their function, procedures should be in place to ensure that the vents are monitored and any such accumulations are cleared as soon as possible.

8.1.4 The function of explosion vents should be explained to all employees working in the area and the need to keep the immediate vicinity clear of obstructions, including fittings such as pipework and cabling, must be made clear.

8.1.5 Vent sizing is a specialist field and calculations should be verified by a competent chemical engineer. In the event of plant or buildings being altered the vent sizing should be re-assessed.

8.1.6 If venting alone is deemed to provide inadequate or unsafe protection, for example due to insufficient design strength of the vessel, additional measures as outlined in 8.2 or 8.3 should be applied.

8.2 *Inert gas protection (inerting)*

Explosions may be prevented in many plants and processes where the dust or powder is confined within an enclosure by the replacement of the normal atmosphere with an inert gas. Gases such as nitrogen or carbon dioxide are commonly used.

Expert advice should be sought from a qualified chemist or chemical engineer familiar with the materials in use, particularly where metal dusts are concerned, as some forms have sufficient reactivity to ignite in the presence of the common inerting gases.

N.B. Where such an inerting gas is used the risk of asphyxiation during maintenance and from accidental leakage must be assessed and proper controls put in place. For example, proper entry into confined spaces procedures must be in place and plant must not be installed in basements or other locations where inerting gases may accumulate.

8.3 *Suppression*

Provision of an explosion suppression system is recommended for suitably enclosed plant. There may be limitations on the size of vessel that can be protected in this way. Experience has shown that vessels up to 250m$^3$ can be protected. However it is theoretically possible to protect vessels up to 1000m$^3$.

In these systems, sensitive detectors are installed inside the plant. The detectors are connected to a reservoir of inerting agent. The detectors are able to detect an incipient explosion and the system can react with sufficient speed to inject the agent into the plant and disrupt the explosion flame front before dangerous pressures are reached. The detectors normally used are pressure sensors. Optical and heat sensitive instruments do not offer adequate sensitivity or speed of reaction.

8.4 *Containment*

Where it is not possible to control the risk of explosion using methods in 8.1 to 8.3 above precautions should be taken to ensure that:

- vessels and equipment are designed to withstand the maximum pressures that can be generated in an explosion; and

- any explosion is prevented from spreading within the plant.

This can be achieved by:

- the use of individual vessels isolated from other plant; or
- by the sub-division of continuous plant with rotary valves, rapid-action valves or similar barriers.

Other separating systems (chokes) include:

- screw conveyors with a section of the flight removed; and
- a baffle plate within a screw conveyor for horizontal applications only.

It is also important to ensure that where vessels are protected by containment the vessels should be isolated from the rest of the plant at upstream and downstream connections.

8.5 *Dilution*

For some processes it may be possible to reduce the risk of explosion by diluting the explosible material below its explosive limit with an inert powder.

## 9 Fire extinguishing appliances

9.1 Portable fire extinguishing appliances, with extinguishing media appropriate to the hazardous materials present, should be provided in accordance with BS 5306: Part 8[12].

9.2 Where the application of water will not increase the risks by creating a dust or powder cloud or by reacting with the material (for example, burning aluminium powder will react explosively with water), hose reels should be provided in accordance with BS 5306: Part 1[13].

## 10 Training

10.1 Personnel working in areas where explosible dusts or powders are or may be present should be given training in the use of fire extinguishing equipment. This is particularly important to ensure that the correct types of extinguishers are used and the use of any extinguisher does not produce a cloud of dust or powder by disturbing deposits.

10.2 New employees working within the hazardous areas should be given induction training so that they understand the hazards and the control measures.

10.3 Periodic refresher training should be given to all staff but in particular to those involved with inspection, maintenance and the operation of permits to work.

## 11 Management

11.1 Management procedures should reflect these recommendations. In particular the following should be in place:

- good housekeeping;
- appropriate maintenance and service contracts including specialist companies for suppression and venting systems;
- a permit to work scheme (including hot work controls) which incorporates the auditing of permits;
- regular monitoring of changes of activities/processes within hazardous areas.

11.2 The local fire service should be encouraged to make familiarisation visits to the hazardous areas.

## REFERENCES


1 ATEX Directive. Directive 1999/92/EC on minimum requirements for improving the safety and health of workers potentially at risk from explosive atmospheres.

2 The Dangerous Substances and Explosive Atmospheres Regulations 2002 (SI 2002, No 2776).

3 Control of Substances Hazardous to Health Regulations 2002 (SI 2002, No 2677). Amended from time to time to take account of technical progress.

4 EH40, *Occupational exposure* limits, published annually by HSE.

5 FPA *Recommendations for Hot Work:* 2002 (Fire Protection Association, RC7).

6 BS EN 13463-1: 2001: *Non-electrical equipment for potentially explosive atmospheres. Basic method and requirements.*

7 Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (SI 1996, No 192 as amended by SI 2002, No 3766).

8 BS EN 50281-1-2:1999: *Electrical apparatus for use in the presence of combustible dust. Electrical apparatus protected by enclosures. Selection, installation and maintenance.*

9 BS 7671: 2001 *Requirements for electrical installations. IEE Wiring Regulations.* Sixteenth edition.

10 BS 5958-1:1991: *Code of practice for control of undesirable static electricity. General considerations.*

11 BS 5958-2:1991: *Code of practice for control of undesirable static electricity. Recommendations for particular industrial situations.*

12 BS 5306-8: 2000: *Fire extinguishing installations and equipment on premises. Selection and installation of portable fire extinguishers. Code of practice.*

13 BS 5306-1:1976: *Fire extinguishing installations and equipment on premises. Hydrant systems, hose reels and foam inlets.*