



RP 44-12

**PROTECTION OF CHEMICAL
PROCESSING PLANTS HANDLING
FLAMMABLE DUSTS**

March 1997

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SCOPE AND PURPOSE This Recommended Practice gives guidelines to BP general requirements for protective features in the design of plants handling flammable dust. It applies to any installation involving the creation, handling, transportation, or storage of dusts or particulate solids of a fine nature, liable to be suspendable in the gaseous phase as a dust, unless by the tests outlined herein they are shown to be non-flammable or there is reliable evidence to show that they are non-flammable. It also provides general information on the basic design, as such, of these installations. In this however, it does not set out to be a comprehensive general design manual for such plants.											
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This Recommended Practice gives guidelines to BP general requirements for protective features in the design of plants handling flammable dust. It applies to any installation involving the creation, handling, transportation, or storage of dusts or particulate solids of a fine nature, liable to be suspendable in the gaseous phase as a dust, unless by the tests outlined herein they are shown to be non-flammable or there is reliable evidence to show that they are non-flammable.

It also provides general information on the basic design, as such, of these installations. In this however, it does not set out to be a comprehensive general design manual for such plants.

Application

This document may refer to local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirement lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Qualifications to Applicability

This Recommended Practice although a Group document has been prepared and developed by BP Chemicals and is specifically designed for use in Chemical Plants.

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. SCOPE AND PURPOSE

This Recommended Practice gives guidelines to BP general requirements for protective features in the design of plants handling flammable dust. It applies to any installation involving the creation, handling, transportation, or storage of dusts or particulate solids of a fine nature, liable to be suspendable in the gaseous phase as a dust, unless by the tests outlined herein they are shown to be non-flammable or there is reliable evidence to show that they are non-flammable.

It also provides general information on the basic design, as such, of these installations. In this however, it does not set out to be a comprehensive general design manual for such plants.

This Code does not cover:-

- (a) the requirements for plants handling materials defined as deflagratory or detonating explosives by the UK Home Office tests,
- (b) the handling of reactive metals such as aluminium and magnesium (see [NFPA 48](#)),
- (c) requirements for the heat treatment, e.g. drying, of materials which on heating exhibit exothermic decomposition with rapid evolution of large volumes of gas even in the absence of air.

2. GENERAL REQUIREMENTS

- 2.1 Equipment within plant handling flammable dust shall be designed where practicable to prevent any fire or explosion and shall in any case be designed to reduce the risk of fire or explosion and to limit the extent and mitigate the effects of a fire or explosion. The effects of an explosion may be limited by venting, explosion suppression, or containment. An explosion may be prevented by inerting, eliminating ignition sources and explosive concentrations. Fires may be limited by inerting, suppressing, chokes or baffles. This Recommended Practice gives guidance on the choice and design of these alternatives.
- 2.2 Plant handling dusts shall be generally designed to prevent the accumulation of dusts on any surfaces, particularly surfaces which are not readily accessible, e.g. ledges and girders. They shall also be designed to facilitate the removal of dust which accumulates in spite of the design for initial containment. For this purpose, vacuum cleaning equipment should be specified. Care should be taken as electrostatic ignition hazards can occur as a result of the vacuum cleaning of dust.



- 2.3 Work areas within plant shall be adequately ventilated. Any particulate or gaseous matter, specified by BP as injurious to health, shall preferably be contained. If impractical to do so then it shall be exhausted from near to the point of origin to a safe location for personnel protection. Note that statutory limitations may also be applicable.

3. SOLIDS CHARACTERISATION

3.1 Fire and Explosion Classification

- 3.1.1 Solids of chemical composition not previously encountered should be checked to identify deflagratory or detonatory substances according to the method given in the 'User Guide to Fire and Explosion hazards in the Drying of Particulate Materials' (Appendix B, Technical Reference No. 4). This guide gives an indication of solids which may be deflagratory or detonating explosives on the basis of chemical composition and oxygen balance. For hazardous solids identified by this method, precautions in the processing of such materials will be specified by BP.

- 3.1.2 Particulate solids of less than 500 micron diameter, as a dust suspended in air, shall be classified as follows:-

Group (a): Dust which ignite and propagate flame.

Group (b): Dust which do not ignite and propagate flame.

The classification shall take account of the full range of applicable particle shapes and sizes (including produced fines), temperatures, pressures and oxygen concentrations. Examples of materials which normally give rise to Group (a) dusts are coal, polystyrene, polyethylene, phenolic resins, phthalic anhydride and hydroxy ethyl cellulose. Examples of Group (b) dusts are fuel ash, millscale and barytes.

Classification from test work at ambient temperature may be applied up to 100°C. At higher temperatures, classification shall be based on testing at the actual temperature.

If the dust is liable to be exposed to temperatures above 110°C, then provisional Group (b) dusts shall be further tested for flammability at 1000°C, to the method in 3.2.4(i). If flame propagation is observed, the dust shall be classified as Group (a) unless it can be shown that the



ignition temperature in °C is more than 50% higher than anticipated plant conditions.

3.2 Characterisation of Group (a) Dusts

3.2.1 Properties

The following properties are commonly used to characterise the fire and explosion properties of Group (a) solids:-

- (a) Explosible concentration.
- (b) Minimum ignition temperature (MIT)
- (c) Minimum ignition energy (MIE).
- (d) Maximum permissible oxygen concentration to prevent ignition (MOC).
- (e) Maximum explosion pressure and rate of pressure rise.

Typical data for some BP products are given in Appendix C.

MIE shall be determined by the method given in [BS 5958](#). Tests to determine these characteristics shall be carried out as described in Appendix B Technical References Nos. 2, 3, 4 and 6.

The use of these results is given in Section 4.

3.2.2 Testing

Solids identified as Group (a) dusts shall be tested for the 'train firing' characteristic, by the train firing test (see Appendix B, Technical Reference No. 5). This test is described in Appendix D.

3.2.3 Explosible Concentration

Group (a) dusts will only deflagrate when at a concentration between the minimum and maximum explosible concentrations. The minimum explosible concentration of the dust suspended in air shall be determined by the 'vertical tube test' as described in Appendix B, Technical Reference No. 3.

Note that the maximum explosible concentration is difficult to measure but is generally around 10 kg/m³ (0.6 lb/ft³). Although a mixture which has a concentration above the maximum explosible concentration is not a flammable atmosphere, it can become so by dilution and shall therefore be considered as a flammable atmosphere.

3.2.4 Minimum Ignition Temperature (MIT)

This is relevant to the situations in which dust comes into contact with a hot surface. Tests shall be carried out on dust suspensions and on dust layers as described in Appendix B, Technical References Nos. 2, 3, 4 and 6.

- (i) Cloud Test: The minimum ignition temperature of a dust cloud in a Godbert Greenwald furnace shall be determined as in Appendix B, Technical Reference No. 3
- (ii) Layer Test: The minimum ignition temperature of the 5mm (0.2in) layer, and of thicker layers of dust if these are unavoidable, shall be determined. The temperature of a hot plate on which the dust is placed is progressively increased to determine the minimum ignition temperature of the layer (see Appendix B, Technical Reference No. 4)

3.2.5 Minimum Ignition Energy (MIE)

The minimum ignition energy is the minimum spark energy that will ignite an explosible mixture of the dust and air at room temperature using a capacitor generated electrical discharge ([BS 5958](#), Part 1). Dust shall be classified according to the minimum ignition energies as follows:-

- (a) Greater than 100 mJ: Not liable to electrostatic ignition.
- (b) 25 mJ to 100 mJ: Liable to electrostatic ignition from an operator even when the plant equipment is earthed.
- (c) Less than 25 mJ: The majority of ignition incidents occur when ignition energy is below this level. The hazard from electrostatic discharges from dust clouds shall be considered.
- (d) At or less than 10 mJ: Highly liable to electrostatic ignition and requires special precautions. Conveying of such powders shall be in an inert atmosphere e.g. nitrogen. Consider restriction on the use of high resistivity materials (plastics).
- (e) At or less than 1 mJ: Extremely sensitive to ignition. Precaution shall be as for flammable liquids and gases.



The minimum ignition energy is very dependent on the particle size, falling with smaller particle sizes. Tests should always be carried out on dust of the smallest relevant particle size.

3.2.6 Maximum Permissible Oxygen Concentration (MOC)

The maximum permissible oxygen concentration to prevent ignition shall be determined for use in establishing inert gas requirements where this is used to protect the system (Appendix B, Technical References Nos. 3 and 6).

This varies from 3% to 15% V/V, depending on the nature of the solid; with most organic dusts, a level of oxygen concentration of 8% is satisfactory for preventing ignition. Coal, however, can contain sufficient oxygen chemically combined to maintain slow combustion, even in an inert atmosphere.

3.2.7 Maximum Explosion Pressure, Dust Explosion Constant and Rate of Pressure Rise

The maximum explosion pressure and the rate of pressure rise shall be determined. Test results from a test vessel of at least 20 litre (4.5 gall.) volume shall be used where practicable, e.g. results from the UK Fire Research Station 20 litre (4.5 gall.) sphere, or the 1m³ (35ft³) explosion chamber (VDI 3673 and Appendix B, Technical References Nos. 6 and 7), are preferred to those from the Hartmann Bomb approx. 1 litre (0.2 gall.), (Appendix B, Technical Reference No. 3). A strong ignition source shall be used for all testing. In the case of the 20 litre (4.5 gall.) sphere, this shall be either a 100 Joule capacitive discharge or a 10,000 Joule (9.5 Btu) chemical detonator.

The 20 litre (4.5 gall.) sphere is limited to material of less than 150 micron in particle diameter. Fines below 150 micron shall be separated for testing where these are present in a dust cloud.

The maximum explosion pressure shall be used to determine the design pressure of plant or equipment designed to withstand the effects of an explosion without venting, making due allowance for inserts in equipment, e.g. bags in filter housings, and increased explosion pressures when two or more vessels are interconnected.

The maximum rate of pressure rise shall be used to classify dusts and determine explosion relief venting and suppression requirements (see Sections 8 and 10).



Group (a) solids shall be classified by the measured maximum rate of pressure rise $(dp/dt)_{\max}$ in the given apparatus:-

$$K_{St} = (dp/dt)_{\max} \times V^{1/3}$$

(K_{St} in bar. m/sec)
20 litre or 1m³ Test
Strong Ignition
Source (10 KJ)

Dust Explosion Class	K_{St} (bar. m/sec)	Characteristics
St.0	0	No explosion
St.1	<200	Weak explosion
St.2	200-300	Strong explosion
St.3	>300	Very strong explosion

The Parameter K_{St} is known as the dust explosion constant.

Data from the Hartmann Bomb or Vertical Tube test may be used only to calculate relief areas by the vent ratio method. For any other application, it can be used only with the agreement of BP:-

Dust Explosion Class	Maximum Rate of Pressure Rise.bar/sec
St.0	0
St.1	<500
St.2	500-1500
St.3	<1500

Only the classification based on strong sources of ignition should be used.

3.2.8 Presence of Flammable Vapours

The presence of flammable vapours even at concentrations well below the lower flammable limits shall be assumed to increase maximum explosion pressure and the rate of pressure rise, and testing shall be carried out to determine the magnitude of the effect, as far as is practicable (see 6.2.12).

3.3 Electrical Properties

3.3.1 If required by BP, the electrical properties of particulate solids in a process shall be determined to characterise the electrostatic properties



of the solid and to assess whether electrostatic discharges are a possible source of ignition, either to the solid itself or to other flammable substances in the plant. The volumetric resistivity of the solids shall be determined by an acceptable method such as in [BS 5958](#): Part 1.

- 3.3.2 Solids with a volumetric resistivity greater than 10^6 ohm.m (3.3×10^6 ohm. ft) have long charge relaxation times and should be considered as likely to produce incendive discharges. They shall be contained within earthed conducting containers (see Section 6).

Note that polymers manufactured by BP have volume resistivities in the range 10^{16} ohm.m (3.3×10^{16} ohm.ft) to 10^{18} ohm.m (3.3×10^{18} ohm.ft) and are considered to be high resistivity powders.

Solids with resistivities less than 10^6 ohm.m (3.3×10^6 ohm. ft) have short relaxation times and should be considered as unlikely to produce incendive discharges.

4. AREA CLASSIFICATION

4.1 Zonal Classification

- 4.1.1 Potentially hazardous areas, outside the dust handling equipment, shall be classified according to the likelihood of the existence of flammable dust atmosphere for the purpose of the selection and installation of electrical equipment in accordance with BP general requirements as follows:-

Zone Z Area in which combustible dust, whether as a layer or a cloud, is, or may be, present during normal processing, handling or cleaning operations in sufficient quantity to be capable of producing an explosive concentration in a mixture with air.

Zone Y Area, not classified as zone Z, where under abnormal conditions combustible dust may accumulate and give rise to combustible dust mixtures with air within the area. A zone in which a flammable dust-air mixture can occur, but is not expected to occur in normal operation. Zone Y areas can occur independently of zone Z areas.

(Note that the definitions and/or designations of zone Z and Y areas may be altered by a forthcoming EU directive. When this is issued, the definitions in this document will be changed so as to be compatible).



4.1.2 Although a mixture which has a concentration above the maximum explosible concentration is not a flammable atmosphere, it can become so by dilution and shall be considered as a flammable atmosphere.

4.1.3 The design, operation and location of process equipment should generally minimise the number and extent of zone Z areas.

4.2 Sources of Release

4.2.1 Process systems with the potential to release only Group (b) dusts do not constitute flammable risks, and shall be excluded from these requirements for area classification.

4.2.2 Plants handling Group (a) dusts under vacuum are generally preferred, as any leak whilst a plant is in operation will be inwards and thus will not give rise to a source of release.

Where process equipment is designed to avoid failure of process containment due to fracture, rupture or impact, such failures shall not be considered as sources of release.

4.2.3 Dust layers shall be considered in area classification, since any release during plant operation will fall out and remain in the vicinity as dust layers.

4.2.4 Where flammable gases may be present, areas shall be classified in accordance with BP Group [RP 44-6](#), in addition to powder classification.

4.3 Sources of Ignition

4.3.1 Potential sources of ignition are fired heaters, unclassified electrical equipment and hot surfaces, defined by the maximum surface temperatures permitted in either zone Z or zone Y areas, also self ignition in bins, silos and other bulk storage devices; determined so as to allow a safety margin from the minimum ignition temperature of the dust concerned (see 3.2.4). The maximum surface or storage temperature shall not exceed:-

- (a) 2/3rds of the minimum ignition temperature in °C of the dust/air mixture.
- (b) 75°C below the minimum ignition temperature of a 5mm (0.2 in) layer of the dust concerned.

- (c) 75°C below the minimum ignition temperature of the relevant dust layer thickness, if this is unavoidably greater than 5mm (0.2 in).
- 4.3.2 Permanent ignition sources, e.g. open fired heaters and hot surfaces shall be at least 1.5 times the normal zone Y distance, (see 4.5.2), from a source of release. Fired heaters, e.g. for inert gas generation, which are closed from the zone Y atmosphere and take their air intake from outside the zone Y area, are permitted, provided that no hot surfaces as defined in 4.3.1 are created (see 4.3.4).
- 4.3.3 The introduction of continuous ignition sources, even for short periods at low frequencies, violate the zone Y concept and shall not be part of the normal design operating philosophy.
- 4.3.4 Major damage to electrical equipment such as that due to a fracture or impact need not be considered as a source of ignition. If any such impacts are considered likely as a design premise, the equipment shall be protected from such an impact.
- 4.3.5 Protective covers or enclosures shall be provided where required to prevent dust contacting hot surfaces, e.g. closely coupled process heaters, steam lines or electrical apparatus.
- 4.3.6 The presence of tramp metal, particularly hot tramp metal, is a source of ignition. Designs should as far as practicable reduce the likelihood of tramp metal in the system and provide facilities for its removal.
- 4.3.7 Electrostatic discharges are a potential source of ignition and the build-up of electrostatic charges shall be avoided (see Section 6).

4.4 Zone Z Areas

- 4.4.1 The following features give rise to zone Z area classification:-
 - (a) Regular breakage of containment for operating purposes, e.g. areas around sample points, bag filling and bag emptying points. Also, breakage of containment of ducts and pipes for the purposes of clearing blockages and cleaning and any places where the containment can be broken without significant engineering efforts e.g. at valved tees, inspection ports and vents. It shall be assumed that dust layers within equipment cannot be cleared prior to breakage of containment.
 - (b) Interior of dust-handling equipment such as filters, silos, air conveying equipment, etc.

- (c) Areas normally inaccessible e.g. behind blast walls. (These areas are not accessible for housekeeping on a frequent basis and are unobserved).
 - (d) Areas underneath equipment such as belt conveyors.
- 4.4.2 The concentration within equipment may be continuously above the maximum explosible concentration, and hence the contents are non-flammable. However, for area classification purposes, such areas shall be classified as zone Z.
- 4.4.3 Zone Z areas within equipment shall extend throughout the enclosed space.
- 4.4.4 Zone Z areas in the open air shall be of minimum extent, 1 metre vertically upwards and horizontally from the point of release and extending vertically downwards to the solid floor level. A zone Y area is associated with each zone Z area.
- 4.5 Zone Y Areas**
- 4.5.1 The following features give rise to zone Y area classification:-
 - (a) Vents to atmosphere from cyclones may lead to emission of a flammable dust cloud due to system malfunction.
 - (b) Vents to atmosphere from filters handling dusts, where system malfunction, e.g. filter bag rupture, may lead to emission of sufficient quantity of dust to create a flammable dust cloud.
 - (c) Releases from systems that are inerted but which may become flammable on dilution with air.
 - (d) Straining and filtering devices requiring to be opened at infrequent intervals, e.g. for cleaning.
 - (e) Safety valve, bursting disc and explosion vents to atmosphere.
 - (f) Valve manifolds in which spades are required to be swung during normal process operations.
- 4.5.2 Generally, plant containing Group (a) dust shall be given a blanket zone Y classification extending from the potential points of releases:-
 - (a) Horizontally 15m (50ft) or to the walls of the enclosure, whichever is less.

- (b) Vertically 8m (25ft) up or to the ceiling, whichever is less.
- (c) Vertically down to solid floor level.

Small zone Z areas should be determined by detailed assessment. Specific experience and judgement should be employed to determine the extent of zone Y boundaries which should be smoothed and adjusted to conform to recognisable features such as walls, plant limits, roads etc.

For vents from bag filters, filtering wash air from elutriators on pellet conveying duties, a 3m radius extent of zone Y shall be given.

- 4.5.3 For enclosed plants, the whole area within the building or enclosure shall normally be classified as zone Y, but the limit shall not normally extend beyond the building walls or the boundaries of the enclosures.

For the particular case of an extruder in a building, the following shall be followed:-

- (a) Minimise the creation of dust in the extruder area.
- (b) Use solid floor, e.g. concrete or chequer plate, for ceiling above the extruder and provide seals around pipe/cable entries through it to avoid migration of dust.
- (c) Use IP 55 enclosures for electrical appliances.
- (d) Provide adequate extraction at feed hopper openings that may create dust hazard e.g. draw magnets, to either remove all dust or restrict the spread to a confined volume.

The extent of zone Z shall be within the extraction zone. If all dust is removed, there is no zone Y.

If dust is likely to fall to the floor, then 3m extent of zone Y outside and zone Z within the extraction air curtain shall be specified.

- 4.5.4 A zone Y area shall be defined where appropriate around items of equipment not encompassed by a 'blanket' zone Y area, and any zone Z areas shall also be identified.

4.6 Area Classification Drawings

- 4.6.1 All zone boundaries shall be shown on drawings, both in plan and in elevation, and these shall be subject to approval by BP.

- 4.6.2 Hatching on drawings to identify zone areas shall be as shown in Figure 1.
- 4.6.3 Typical zone boundaries for an open air plant are shown in Figure 2. The zone Y boundary is 15m (50ft) from equipment containing Group (a) dusts at ground level, extends to 8m (25ft) high, or 3m (10ft) above the elevated equipment surfaces, whichever is the higher.
- 4.6.4 Typical zone boundaries for plant equipment located within an enclosed building area are shown in Figure 3.
- 4.6.5 Drawings for plant containing sections handling a range of materials shall either be drawn in terms of the most onerous temperature limit, or shall identify the boundaries to those areas within which materials have different temperature limits. This may be achieved by defining the individual areas by dotted lines and recording the specific temperatures within each boundary.
- 4.6.6 Personnel exclusion zones shall be shown (see 8.8).

5. ELECTRICAL EQUIPMENT

5.1 General

Electrical equipment shall not be installed in locations where Group (a) dust may be deposited in thicknesses that cannot be controlled.

Electrical equipment shall be selected and installed in plants handling Group (a) dust in accordance with the requirements of BP Group [RP 12-2](#).

In practice, equipment to electrical dust classification is not readily available, but equipment classified to EExN is suitable for dust duties also. Typically, equipment whose surface temperature does not exceed 200°C is suitable for BP products listed in Appendix C.

6. STATIC ELECTRIC DISCHARGES - PREVENTION

6.1 General

- 6.1.1 The design of plants handling Group (a) dusts shall be in accordance with [BS 5958](#): Part 1 and 2 or local equivalent national standard approved by BP.



- 6.1.2 The design of plants handling Group (a) dusts shall satisfy the requirements outlined below within areas classified as zone Z or Y, to eliminate the hazards of static electricity.

6.2 Design Measures

- 6.2.1 Connections for electrical continuity shall be provided so that the earth resistance does not exceed 10^6 ohms, unless non-conducting pipes are used.

The use of non-conducting plastic pipes for conveying Group (a) high resistivity solids ($>10^{12}$ ohm.m) is generally **not** recommended, unless careful checks are made to ensure that hazardous static electric discharges will not occur (see 3.3).

- 6.2.2 Particular attention should be given to the possibility of static electric energy generation in the design of silos, bunkers and similar storage vessels for particulate solids. The design of these vessels is covered in Section 15 of this Recommended Practice.
- 6.2.3 Machinery used to process Group (a) solids such as grinders, classifiers, mixers, etc. shall have all conducting parts earthed. In some cases, this may require the use of bonded earthing strips, e.g. when a bearing is non-conducting.
- 6.2.4 All metallic parts of a fill-pipe assembly for road tankers shall form a continuously earthed path. Electrical continuity shall also be provided between the fill-pipe and the tanker. This may be achieved by means of a bonding cable.
- 6.2.5 Epitropic (partially charred acrylic fibre) or other conducting fabric shall be used for filter bags.
- 6.2.6 Areas of non-conducting plastic surfaces greater than 200mm^2 (0.3in^2) shall not be used. Conducting plastics may be used.
- 6.2.7 Designs should not require operators during normal operation to enter areas where hazardous levels may be present of Group (a) dusts with minimum ignition energies of less than 100mJ.
- 6.2.8 If a Group (a) dust at the relevant particle size has a minimum ignition energy of less than 25mJ, conductive flooring shall be used.
- 6.2.9 Designs shall avoid charge densities greater than 10^{-5}C/m^2 . The charge density on a solid can be measured by using a Faraday cup and electrometer.

- 6.2.10 Designs shall avoid field strengths of greater than 5kV/cm. The field strength is measured using a field meter.
- 6.2.11 Designs shall avoid a potential for charge transfers between two points of greater than 75×10^{-9} C.
- 6.2.12 Designs shall avoid the addition of high-resistivity solids, i.e. greater than 10^6 ohm.m, to a vessel containing a potentially flammable atmosphere due to the presence of a fluid, unless approved by BP. Where the addition of high resistivity solids to a vessel containing a potentially flammable atmosphere is unavoidable, one or more of the following measures may be taken:-
- (a) Maintain the flammable liquid in the vessel at a temperature below its flash-point.
 - (b) Provide an inert atmosphere, e.g. nitrogen blanketing.
 - (c) Add the particulate solid via an earthed hopper and thence via an earthed screw feeder.
 - (d) Dampen the solid with a conducting fluid.

7. INERTING

- 7.1 Inert gas systems may be used to reduce the level of oxygen in a system to a level where a fire or explosion cannot occur. Where inerting is used as the sole means of protection, the inert gas systems shall be of high reliability and shall be provided with oxygen analysers or other suitable protective devices initially to warn of any malfunction of the inerting system, and subsequently to shut down the system protected in a safe manner.
- 7.2 An inerting system based on the recycling of inert gas shall be designed with a suitable purge or blow-down so that there is no build-up of undesirable contaminants from any source.
- 7.3 Systems involving the use of inert gas shall be fitted, if practicable, with interlocks to prevent the operation of the system unless the oxygen concentration is within the acceptable range. Interlocks shall also be provided to prevent entry into vessels protected by inerting before adequate purging has been carried out.

8. PRIMARY EXPLOSION RELIEF

8.1 General

8.1.1 Where flammable concentrations of dust inside a plant are possible and sources of ignition cannot be totally eliminated, the following design measures shall be taken:-

- (i) To limit the volume of dust-air mixture involved.
- (ii) To prevent a fire or explosion spreading within the plant.
- (iii) To contain flame and hot gases produced by an explosion within the plant or relieve an explosion to a safe atmospheric location.

8.1.2 Where the requirement of explosion relief is established and the statutory authority does not recommend the system by which the relief areas are to be calculated, the relief areas shall be calculated by:-

- (i) The cubic law system (see 8.2) wherever practicable.
- (ii) The vent ratio system (see 8.3), where applicable, but only when insufficient information is available to apply the cubic law.
- (iii) Where neither (i) nor (ii) are applicable, e.g. in high aspect ratio buildings (see 8.4) and in cases of detonative combustion or high pressure operation, BP will specify requirements.

8.1.3 The presence of flammable gas or vapour with the dust will add to the severity of an explosion, even though the concentration is below the lower flammable limit. Where the hydrocarbon concentration is more than 0.2% vol, the hydrocarbon shall be taken into account when sizing the explosion relief system.

8.1.4 The solids shall be characterised as described in 3.

8.2 Cubic Law System of Relief Area Calculation

8.2.1 The cubic law system calculation method is given in [NFPA 68](#) and the [VDI 3673](#) guidelines. Only nomographs based on the strong ignition sources shall be used without the prior consent of BP.

8.2.2 The limitations of the cubic law method of calculation are:-

Maximum vessel volume	1000 m ³
Maximum length: diameter ratio	5:1
Maximum reduced explosion pressure, Pred	2 bar (ga)



Maximum vent cover mass/vent area ratio	Max 15 kg/m ² but preferably 10 kg/m ² or less
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Outside these limits, the vent ratio system shall generally be used.

The above only applies to vessels with an aspect ratio of approximately 5:1, e.g. silos; for taller, thinner vessels see 8.4.

8.3 Vent Ratio System of Relief Area Calculation

- 8.3.1 The vent ratio system of relief area calculation shall generally be used outside the limits in 8.2.2 and for weak vessels, where the pressure limitation is 0.2 bar (ga) (3 psig) or less, except that the vent ratio system is only applicable to very low aspect ratio vessels (vessel height to diameter ratios of 1.5:1 maximum); otherwise see 8.4. The vent ratio system of relief area calculation is summarised in Appendix E.

8.4 High Aspect Ratio Vessels

- 8.4.1 High aspect ratio vessels are those having a height to diameter ratio greater than 1.5:1 for the vent ratio system and greater than 5:1 for the cubic law system.
- 8.4.2 As far as possible the entire roof area shall be for relief venting (see 8.7.4). The only allowable exception are the location of necessary equipment, and the protection of operating personnel on the roof; the design should minimise such requirements.
- 8.4.3 The installed vent area shall never be less than the area calculated by the vent ratio or the cubic law system, ignoring the aspect ratio.
- 8.4.4 The vessel volume shall not exceed 1000 m³ (35 000 ft³).
- 8.4.5 Vents shall be placed only in the roof, not in the walls, of high aspect ratio vessels.

8.5 Relief Ducts

- 8.5.1 Those parts of enclosures, vessels, etc. which contain relief devices shall, as far as possible, be located in the open air, to minimise the risks of secondary explosions and to avoid the requirement for ducting the combustion or explosion products to a safe location.
- 8.5.2 Relief ducting shall not be used on vessels with vents designed by the vent ratio system.

- 8.5.3 Where location within a building or enclosure is unavoidable, the use of even short relief ducting may increase the explosion pressure within the vessel. The relief duct pressure drop shall be determined using [NFPA 68](#) and incorporated in the calculations to determine the relief area and vessel pressure tolerance.
- 8.5.4 Relief ducts shall be absolutely straight and as short as possible; preferably less than 3m (10ft), no longer than 5m (16ft) without the approval of BP, and in no case longer than 10m (32ft). This is to avoid the possibility of transition to a detonative explosion mode.
- 8.5.5 Relief ducts shall be preferably of round cross-section and shall not change in shape.
- 8.5.6 Relief ducts shall be of at least the same cross-sectional area as the vent which it serves, and the open end of the relief duct shall be unobstructed (see 8.7.1 h.)
- 8.5.7 Relief ducts shall be to the same design pressure rating as the vessel which it serves and the reaction forces which may be imposed on it by a relief or explosion event shall be allowed for in design.
- 8.5.8 Access doors or a suitable removable section shall be provided in relief ducting to facilitate inspection and maintenance.
- 8.5.9 Where rain water or condensation is liable to accumulate in relief ducting, low point drains with a minimum nominal diameter of 40mm (1.5 in) shall be provided. Weather caps or cowls should not be used.

8.6 Connected Vessels

- 8.6.1 If two or more vessels are connected by unobstructed pipework or ducting, the effects of a fire or explosion in one on the contents of the other shall be taken into account in the design. The significant effects to be considered are precompression, increased turbulence - leading to the formation of dust clouds, and ignition by a large surface area flame jet. These will increase the potential violence in the second vessel and are known as 'pressure piling'.

This effect is particularly severe if the vessels are of significantly differing sizes; in this context this is defined as $vol_1 > 1.5 \times vol_2$.

8.6.2 Where relief devices protect connected vessels, the design shall meet the following requirements:-

- (a) The vent area shall be sized for the lowest practicable relief device activation pressure and based on the strong ignition/turbulence nomograph.
- (b) Where the enclosures have approximately the same volume ($\Delta V \pm 10\%$), both shall be relief vented according to the normal requirements.
- (c) Where the enclosures differ significantly in size the relief areas are calculated as normal but the vessels shall be designed to withstand a pressure of 2 bar(ga) (30 psig). If the smaller vessel is not relief vented, it shall be designed to have a pressure shock resistance of at least the relevant maximum explosion pressure.

8.7 Relief Devices

8.7.1 General

Various types of relief device may be used but the design of the system shall meet the following requirements:-

- (a) The relief device shall be located so that there is no obstruction to the flame front, e.g. by internal vessel fittings, as it passes towards the vent.
- (b) The relief device shall be designed to minimise the partial sealing effects of corrosion, careless over-painting (especially of the edges of explosion doors) and accumulations of snow and ice.
- (c) The relief device shall be designed so that accumulation of solids cannot occur on the inside of the opening.
- (d) The effects of ageing, and both ambient and design temperatures on systems relying on plastic or rubber components shall be considered in the design, and procedures for the maintenance or replacement of necessary vulnerable parts established.
- (e) The inertia of the system shall be minimised. Light explosion panels or doors are preferred. The weight per unit area of such devices shall not exceed 10 kg/m² (2 lb/ft²).
- (f) The vent set pressure shall be minimised. However the effects of wind pressure may become significant at set pressures below 0.035 bar(ga) (0.5 psig).



- (g) Vacuum supports shall be provided, and internal grids as necessary to prevent personnel from falling through unprotected weak panels.
- (h) The vent from the relief device, including ducts, etc., shall be unobstructed as far as practicable. The use of deflector plates, cowls and similar devices shall be subject to approval by BP.
- (i) Pressure sensors shall be used to monitor the activation of the relief device. Interlocks shall be provided on the feed and discharge valves such that upon such detection, the isolation valves are closed and/or rotary valves are stopped.

The pressure sensors can be integral with the relief device or mounted on the protected vessel itself.

8.7.2 Bursting Discs/Panels

- (a) The design shall prevent fragments from brittle or deformable discs and panels becoming missiles that might endanger personnel or other equipment.
- (b) Deformable panels, i.e. bursting panels made of plastic or metal foil, which will tear rather than shatter when subjected to the design over-pressure, may be used. However, alternative relief devices shall be sought when the normal working pressure is close to the bursting pressure, or if the vessel is subject to high temperatures or pressure cycles during normal operation. Testing of the bursting device may be required.
- (c) Re-usable panels of non-breakable material may be considered if a satisfactory seal can be devised. They shall be restrained, e.g. by chains, so as not to become missiles.

8.7.3 Explosion Doors

Explosion doors shall be fitted with resilient buffers to cushion the impact as the door opens at high speed following an explosion. They may be held closed by mechanical or magnetic latches or by their own weight. When relevant, the self-closing potential of explosion doors shall be utilised, if practicable.



8.7.4 Weak Roof Seams

The entire roof of large or tall silos may if necessary be made into vent area by incorporating weak roof seams into the design. These shall be in accordance with [API Std 2000](#).

8.8 Personnel Exclusion Zones

8.8.1 General

Although the successful venting of a dust explosion may eliminate high overpressure inside the equipment, the effects of the vented explosion outside the vent cannot be discounted. The most obvious effect is that a flame is ejected, but because more dust is involved than can be burnt, much unburnt dust is also ejected from the vent. A secondary flash explosion can then take place ignited by the vented flame and utilising the oxygen from the surrounding air.

The blast and pressure effects from the vented explosion can also have harmful consequences e.g. damage to ear drums, serious injury to personnel, damage to nearby plant. It is therefore important that the extent of the flame produced by the vented explosion be limited. Deflectors should be installed on vents to guide the vented explosion to a safe area, especially away from personnel and weak parts of the structure.

8.8.2 Access Restrictions

Unless otherwise protected, personnel access shall be excluded from the following areas of an operating equipment fitted with a relief device:

- (a) 15m in the direction of a flame likely to issue from such a vent,
- (b) If a strongly mounted deflector plate is installed in front of an explosion vent, then 7-10m behind the deflector plate
- (c) 3 to 5 times the vent dimension at right angles to the direction of the flame.

These areas should be identified on the area classification drawings.

9. SECONDARY EXPLOSION RELIEF

9.1 General

Secondary explosion relief is applied to buildings rather than plant. In general, the vent area to volume ratio allowed is lower, reflecting the



greater volume of the buildings which results in a lower rate of increase in explosion pressure. Explosive concentrations within buildings will exist only in pockets, rather than as the more uniform explosive mixtures likely in vessels. Buildings containing equipment handling group (a) dusts shall be equipped with secondary relief facilities.

9.2 Relief Facilities

9.2.1 Buildings shall be sub-divided for the purposes of relief calculations into ground areas with a length to width ratio of no more than 3. In a rectangular building when $L_1:L_2$ is greater than 3, the effective value of width shall be taken as $(L_1 \times L_2)^{1/2}$.

9.2.2 The vent areas shall then be calculated by the method of [NFPA 68](#):-

$$A = (C \times L_1 \times L_2) / P^{1/2}$$

Where

A	=	Vent area (m ²)
L ₁	=	Smallest dimension of the rectangular enclosure (m)
L ₂	=	Second smallest dimension of the rectangular enclosure (m)
P	=	Maximum internal building pressure that can be withstood by the weakest member not designed to bend or break (kN/m ²)
C	=	A constant, characteristic of the dust; this characteristic number will be supplied by BP, e.g. 6.8 (SI units) for organic dusts.

9.2.3 Vent areas should preferably be distributed over all walls of the building and shall never be confined to one wall only.

Where walls are designed to resist blast effects or where silos having roof explosion panels are housed under cover, venting through restrained roof panels can be used.

9.2.4 Venting of buildings may be achieved via its window areas. In such a case, the window material shall be light, not more than 7.5 kg/m² (1.5 lb/ft²), mounted in a rigid framework, suitably sealed against the weather but able to blow out from the mounting frame. The windows shall be restrained to prevent them becoming missiles e.g. by hinges or chains. Adjacent pedestrian and working areas shall be protected.

10. EXPLOSION SUPPRESSION

10.1 General

- 10.1.1 In the design of plants handling Group (a) dusts, the provision of explosion suppression should be considered. In systems where there is thought to be a high probability of an explosion by virtue of historical or other evidence, the provision of explosion suppression should be the primary safety system. If the risk of explosion is thought to be low, venting and explosion relief should be regarded as sufficient protection for the plant.
- 10.1.2 Explosion suppression systems shall be designed so that their operation does not in itself produce an additional hazard by, for example, overpressuring the system or causing relief devices to open unnecessarily and allow the ingress of oxygen. Explosion suppression systems containing explosive materials shall not be positioned to constitute a hazard to personnel.
- 10.1.3 Explosion suppression systems on large plants shall be designed in groups between isolation equipment such as en-masse conveyors or rotary valves, so that an explosion in one area does not activate unnecessary parts of the plant.
- 10.1.4 Whenever an explosion suppression system has been activated, the equipment concerned should be shut down and inspected before operations are allowed to restart.
- 10.1.5 An explosion suppression system should typically consist of:-

Detectors.
Control Unit.
Suppressant System.
- Details of the system (detection, control and suppression) shall be subject to approval by BP.

10.2 Detectors

- 10.2.1 The type and location of explosion detectors shall be subject to approval by BP.
- 10.2.2 Designs shall permit the removal, inspection and testing of detectors at frequent intervals.
- 10.2.3 Detectors shall be placed close to the point at which an explosion could be generated, and throughout the plant.



- 10.2.4 If pressure type detectors are used, two shall be mounted at right angles to each other at each location, to prevent spurious activation if significant plant vibration occurs. The suppressant system shall be activated on the operation of two or more sensors.
- 10.2.5 Pressure rise detectors are not activated by fire and so the installation of fire detectors should also be considered.
- 10.2.6 In equipment where normal pressure fluctuations may temporarily exceed the threshold level for which activation is necessary, pressure rise type detectors shall be used.
- 10.2.7 Detectors shall be protected against the ingress of moisture or other contaminants that might impair their performance.
- 10.2.8 In any detector installation, an indication of first unit activated' shall be provided.
- 10.3 Control Unit**
- 10.3.1 Control unit actions, upon receipt of a signal from the detector units, shall:-
- (a) Actuate the suppression system.
 - (b) Shut down the equipment in a predetermined safe manner.
 - (c) Actuate an alarm.
- The control unit shall be linked into the fire alarm and plant shut-down logic system.
- 10.3.2 A control unit shall have a class B power supply, as specified in BP Group [RP 12-5](#) to maintain availability of the explosion suppressant system during the run-down of a plant following a power failure.
- 10.3.3 A control unit shall be designed so that start-up of the equipment it protects is prevented when the suppression system is not in operation, and entry into equipment protected by a suppression system shall not be possible unless the suppression system is deactivated, e.g. by key interlocks. However, means shall be provided to test the control system while the plant is in operation.
- 10.3.4 The design of a control unit shall permit the operation of individual items of equipment with no product throughput, for test purposes.

10.4 Suppressant System

- 10.4.1 Suppressant equipment shall be designed to quench a combustion wave as close as possible to the source of the explosion by discharging a spray of liquid, powder or inert gas, as soon as possible after the suppressant system is activated.
- 10.4.2 Liquid (Halon) explosion suppressants shall not be used for initiation system pressures greater than 0.1 bar(ga) (1.5 psig). Halon should be avoided where possible as this material is being phased out.
- 10.4.3 When liquid suppressants are used in conjunction with self-closing relief doors or valves, vacuum relief shall be provided unless the equipment is designed to take full vacuum.
- 10.4.4 Powder suppressants, e.g. ammonium phosphate, shall be used where violent explosion hazards are anticipated and where pressure rise detection is used because of the high initial pressure. Connected plant shall be designed to withstand a pressure pulse of 1 bar above the normal design pressure.
- 10.4.5 Suppressant containers shall be isolated from the system if there is any possibility of their accidental discharge during maintenance of the equipment protected by the suppressant.
- 10.4.6 When suppressant containers are attached via hoses, these hoses shall be properly secured (not with hose clips) and conform to national standards such as [BS 1435](#) and [BS 3492](#).
- 10.4.7 Ductwork used to vent equipment shall be designed for the pressures in the duct resulting from the suppressed explosion.

11. FIRE SUPPRESSION

11.1 General

- 11.1.1 In the design of plants handling Group (a) dusts, the suppression of fire should be considered, particularly to avoid a source of ignition for secondary explosions.
- A fire suppression system should be provided to prevent fire or explosions in receiving bins and silos when the system is not otherwise protected by inerting (see Section 7).
- 11.1.2 Fire suppression systems shall be actuated only when two or more detectors have indicated the presence of fire. Manual activation shall also be provided.



11.1.3 A fire suppression system should typically consist of the following:-

Detectors.
Control Unit.
Suppressant System.

Details of the system (detection, control and suppression) shall be subject to approval by BP.

11.2 Detectors

11.2.1 The main fire detection duties and the type of detectors to be used shall be as follows:-

- (a) Dusts and dust clouds, lean phase operations: use IR detectors.
- (b) Silos, bag filters, cyclones, dense phase operations: use temperature sensitive detectors, either rate of temperature rise or temperature threshold, or combined rate of rise/threshold temperature detector.

11.2.2 IR detectors, when installed, shall be:-

- (a) Insensitive to changes in surrounding light.
- (b) Set to give a cross-sectional cover of equipment.
- (c) Positioned so that any harmless sparks, emanating from say grinding machinery, have time to die before reaching the detector.
- (d) Arranged in banks of at least seven detectors.

11.2.3 Temperature detection heads in silos, bins, bag filters, cyclones, etc., shall be located at various levels throughout the equipment.

11.3 Control Unit

11.3.1 The control unit actions, upon receipt of at least two signals from the detector units, shall:-

- (a) Actuate the suppression system.
- (b) Shut down the equipment in a predetermined safe manner.
- (c) Actuate an alarm.



The control unit shall be linked into the fire alarm and plant shut-down logic systems.

11.3.2 The control unit shall have a class B power supply (see BP Group [RP 12-5](#)) to maintain availability of the fire suppressant system during the run-down of a plant following a power failure.

11.3.3 The control unit shall be designed so that start-up of the equipment it protects is prevented when the suppression system is not in operation and entry into equipment protected by the suppression system shall not be possible unless the suppression system is deactivated, e.g. by key interlocks. However means shall be provided to test the control system while the plant is in operation.

11.3.4 The design of the control unit shall permit the operation of individual items of equipment with no product throughput, for test purposes.

11.4 Suppressant System

11.4.1 Suppressant equipment shall be designed to quench a fire as close as possible to its source. The use of bursting discs would permit the minimum distance between detectors and extinguishing zone in ductwork systems.

11.4.2 The use of carbon dioxide propellant should be considered in silos, bins, cyclones, etc.

11.4.3 The use of water as the simplest extinguishing agent should be considered for use in ductwork. When employed, it shall be used through a deluge system.

11.4.4 Water deluge systems shall not be used in bulk systems such as silos and filter housing where there is a danger of forming explosive dust clouds.

11.4.5 Water based foams may be used in bulk systems.

11.4.6 Inert gases such as carbon dioxide, nitrogen or Halon may be used in ductwork but shall be contained within the extinguishing zone by the system design of isolating valves.

11.4.7 Because fans cannot be stopped very quickly, quick-acting valves shall be used to divert the airstream.

11.4.8 The discharge of suppressants such as carbon dioxide and Halon can potentially give rise to a source of ignition due to the production of a

static electric discharge. The precautions given in Section 6 shall be applied to the suppressant system, with the additional requirements of 11.4.9 to 11.4.12.

- 11.4.9 Antistatic nozzles shall be used. Discharge nozzles shall be of the simplest form consistent with achieving the required distribution of the suppressant.
- 11.4.10 Directional horns shall not be used.
- 11.4.11 The nozzles shall be sited in a clear space so as not to impinge high velocity solid particles or jets on surfaces. A minimum clearance of 0.5m (20in) shall be used.
- 11.4.12 Means shall be provided for the removal and the prevention of the accumulation of foreign matter, such as corrosion products, in the distribution pipework.

12. BLAST WALLS

12.1 General

Blast walls for personnel protection shall be provided in addition to the normal facilities when:-

either

- (a) Flammable dust forms an atmosphere liable to cause an explosion so severe that suppression and venting systems cannot be totally relied upon.

Or

- (b) An explosion suppression system is used on a system liable to frequent incipient explosions.

12.2 Design

- 12.2.1 Blast walls shall be designed as rectangular boxes, with the roofs fully open, except for light-weight panels for weather protection as required.
- 12.2.2 Blast wall enclosures shall be designed as tall silos (see 8.4). From the characteristics of the dust, the area of the roof and the enclosure volume, the maximum explosion pressure shall be calculated by the cubic law using the nomograph for strong ignition/turbulence in [VDI 3673](#). The static activation pressure of the roof shall be taken as 0.1 bar(ga) (1.5 psig).



- 12.2.3 The maximum explosion pressure in the enclosure shall be considered as a static loading applied to the walls, but it is in fact an instantaneous dynamic load, and as such shall not be included in the foundation design of the enclosure.
- 12.2.4 Materials which may be considered for the structural elements of the design shall have suitable ductility, and shall not be brittle. Reinforced brickwork, cast in-situ reinforced concrete structure, reinforced concrete panels and protected metal sheeting are acceptable; mass concrete and masonry are not acceptable.

13. PIPING

13.1 General

- 13.1.1 Eliminate the possibility of adding burning material or other ignition sources e.g. tramp metal striking pipe wall, to transfer piping as far as practicable.
- 13.1.2 For Class St2 and St3 dusts (as defined in paragraph 3.2.7), it is as yet not practical to design piping to withstand explosion pressure.
- 13.1.3 In lieu of designing for detonation pressures, class St1 (as defined in paragraph 3.2.7) dusts may be handled in systems designed to withstand 10 bar (ga) without bursting (see [NFPA 68](#)).
- 13.1.4 The length of pipes handling group (a) dusts shall be minimised.

13.2 Design

- 13.2.1 For Class St1 dusts, piping shall be designed to withstand a test pressure of 1.5 times the maximum normal operating pressure.
- 13.2.2 Piping shall be checked to ensure that it can withstand the shock loading generated by 10 bar (ga) pressure without bursting.
- 13.2.3 If especially high pressures are expected at bends or end flange of long pipe lines (> 20 m) these must be released in axial direction without decrease of cross-section. Use bursting discs or other tested relief devices with set pressures 1.5 to 3 bar (ga).
- 13.2.4 For Class St2 and St3 dusts explosion vents shall be provided per [NFPA 68](#) for the particular initial velocity, length to diameter ratio and Pred requirements.



- 13.2.5 For all other requirements piping shall be designed in accordance with BP Group [RP 42-1](#) where applicable.
- 13.2.6 Piping between vessels shall be designed for explosion pressures in either vessel, making due allowance for venting, suppression or other explosion control systems.
- 13.2.7 Piping shall be designed to avoid accumulation of dust. Where expansion bellows or other items of equipment liable to collect dust are used, purging or other methods of dust removal shall be provided.

14. CONVEYORS

14.1 General

- 14.1.1 Sources of ignition shall, as far as practicable, be eliminated from the design, particularly electric discharges and hot tramp metal.
- 14.1.2 Electrical bonding shall be provided to ensure a continuous electrical path to earth from all equipment and conveying lines (see Section 6). The electrical continuity shall be checked after construction.
- 14.1.3 The design shall include facilities to exclude or remove tramp metal from the system as and when appropriate.
- 14.1.4 Choke devices shall be provided to prevent the transmission of an explosion from one section of the plant to another (see 14.4).
- 14.1.5 Conveying systems and associated equipment shall be located in the open air unless specific design requirements by BP necessitate indoor location. For example, a bagging point may require indoor location but storage and lines shall be in the open air and fed to the bagging point by a suitable choke (see 14.4).
- 14.1.6 Where conveying equipment is located indoors and an inert gas suppression system is not installed, the equipment shall be fitted with suitable explosion relief panels and ducts to convey the vented gases to a safe outdoor location. The equipment layout should be designed to minimise the length of both conveyors and relief ducting.
- 14.1.7 Where a moisture content in a solid can be tolerated, or can be removed later in the process, the solid may be damped by, say LP steam spray, to prevent the accumulation of static charges. The spray nozzle shall be made of an electrically conducting material and shall be earthed. This system shall be used when practicable for the conveying of dusts with a minimum ignition energy of less than 10 mJ.



14.2 Pneumatic Conveying

14.2.1 Air should be used as the conveying gas whenever practicable, with the addition of fire and explosion suppressant systems when appropriate. The use of closed-circuit inert gas carrier systems may be considered for particularly dangerous powders with a high percentage of fines and a low ignition energy, or when there are proportions of flammable gas present with a lower ignition energy than the powder. Inert gas shall be used to convey solids when the flammable gas or vapour content is likely to exceed 33% of the relevant lower flammable limit.

Inert gas carrier systems shall be used in any cases of doubt. Inert gas systems shall be of closed-circuit, recycle type wherever practicable.

14.2.2 In pneumatic conveying systems, the material to air ratios used shall be defined as follows:-

	kg material/kg carrier gas
Lean phase	less than 5
Medium phase	5 to 50
Dense phase	above 50

14.2.3 Concentration of fine material at the disengagement device at the receiving end of a transfer system can give rise to a hazard, due to the combination of particle size range and concentration, in a system which otherwise is non-hazardous. In such cases, specific design measures shall be taken to eliminate it.

14.2.4 To avoid blockages in pneumatic conveying systems that operate in the batch mode, the systems shall be designed for the following operating sequence:-

- (a) Conveying gas only.
- (b) Conveying gas plus solids.
- (c) Conveying gas only to clear lines.

Blockages in the pipework can usually be detected by an increase in the pressure at a point prior to the introduction of the solid, and suitable facilities shall be provided for this detection duty.

14.3 Screw, Vibrating and En-Masse Conveying

14.3.1 Internal moving parts shall be considered to constitute a source of ignition in a conveying system.

14.3.2 Explosion relief shall be assessed and designed as follows:-

either

- (a) For conveyors with short transfer piping (3m (10ft) or less) and for conveyors where the transfer piping is effectively full, thus inhibiting the propagation of dust clouds and explosions, the boot and hood volume shall be treated as for vessels (see Section 8) and the transfer piping as piping (see Section 13).

or

- (b) For long conveyors (more than 3m (10ft)) and for conveyors where the transfer piping will allow the propagation of dust clouds and explosions, the boot and hood volume shall be treated as a vessel (see Section 8) and explosion relief panels shall be placed in the transfer piping with a vent area not less than the area calculated by the same system as used on the boot and hood.

14.3.3 Purging by a small inert gas purge through the upper part of the casing may be used for screw conveyors.

14.4 Choke Devices

14.4.1 Rotary valves may be used as chokes to separate parts of the plant for the purposes of explosion protection. The rotary air lock shall be immediately shut down automatically to prevent a secondary fire or explosion downstream due to the transport of smouldering material or burning product.

14.4.2 For the rotary valve acting as a choke, the thickness of the rotary vanes for Class St1 dusts shall be not less than 15mm. The radial gap width between the tip of the rotary vane and the housing wall shall not be more than 1.25mm. There shall be two or more number of vanes per housing side always in diametric opposition.

14.4.3 Screw conveyors can form a partially effective choke if the trough runs partially full. If a screw conveyor is required to act as a choke, this may be achieved either by the removal of one or more flights in the screw in sloping conveyors, or an internal baffle across the top half of the trough casing in horizontal conveyors.

14.4.4 Rapid-action valves may also be used to disconnect parts of a plant from the effects of an explosion, but their use is subject to BP approval in each case.



15. BINS AND SILOS

15.1 General Design

Specific attention shall be given to the possibility of static electric energy generation in the design of silos, bunkers and similar storage vessels for particulate solids. These vessels shall be constructed from conducting materials and earthed through the framework of the structure. Any accessory shall be of electrical conducting material and electrical continuity shall be maintained between the accessory and the vessel structure. (See 6.2).

15.2 Mechanical Design

15.2.1 The design pressure shall include the pressure which may occur transiently during any possible explosion and the requirements for explosion relief, if fitted.

15.2.2 The supporting structure shall take account of the possible recoil reaction which may occur when the vessel is vented.

15.2.3 In some cases, it is practicable to design vent such that the deflagration pressure inside the vented enclosure is prevented from exceeding two thirds of the ultimate strength of the weakest part of the enclosure which must not fail. This criterion does anticipate that the enclosure may bulge or otherwise deform. This explosion pressure shock resistance (EPSR) method is only to be used with permission from BP.

15.2.4 The localised effect from suppression bottles reacting against the bin shall be taken into account in the design of connecting nozzles.

15.3 Location

15.3.1 Bins and silos should be located in safe areas as far as practicable, with respect to area classification of flammable liquids and vapours. Note that location and spacing should permit safe access for all operation and maintenance requirements.

15.3.2 Explosion vents and bursting panels shall be located so as not to discharge into areas routinely accessible to personnel. If this is not possible, ducting or solid screening of a suitable material shall be provided (See 8.8).

15.4 Solids or Transfer Medium Disengagement

15.4.1 Lean Phase Systems.



- (a) Bag filters are used where a very low discharge to atmosphere is required.
- (b) They shall be isolated from the body of the vessel which they feed by a rotary valve or other effective choke (see 14.4).
- (c) Where an inevitable higher rate of solids loss is acceptable, cyclones may be used.
- (d) The receiving vessel shall be provided with a separate vent and not vented through the cyclone, since this would reduce its efficiency. Note that multiple cyclones are used in series to obtain efficiencies that are greater than in single cyclones but less than in bag filters.

15.4.2 Dense Phase Systems

In dense phase transportation systems where the flow is directly to a receiving vessel, the exhaust may produce an unacceptable emission. Bag filters should be fitted; internal type bag filters are acceptable.

15.5 Inerting and Pressure Relief

- 15.5.1 Pressure relief shall be provided to protect vessels from overpressuring by the transport medium in the event of blockage of the normal vent.
- 15.5.2 If vents are fitted with closure devices, they should be designed so that they do not allow the development of a vacuum in the enclosure after heated gases have cooled.
- 15.5.3 Unless vessels are designed for full containment of explosion pressures or are protected by continuous inerting, vessels handling Group (a) dusts shall be provided with explosion relief or suppression.
- 15.5.4 The effect of vapour and powder components on the lower flammable limit of a mixture shall be considered to be additive. The much lower ignition energy of flammable vapours increases the probability of an explosion in a vapour/powder mixture over that in a powder-only system. If there is any significant risk of vapour contamination in an upset condition, e.g. in the first in-line vessel after a reactor containing a flammable vapour, the system shall be protected by inerting rather than by the provision of explosion relief only.

Where there is a less significant risk of flammable vapour contamination and air is the conveying medium, a flammable gas detector may be fitted, set to alarm at 25% of the LFL. A permanent piped supply of

inert gas shall be provided for batch inerting of the system in the event of a gas exceeding 25% of the LFL.

- 15.5.5 Small vessels up to 0.6 m³ (20 ft³) size, containing material with a maximum rate of pressure rise of less than 345 bar/s (5000 psi/s), do not require explosion protection or prevention unless specified by BP.

15.6 Instrumentation

Oxygen, flammable gas, etc. meters shall be of the aspirated sample type. They shall incorporate control room mounted malfunction alarms including a 'loss of sample flow' alarm.

16. FILTERS AND CYCLONES

16.1 Bag Filters

- 16.1.1 Bags may be cleaned by reverse jet purge flow or by reverse blow. Reverse blow units shall be subdivided so that bags to be blown can be taken out of use. Cleaning by mechanical shakers shall not be used.
- 16.1.2 A reverse jet purge pulse shall be steep fronted and of less than one second duration. The minimum purge gas pressure should be 5 bar(ga) 72.5 psig) and the maximum 8 bar(ga) (116 psig).
- 16.1.3 The bag clamping arrangement at the bag top shall hold the bag in place vertically, shall be accessible from the clean side and shall provide an electrical earth connection.
- 16.1.4 Filter bag materials shall be chosen principally for their chemical resistance, thermal stability and mechanical strength. Filter bag materials shall be conducting or antistatic. Stainless steel or partially charred acrylic fibre (epitropic) are acceptable means of providing conductivity.
- 16.1.5 The position of entry of the dirty gas to the bag should be from below.
- 16.1.6 Bags for reverse jet cleaning shall not exceed 115mm (4.5in) diameter and shall not exceed 3.05m (10ft) in length.
- 16.1.7 Explosion relief shall be installed on filter housings handling Group (a) dusts. Explosion suppression shall not be relied upon, due to the difficulty of sensing the whole volume of the filter housing and adequately distributing the suppressant.



16.2 Cyclones

- 16.2.1 Cyclones should be designed, where practicable, to withstand the maximum pressure which may be imposed in the event of a blockage in the gas outlet. External ribbing may be used to provide the necessary strength.
- 16.2.2 Explosion relief when required shall be installed, as far as is practicable, in the roof of cyclones.

17. GRINDERS

17.1 General

- 17.1.1 By its nature, grinding is a most hazardous activity in the handling of powders. Particular attention should be paid to the elimination of the hazards involved, and appropriate protection for fire and explosion provided.
- 17.1.2 Slow-running equipment shall be used whenever practicable to minimise generation of dust and of frictional heat.
- 17.1.3 Metal detectors should be provided to indicate the required removal of tramp metal or to shut down vulnerable grinding equipment.
- 17.1.4 All rotating parts as well as casings shall be earthed.
- 17.1.5 Temperature sensors should be provided to give high temperature alarm and shut-down signals; these should be from separate, independent devices.
- 17.1.6 Where heat-sensitive materials are being handled, water-cooled casings should be provided.
- 17.1.7 Bearings should be outside the casing and separated from the powder by dust-tight seals.
- 17.1.8 Dust release to the surroundings shall be minimised by dust extraction or operation under negative pressure.
- 17.1.9 Vents shall not discharge inside a building. Any vent ducting shall meet the requirements of 8.5. Designs shall allow for the rapid rise in pressure which may occur.



18. MIXERS AND BLENDERS

18.1 General

- 18.1.1 Bulk powder blending silos may only be used with the approval of BP.
- 18.1.2 Explosion protection for mixers and blenders shall be provided as follows:-
- (a) For dusty solids with a minimum ignition energy of less than 25 mJ, the interior of the equipment shall be inerted.
 - (b) For other dusty solids which may form explosive mixtures, explosion relief shall be provided.
- 18.1.3 Provision shall be made for the detection and removal of tramp metal which might damage machinery with close tolerance and/or high power consumption. The metal detector should generally activate an automatic feed diversion valve. Magnetic devices may be used only where the removal device can be inspected and cleaned regularly, and non-magnetic tramp metal is not involved.

19. DRIERS

19.1 General

- 19.1.1 Solids which are subject to heating in a drying process shall be tested in accordance with Section 3; note particularly 3.1.1, 3.1.2 and 3.2.
- 19.1.2 These solids shall be classified into three groups:-
- (i) Materials defined as deflagrating or detonating explosives by the tests in Section 3.
 - (ii) Materials which on heating exhibit exothermic decomposition with rapid evolution of large volumes of gas, even in the absence of air.
 - (iii) Materials which can undergo exothermic oxidation or decomposition when heated in air, i.e. Group (a) dusts.

This section only gives the general requirements for the handling of materials in group (iii). Materials in groups (i) and (ii) require special handling, which will be specified by BP.

- 19.1.3 If flammable vapour can be given off during the drying process, either as the solvent or as a decomposition product of the solid, the auto-



ignition temperature and concentration of the vapour shall be determined, and the requirements of 3.2.8 and 15.5.3 applied if appropriate.

19.1.4 Driers shall be earthed.

19.1.5 Driers should be provided with means to remove all solids from the vessels during periods of inactivity.

19.2 Rotary Driers

19.2.1 Rotary driers and associated filters shall be fitted with explosion relief doors.

19.2.2 Bearings and hot surfaces shall be isolated from dusty atmospheres.

19.2.3 Static electric discharges shall be regarded as a potential source of ignition in rotary driers and rotary driers shall be used only for solids with a minimum ignition energy of less than 100 mJ under an inert atmosphere.

19.3 Spray Driers

19.3.1 Spray driers shall be fitted with explosion relief vents.

19.3.2 Spray driers shall be designed and installed as far as practicable to avoid the hold-up of layers of dust that constitute a fire or explosion risk.

19.3.3 The operating temperatures of spray driers shall be limited to prevent exothermic reactions.

19.3.4 Sparks from, e.g. direct fired oil burners or flue gas heaters from oil-fired burners, shall be removed.

19.4 Fluidised Bed Driers

19.4.1 Fluidised bed driers handling Group (a) dusts shall be fitted with explosion vents in the space above the fluidised bed surface. Water sprays over the fluidised bed may be used to control the operating temperature and to extinguish any fires.

19.4.2 Fluidised bed driers shall be designed to maintain a continuously moving bed with no dead or stagnant volumes which might give rise to exothermic reactions.

19.5 Band Driers

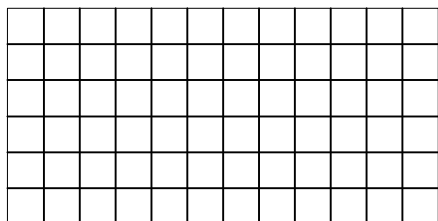
- 19.5.1 The velocity of the heated gas flow across the solid being dried shall be limited to prevent the dust in the solid, particularly when it is dry, from being lifted into the gas flow.
- 19.5.2 The temperature of the drying gas flow shall be limited to prevent the initiation of exothermic reactions in the dried solids.
- 19.5.3 Explosion vents shall be fitted to band driers in the space above the band.

19.6 Tray Driers

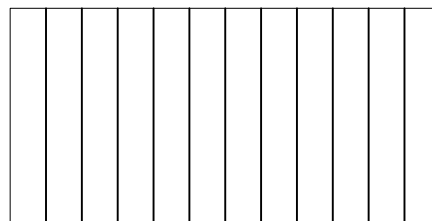
- 19.6.1 The velocity of the heated gas flow across the solid being dried shall be limited to prevent the dust in the solid, particularly when it is dry, from being lifted into the gas flow.
- 19.6.2 The temperature of the drying gas flow shall be limited to prevent the initiation of exothermic reaction in the dried solids.
- 19.6.3 Explosion vents shall be fitted to tray driers.

19.7 Vacuum Driers

- 19.7.1 Vacuum driers shall be designed to an appropriate pressure code and shall either be designed to withstand a full vacuum or shall be fitted with vacuum breaking equipment which injects a suitable gas, e.g. nitrogen, to maintain the pressure.
- 19.7.2 Vacuum driers shall either be designed to withstand vapour or dust explosions as necessary, or explosion venting shall be provided.
- 19.7.3 Designs shall avoid disturbing the solids either when the vacuum is applied at the start of the drying cycle or whenever the vacuum is broken.



Zone Z



Zone Y

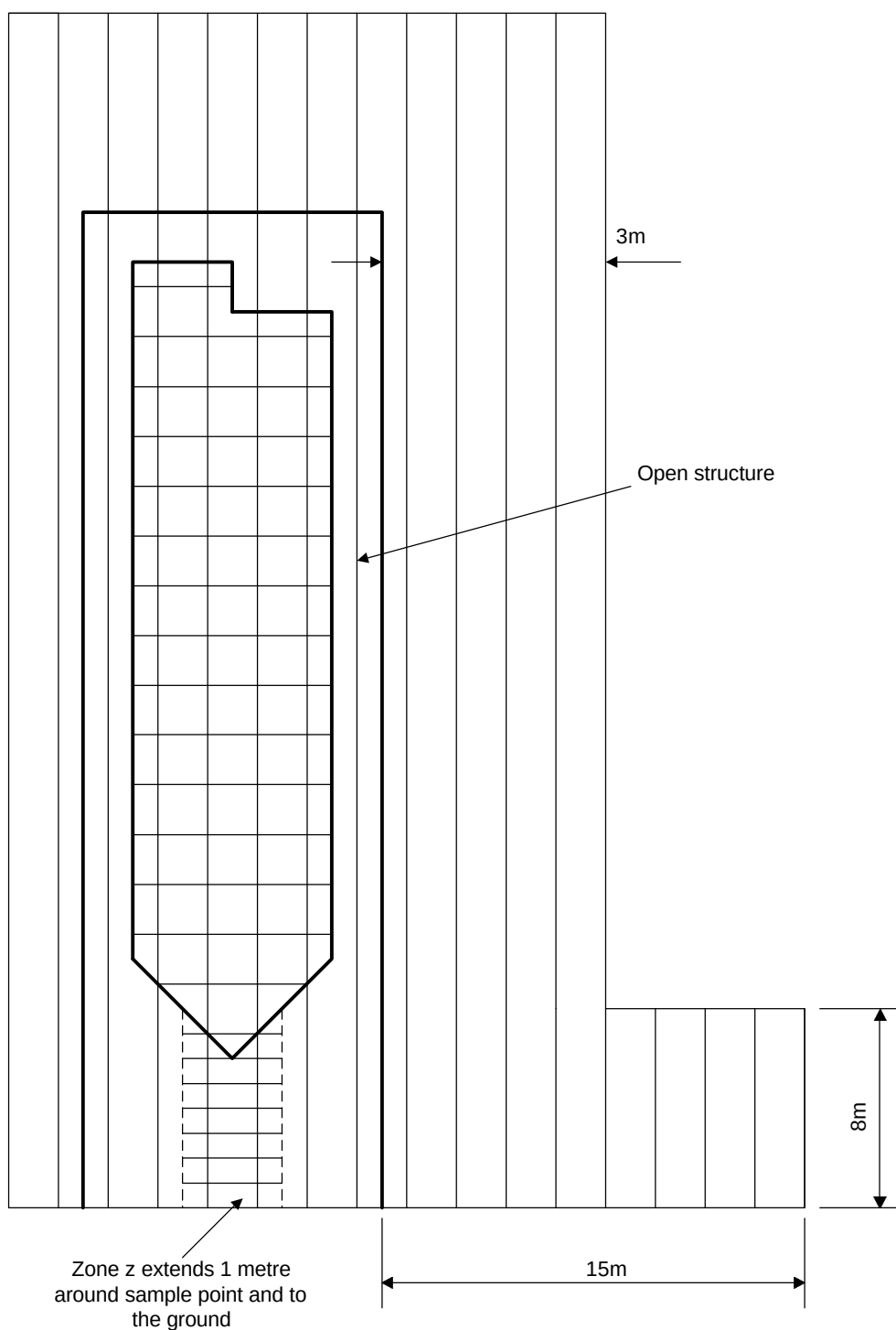
The drawing should show all zone boundaries. A plot plan should give the basis for horizontal boundary definition, while elevations may be shown to clarify the vertical extents.

The hatching at 5mm intervals to identify each area is shown above.

FIGURE 1

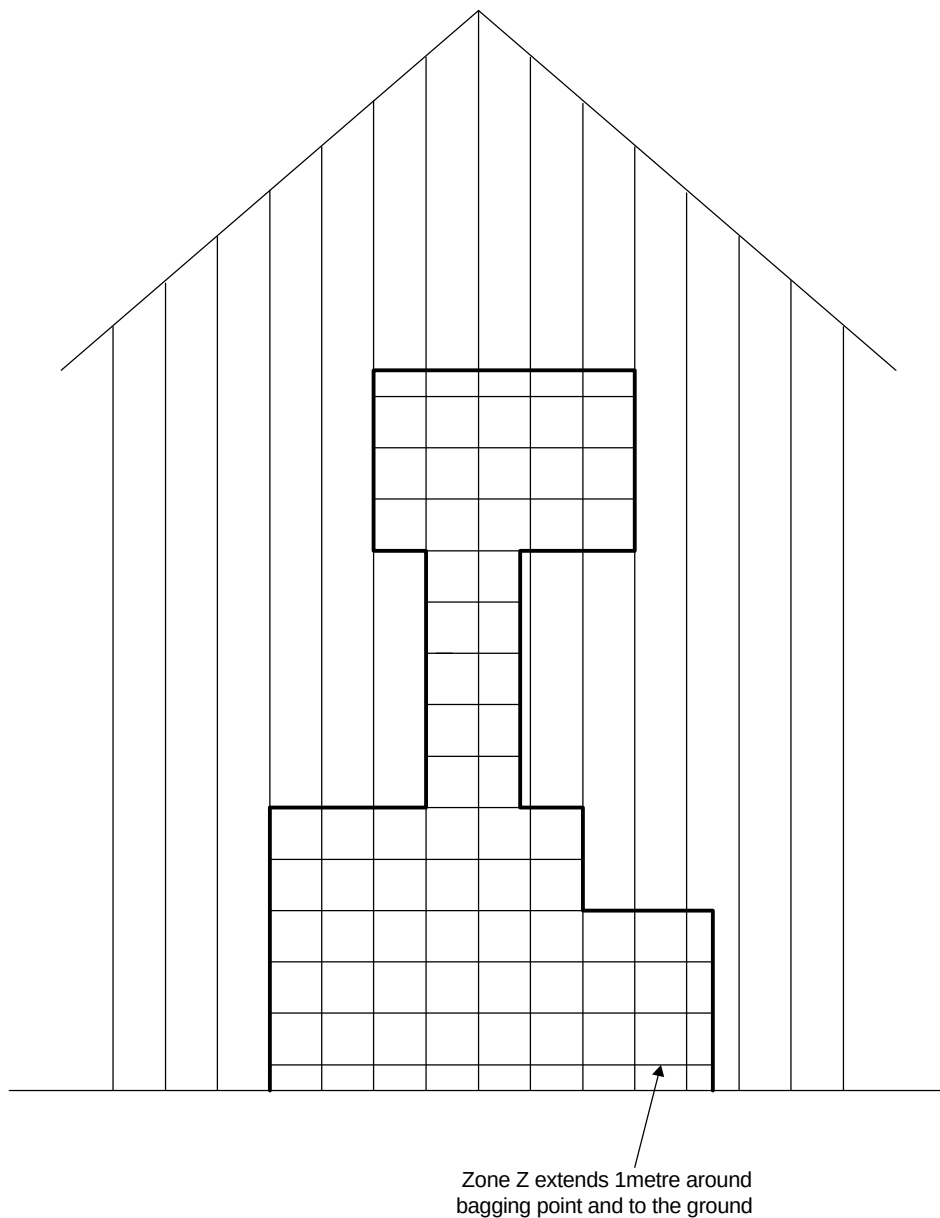
AREA CLASSIFICATION DRAWINGS IDENTIFICATION OF ZONE AREAS





Note: Such areas will typically contain silos etc.

FIGURE 2
TYPICAL ZONE BOUNDARIES FOR OPEN AIR PLANT

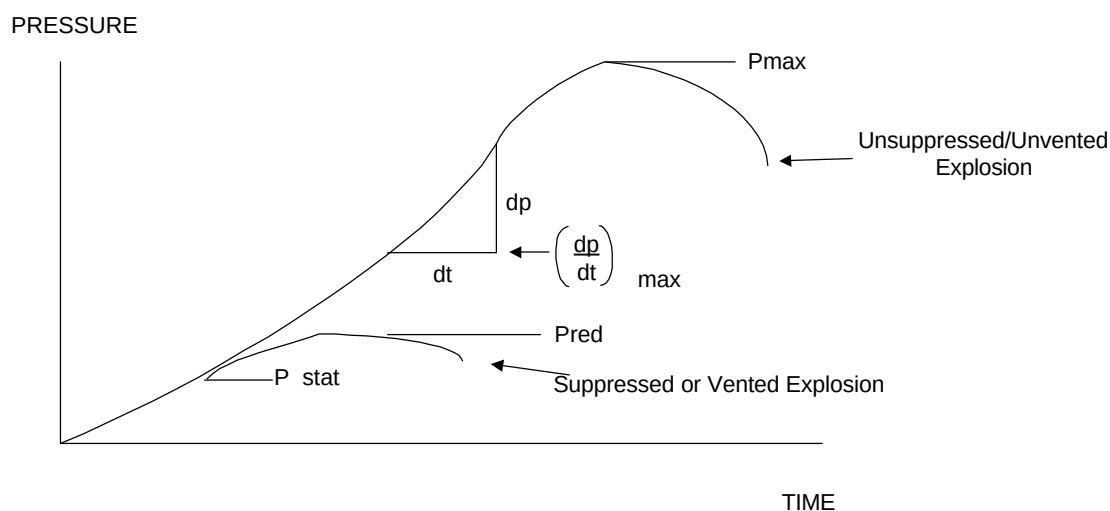


Note: Such buildings will typically contain process equipment used for grinding, classifying, mixing, etc.

FIGURE 3
TYPICAL ZONE BOUNDARIES FOR ENCLOSED BUILDINGS

DEFINITIONS AND ABBREVIATIONS

API	American Petroleum Institute
BS	British Standard
BCSA	British Constructional Steelwork Association
HDPE	High Density Polyethylene
IEC	International Electrotechnical Commission
IP	Ingress Protection
IR	Infra-red
Kst	Dust Explosion Constant
LDPE	Low Density Polyethylene
LFL	Lower Flammability Limit
LLDPE	Linear Low Density Polyethylene
LP	Low-pressure
MIE	Minimum Ignition Energy
MIT	Minimum Ignition Temperature
NFPA	National Fire Protection Association (USA)
P _{max}	Maximum Explosion Pressure (See figure below)
P _{red}	Reduced Maximum Explosion Pressure (see figure below)
P _{stat}	Activation Pressure of e.g. explosion vent or suppression system. (See figure below)
PVC	Polyvinyl Chloride
UFL	Upper Flammability Limit
UV	Ultra-violet
VDI	Verein Deutsche Ingenieure



$$K_{st} = \left(\frac{dP}{dt} \right)_{\max} V^{1/3} \quad (K_{st} \text{ in bar m/sec})$$

LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards, that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

International Documents

IEC144 Details of enclosures IP5X and IP6X

National Documents

BS 1435 Rubber hose assemblies for oil suction and discharge services

BS 3492 Electrically bonded road and rail tankers hose and hose assemblies for petroleum products

BS 5958 Recommended of Practice for the control of undesirable static electricity:

Part 1. General considerations

Part 2. Recommendations for particular industrial situations

BS 6467: Guide to selection, installation and maintenance of electrical apparatus with protection by enclosure for use in the presence of combustible dusts

Part 2,
1988

VDI 3673 Richtlinien 'druckenlastung von staubexplosionen' i.e. Guidelines 'Pressure release of dust explosions'

BCSA Booklet
No. 32,
1968.

The theory and practical design of bunkers

NFPA 68, Guide for venting of deflagrations
1988

API Std Venting atmospheric and low pressure storage tanks
2000

NFPA 48 National Fire Protection Agency Code 48 (Section 1)

BP Group Documents



RP 42-1	Piping Systems
RP 44-6	Area Classification to IP 15
RP 12-2	Electrical Equipment in flammable atmospheres and combustible dusts
RP 12-5	Power supplies for control systems

Technical References

Copies of the following documents are available from the custodian of this BP Group Recommended Practice

1. Warren Spring Laboratory 'Hoppers Co-operative Project, Sixteenth Quarterly Report - Supplement A', 1977, and Information sheet No. 4 'Pressures of Solid Materials on Hopper Walls'.
2. Butters, G. 'Plastics Pneumatic Conveying and Bulk Storage', Applied Science Publishers, London, 1981.
3. Palmer, K.N. 'Dust Explosions and Fires', Chapman & Hall, London, 1973.
4. The Institution of Chemical Engineers, 'User Guide to Fire and Explosion Hazards in the Drying of Particulate Materials', 1977.
5. Gibson, N. 'Characteristics of Powders Processed in the Chemical Industry', ISSA International Symposium on Dust Explosion Risks in Mines and Industry, Karlovy Vary, CSSR, 1972.
6. Bartknecht, W. 'Explosions', Springer-Verlag, 1981.
7. Field, P. 'Explosibility Assessment of Industrial Powders and Dusts', Fire Research Station, Dept. of Environment, HMSO 1983.
8. Schofield, Dr. C. 'Guide to Dust Explosion, Prevention and Protection. Part 1, Venting', The Institution of Chemical Engineers, 1984.
9. Bartknecht, W. 'Dust Explosions', Springer-Verlag, 1986.
10. Schofield, Dr. C. and Abbott, J. C. 'Guide to Dust Explosion, Prevention and Protection - Part 2 - Ignition Prevention, Containment, Inerting, Suppression and Isolation', The Institution of Chemical Engineers, 1988.



11. Lunn, G. A. 'Guide to Dust Explosion, Prevention and Protection - Part 3 - Venting of Weak Explosion and the Effect of Vent Ducts, The Institution of Chemical Engineers/BMHB 1988.
12. R. Siwek 'New Knowledge About Rotary Air Locks in Preventing Dust Ignition Breakthrough', Plant/Operations Progress, Vol. 8, No. 3, p 165-176, July 1989.



EXPLOSION DATA ON BP CHEMICALS PRODUCTS**Notes**

1. Most of the data presented in these tables were determined by the Fire Research Station. The data on phenolic resins (ex Barry), HDPE (ex Grangemouth) and polystyrene (ex Stroud) were determined for BP Chemicals.
2. The data on the various phenolic resins J1010G - J4103D were determined in an attempt to relate explosion properties to chemical composition.

These data show that phenolic resins are highly active, several having the highest category of maximum rate of pressure rise 690 bar/s (1000 psi/s).

3. The data on HDPE tend to correlate with the level of fines rather than with median size, R715 with a fines content of 15% showing similar explosion characteristics to the phenolic resins.

For MIE values, use data determined by BS 5958 method only.

4. The data available on polystyrene are limited but are sufficient to show that this product too has a high explosion potential.
5. Up-to-date explosion data on all BP Chemicals products are available from the Process and Technology Group, Polymer Sciences Branch, R & D D. BP Chemicals Ltd, Grangemouth.





High Density Polyethylene Incendivity Test Results
ex Grangemouth

SAMPLE DETAILS	PARTICLE SIZE DATE					MIN. EXPLOSIBLE CONC'N kg/m 3	MIN. IGNITION TEMP CLOUD TEST °C	MIN. IGNITION ENERGY (ME) mJ	EXPLOSION PRESS TEST MARTMANN BOMB		TWENTY LITRE SPHERE TEST				Max O2 Concn to Prevent ignition % vol in N2
	MEDIAN SIZE µm	wt % (CUMULATIVE UNDERSIZE)							MAX EXPLOSION PRESSURE P(MAX) bar	MAX RATE PRESS. RISE d P/dt (max) bar	MAX EXPLOS- ION PRESS- URE P (max) bar	MAX. RATE PRESS. RISE dP/dt(max) Bar/S	SPECIFIC MATERIAL CONSTANT K(ST) bar m/s	DUST EXPLOS- ION CLASS ST	
		<250 µm	<150 µm	<90 µm	<53 µm										
R & DO Ziegler fines sieved	96		100			0.01	390	10	6.8	502					8
XGR 872 As Rec'd	440	15	4.7					400-500	1.1	5.0					
XGR 872 Mat 1 <150µm	141	95	5.8	15.5	5.0			40-50			6.0	118	32	1	
59 CR4 As Rec'd	400	16	4.5	1.0	0.2			200-300	3.4	14					
59 CR4 Mat<150µm	82		93.5	61	17			50-60			6.7	161	43	1	
020-56 As Rec'd	510	10.5	4.0		1.0			400-500	1.8	5.3					
020-56 Mat 1 < 150µm	64		98	70	4.1						7.4	264	71	1	
002-55 As Rec'd	680	2.4	0.5	0.1				>500	0.2	0.4					
006-60 As Rec'd	540	4.2	0.6	0.1				>500	0.4	1.0					
H060-45P As Rec'd	860	2.2	0.3					>500	0.1	0.24					
002-40 As Rec'd	840	2.1	0.5	0.1				>500	0.17	0.37					
HD50-55P As Rec'd	600	19.4	4.2	0.7				500	0.286	0.93					
H050-55P Mat 1 < 150 µm	132		63.5	20	5.5			100-200			6.4	115	31	1	



High Density Polyethylene Incendivity Test Results
ex Grangemouth

SAMPLE DETAILS	PARTICLE SIZE DATA					MIN. EXPLOS- IBLE CONC'N kg/ m 3	MIN. IGATION TEMP CLOUD TEST °C	MIN. IGNITION ENERGY (ME) mj	EXPLOSION PRESS TEST MARTMANN BOMB		TWENTY LITRE SPHERE TEST				Max O2 Concn to Prevent ignition % vol in N2
	MEDIAN SIZE µm	wt % (CUMULATIVE UNDERSIZE)							MAX EXPLOSION PRESSURE P(MAX) bar	MAX RATE PRESS. RISE d P/dt (max) bar	MAX EXPLOSION PRESSURE P (max) bar	MAX. RATE PRESS. RISE D P/DT(max) Bar/S	SPECIFIC MATERIAL CONSTANT K(ST) bar m/s	DUST EXPLOSION CLASS ST	
		<250 µm	<150 µm	<90 µm	<53 µm										
XGR 899 As Rec'd	580	5.0	1.4	0.2	0.1			5-10	0.79	3.0					
XGR 899 Matt <150 µm	93		80	48	26.5			5-10			7.3	3.33	90	1	
HM 5411 As Rec'd	598	3.2	1.0	0.1				>500	0.25	0.56					
HD 5411 < 150 µm	106	97	72	38	17.5			25-30			6.5	3.15	85	1	
HD 59035 As Rec'd	680	4.1	0.6					300-400	0.75	2.75					
HD 55025 Matt <150 µm	158							15-20			7.2	278	75	1	
002-40 As Rec'd	1072	0.1	0.04					>500	0	0					
002-40 Matt <150 µm	118		71.5	33.2	13.5			18-20			7.0	225	61	1	
HD 5903S As Rec'd	600	3.7	0.7	0.1				70-100	2.7	9.1					
HD 59035 Matt <150 µm	110		74.5	58.0	18.5			8-10			8.8	365	99	1	
MIE measured by BS5958:															
TS005-57 As Rec'd	540	18	12.5	11.1	11.0			18-27	3.1	310					
TS 005-57 Matt <150 µm	14.5				100			9-18			8.0	440	119	1	



High Density Polyethylene Incendivity Test Results ex Grangemouth

[illegible]



Linear Low Density Polyethylene Incendivity Test Results ex Lavera

[illegible]



Phenolic Resin Incendivity Test Results ex Barry
Polystyrene Incendivity Test Results ex Stroud

Phenolic Resin

SAMPLE DETAILS	PARTICLE SIZE DATA					MIN. EXPLOSIBLE CONC'N	MIN. I GITION TEMP CLOUD TEST	MIN. IGNITION ENERGY (MIE)	EXPLOSION PRESS TEST HARTMANN BOMB		TWENTY LITRE SPHERE TEST				Max 02 Concn to Prevent ignition % vol in N2
	MEDIAN SIZE	wt % (CUMULATIVE UNDERSIZE)							MAX EXPLOSION PRESSURE P(MAX) bar	MAX RATE PRESS. RISE d P/dt (max) bar	MAX EXPLOS- ION PRESS. P (max) bar	MAX. RATE PRESS. RISE dP/DT(max) Bar/S	SPECIFIC MATERIAL CONSTANT K(ST) bar m/s	DUST EXPLOS- ION CLASS ST	
		<250 µm	<150 µm	<90 µm	<53 µm										
J1010G	11					0.05	600	10	7.52						
J1008	16					0.03	510	10	6.97						
J1109	14					0.07	440	20	7.73						
J 1403H	25					0.03	480	10	7.52						
J1311H	14					0.03	490	10	7.80						
J4103D (Friction Dust)	151					0.05	430	15	8.07						
Fine Ground Resin Fines						0.02	530	5	8.21						
Friction Dust Fines						0.02	420	5	8.21						

Polystyrene

SAMPLE DETAILS	PARTICLE SIZE DATA					MIN. EXPLOSIBLE CONC'N	MIN. IGNITION TEMP CLOUD TEST	MIN. IGNITION ENERGY (MIE)	EXPLOSION PRESS TEST HARTMANN BOMB		TWENTY LITRE SPHERE TEST				Max 02 Concn to Prevent ignition % vol in N2
	MEDIAN SIZE	wt % (CUMULATIVE UNDERSIZE)							MAX EXPLOSION PRESSURE P (MAX) bar	MAX RATE PRESS. RISE d P/dt (max) bar	MAX EXPLOSION PRESSURE P (max) bar	MAX. RATE PRESS. RISE dP/dT(max) Bar/s	SPECIFIC MATERIAL CONSTANT K(ST) bar m/s	DUST EXPLOSION CLASS ST	
		<250 µm	<150 µm	<90 µm	<53 µm										
Crystal Bead						0.02									
Bead Fines						0.02				483					
Hips Finished Goods Fines						0.04			4.14	37					



Incendivity Test Results Material from Unknown Sources
Published by K.N. Palmer and others

[illegible]

TRAIN FIRING TEST

If a powder layer ignites, the probability of this initiating a dust explosion is determined by the ability of a locally-induced red heat decomposition or ignition to propagate through the bulk material or powder layer.

The 'train firing' properties of the powder can be determined by the following test. A train of the material 100mm (4 in) long, 20mm (0.8 in) wide and 20mm (0.8 in) deep is laid on a fireproof, insulating plate and ignited at one end. Two sources of ignition are used (a) a bunsen burner flame and (b) a silicon-lead oxide powder mixture which is intermixed with the first 10mm (0.4 in) of the powder under test.

The extent to which ignition is sustained away from the ignition source is noted and whether combustion takes the form of smouldering or flame.

The test is normally carried out with virtually still air at ambient temperature above the sample, but where it is appropriate to plant conditions, the air above the sample can be moving and at any required temperature.

VENT RATIO SYSTEM FOR RELIEF AREA CALCULATION

Using the maximum rate of pressure raise as determined in the Hartmann Bomb and the volume of the vessel, the vent ratio, i.e. area of vent per unit volume of the vessel, is determined as follows:-

Vessel	Volume	Maximum Rate of Pressure Rise		Vent Ratio	
m ³	(ft ³)	bar/sec	(psi/sec)	m ² /m ³	(ft ² /ftn)
up to 28	(up to 1000)	below 345	(below 5000)	1/6	(1/20)
		345-680	(5000-10000)	1/4.5	(1/15)
		above 680	(above 10000)	1/3	(1/10)
28-700	(1000-25000)	below 345	(below 5000)	1/9-1/15	(1/50-1/80)
above 700	(above 25000)	below 345	(below 5000)	1/15-1/24	(1/50-1/80)

The vent ratio system is applicable to enclosures of very low, i.e. less than 0.20 bar(ga) (3.0 psig) or unknown strength.

The set pressure of the relief device shall be as low as practicable and no more than 0.0517 bar(ga) (0.75 psig).