The Institution of Chemical Engineers

Guide to Dust Explosion Prevention and Protection Part 1 – Venting

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Guide to Dust Explosion Prevention and Protection Part 1 – Venting

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PREFACE

The recommendations presented in this guide will provide a basis for good practice in the protection, by venting, of plant and processes wherein dust explosions could occur. The guide aims to help those responsible for the design, supply and operation of plant to comply with the provisions of the Health and Safety at Work Act and the Factories Act.

It must be recognised that on occasions strict adherence to these recommendations would be inappropriate and further advice may have to be sought. In addition it would be expected that further research and other developments will lead to improved methods and it is not the intention that this guide should inhibit such developments.

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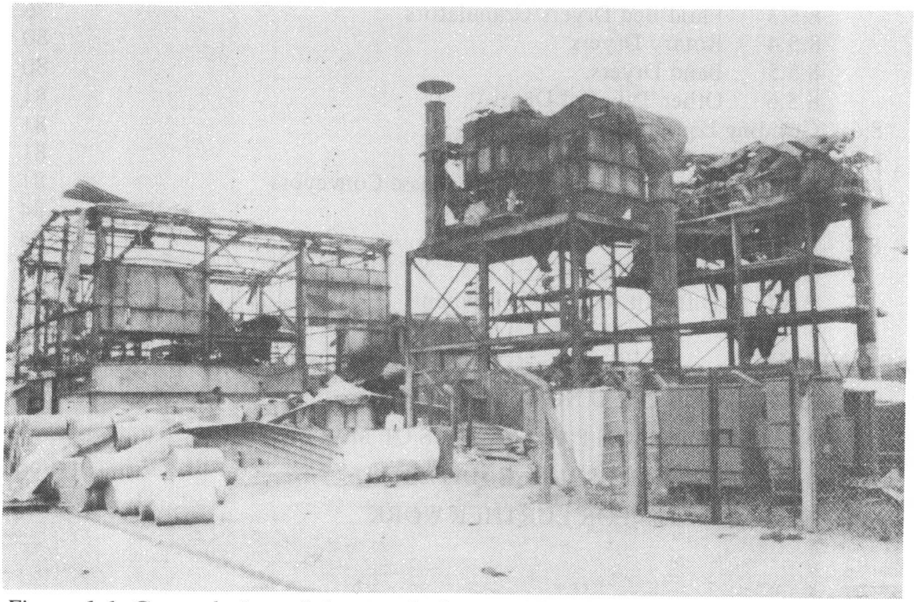

Figure 1.1 General view of damaged plant and buildings following an aluminium dust explosion. (Photo courtesy of Health and Safety Executive).

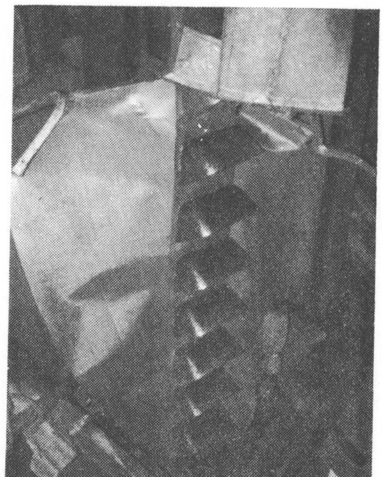

Figure 1.2 Result of an explosion in a bucket elevator handling grain (Photo courtesy of HSE).

CONTENTS

APPENDICES

1
INTRODUCTION

Under certain conditions fine particles of combustible material dispersed in air will ignite and explode. Such explosions cause a rapid increase in pressure in the containing structure and if the equipment is not strong enough to withstand the explosion extensive damage and injury can occur. An additional hazard arises if an explosion disturbs local deposits and accumulations of dust resulting in a larger dust cloud which can cause a very serious explosion. Figures 1.1, 1.2 illustrate the devastation that can be caused by dust explosions.

Statistics on frequency and severity of dust explosions are difficult to obtain but Table 1.1 summarises some data compiled by FIELD (1982).

Table 1.1 Some Dust Explosion Statistics [FIELD (1982)]

Country	Period	Explosions	Fatalities (Injuries)	Reference
USA	1900–1956	1120	640 (1700)	NFPA (1957)
USA	1958–1977	220*	48 (500)*	HALL (1978)
FGR and neighbouring countries	1960–1972	4000		BARTKNECHT (1981)
UK	1958–1967	247	9 (324)	HSE (1976)
	1962–1979	474	25**(633)	HSE (1983A)

* Grain industry only (perhaps 50% of total)
**10 in two incidents

Some of the substances and processes that have been involved in serious dust cloud explosions are listed in [HSE (1976)]. Substances include: organic chemicals, resins, metal powders and food products etc. Equipment includes: cyclones, dust filters, conveyors, blenders, silos, milling and grinding machines and dryers etc. A recent incident, involving corn starch, has been reported in some detail in [HSE (1983)] which graphically illustrates how an equipment malfunction can lead to a dust explosion.

If combustible, dusty materials are handled there is a statutory requirement (in the UK) to take practicable precautions. These requirements are embodied in the Factories Act 1961. Sub-sections 31(1), (2) and (4) and provide as follows:

"(1) Where, in connection with any grinding, sieving, or other process giving rise to dust, there may escape dust of such a character and to such an extent as to be liable to explode on ignition, all practicable steps shall be taken to prevent such an explosion by enclosure of the plant used in the process, and by removal or prevention of accumulation of any dust that may escape in spite of the enclosure, and by exclusion or effective enclosure of possible sources of ignition.

"(2) Where there is present in any plant used in any such process as aforesaid dust of such a character and to such an extent as to be liable to explode on ignition, then, unless the plant is so constructed as to withstand the pressure likely to be produced by any such explosion, all practicable steps shall be taken to restrict the spread and effects of such an explosion by the provision, in connection with the plant, of chokes, baffles and vents, or other equally effective appliances.

"(4) No plant, tank or vessel which contains or has contained any explosive or inflammable substance shall be subjected:

(a) to any welding, brazing or soldering operation;

(b) to any cutting operation which involves the application of heat; or

(c) to any operation involving the application of heat for the purpose of taking apart or removing the plant, tank or vessel or any part of it;

until all practicable steps have been taken to remove the substance and any fumes arising from it, or to render them non-explosive or non-inflammable; and if any plant, tank or vessel has been subjected to any such operation, no explosive or inflammable substance shall be allowed to enter the plant, tank or vessel until the metal has cooled sufficiently to prevent any risk of igniting the substance."

Further there are obligations under the Health and Safety at Work etc Act 1974 Part 1 Sections 2 and 6 which provides as follows:

2(1) 'It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.'

(2) 'Without prejudice to the generality of an employer's duty under the preceding subsection, the matters to which that duty extends include in particular –

(a) the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risk to health;' etc.

6(1) 'It shall be the duty of any person who designs, manufacturers, imports or supplies any article for use at work –

(a) to ensure, so far as is reasonably practicable, that the article is so designed and constructed as to be safe and without risks to health when properly used;' etc

It is the responsibility of the Health and Safety Executive to enforce these legal requirements. Explosion venting is a common precaution against the effects of dust explosions and is widely used in part fulfilment of the legal requirements.

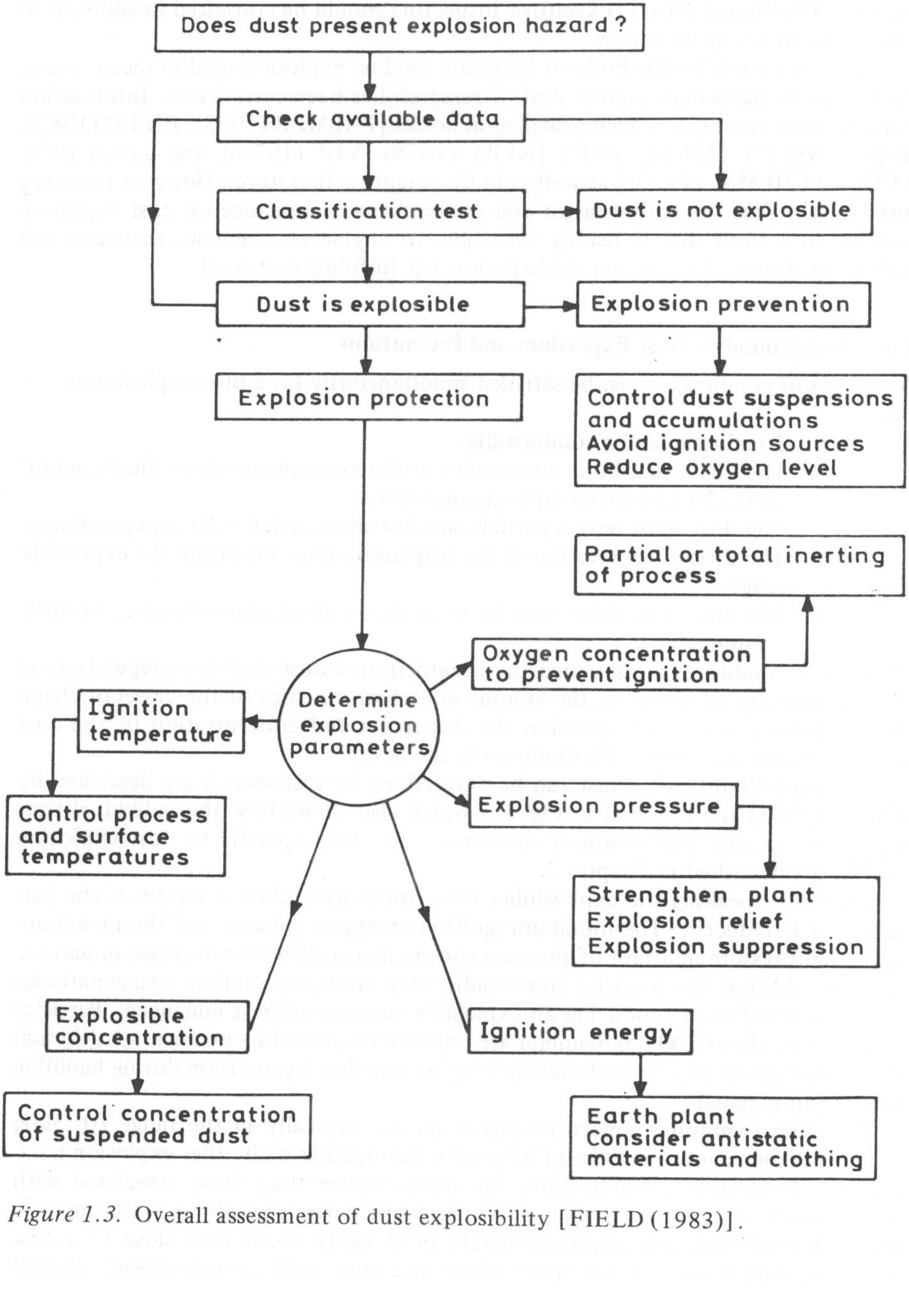

Figure 1.3. Overall assessment of dust explosibility [FIELD (1983)].

In any case of doubt concerning explosion hazard and precautions in a given process the Health and Safety Executive Inspectors should be consulted in addition to obtaining other expert advice.

There is a considerable body of literature on dust explosions and in recent years, in Europe in particular, a great deal of research has been carried out. Information on explosion venting has been provided in books [PALMER (1973), FIELD (1982), BARTKNECHT (1981)], codes [NFPA (1978), VDI (1979)] and guides [HSE (1976), I.CHEM.E. (1977)] as well as in the scientific literature. However there is a need in the UK for authoritative and comprehensive guidance on dust explosion venting in a form that is readily accessible to engineers, scientists, managers and safety specialists. The present guide is aimed at fulfilling that need.

1.1 Background to Dust Explosions and Precautions

A number of conditions must be satisfied simultaneously for a dust explosion to occur:

- (*a*) The dust must be combustible.
- (*b*) The dust must be in suspension in the atmosphere which must contain sufficient oxygen to support combustion.
- (*c*) The dust must have a particle size distribution that will propagate flame.
- (*d*) The dust concentration in the suspension must be within the explosible range.
- (*e*) The dust suspension must be in contact with an ignition source of sufficient energy.

If these conditions are satisfied the hazard from a dust explosion depends upon the explosibility of the dust, the volume and characteristics of the vessel or chamber containing the dust suspension the dispersion and concentration of the dust suspension and the degree of turbulence in the vessel.

The explosibility of a dust can be determined by tests which are described by FIELD (1983) and outlined in Fig. 1.3 which also shows how the individual tests pertain to specific precautionary measures. The tests specific to dust explosion venting are described in Chapter 2.

Generally speaking the explosibility of a combustible dust is greater if the particle size is reduced. The minimum ignition energy is reduced and the maximum explosion pressure and rate of pressure rise are increased with a decrease in particle size. In addition fine particles more readily stay in suspension than coarse particles so the probability of producing an explosible concentration is enhanced. Particles greater than about 500 μm diameter are unlikely to cause dust explosions, although the possibility of coarser materials producing fine dust by attrition during handling must be anticipated.

Minimum explosible concentrations in air are typically in the range 10–500g m^{-3} and some values are given in Appendix A2 together with other explosion parameters. Explosible concentrations are much higher than those associated with toxic hazards or nuisance problems (which might range from about 1–10 mg m^{-3}) and such explosible concentrations would most likely occur very close to a dust source or within an enclosed space where the dust cloud cannot spread. Indeed

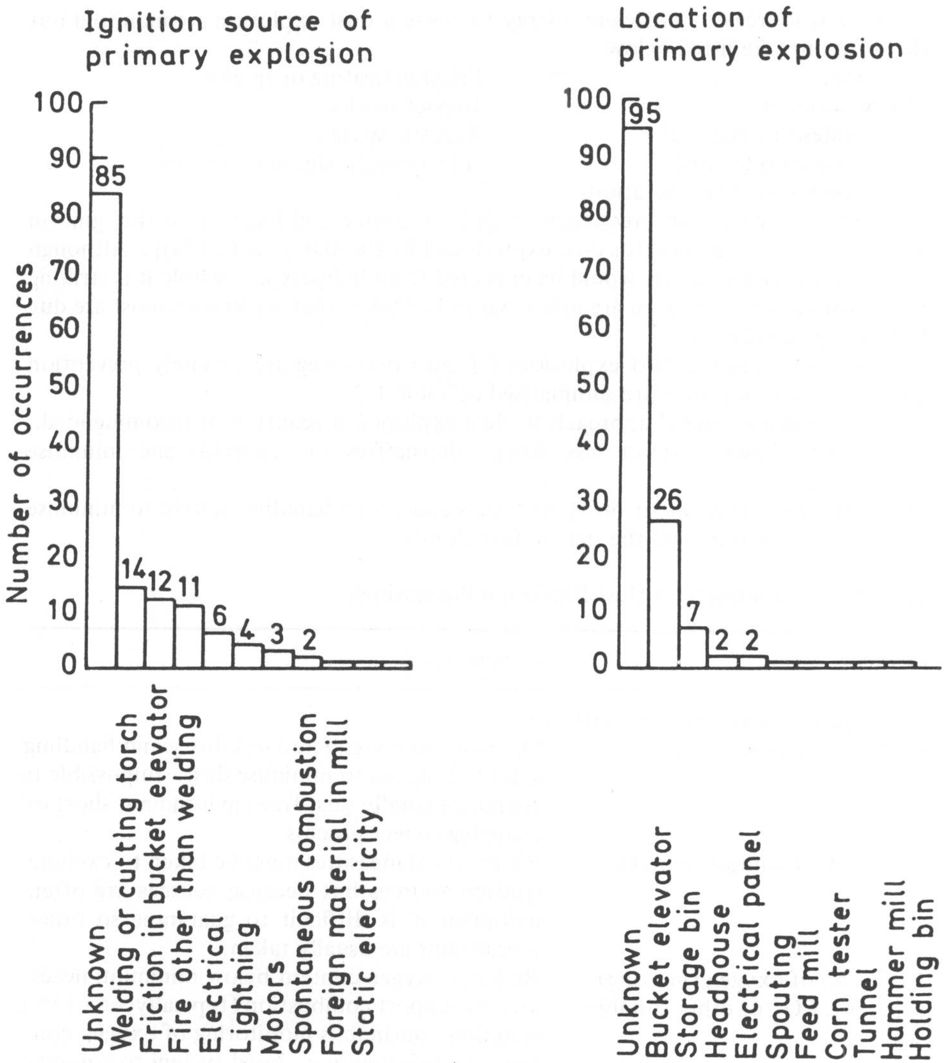

Figure 1.4. Causes and location of grain elevator primary explosions, USA 1958–1975 [VERKADE & CHIOTTI (1976)].

enclosure and confinement of dust sources in order to solve occupational hygiene or nuisance problems may well concentrate the dust cloud and cause an explosion problem.

Ignition sources of sufficient energy to cause a dust explosion are manifold but the main ones are listed below:

Flames	Friction heating or sparks
Hot surfaces	Impact sparks
Incandescent material	Electric sparks
Spontaneous heating	Electrostatic discharge sparks
Welding or cutting operations	

Figure 1.4 shows the frequency of ignition source and location of the ignition associated with grain elevator dust explosions [VERKADE et al (1976)]. Although a slightly different picture would be expected from industry as a whole it is striking that most causes of ignition are unknown and of those that are known most are due to welding and cutting.

Precautions against dust explosions fall into two categories, namely prevention and protection, and they are summarised in Table 1.2.

The following general approach to dust explosion precautions is recommended..

- Where possible select less dusty alternatives for materials and minimise attrition.
- Minimise handling of dusty materials and design handling system to minimise dust generation and the size of dust clouds.

Table 1.2. Summary of Dust Explosion Precautions

Method	Comments
Prevention (of an explosion occurring)	
Exclusion of dust cloud	Material can be rendered less dusty and handling system designed to minimise dust. Impossible to guarantee totally dust free environment short of changing to wet process.
Exclusion of ignition sources	All practical measures must be taken to exclude ignition sources but because sources are often unknown it is difficult to guarantee so other precautions are usually taken.
Exclusion of oxygen (inerting) using N_2, CO_2 or other suitable gas.	Reduces oxygen content below minimum necessary to support combustion (typically <6–15%). Requires continuous monitoring of oxygen content. Usually requires closed system to conserve inert gas. Expensive.
Diluent dust addition – to reduce explosibility of dust	Non-combustible diluent, well mixed with dust, acts as heat sink thus reducing explosibility of dust. Limited application because of contamination and expense. (Typically the amount of inert dust exceeds 50%).

Protection (from the effects of an explosion)	
Containment	Vessel and associated pipework etc built sufficiently strong to withstand the maximum exposion pressure. Expensive in all but the smallest systems.
Venting	Vents provided in walls of vessel to allow escape of dust and combustion products to limit pressure rise to an acceptable level. Widely used.
Suppression	Start of explosion detected by instruments which trigger release of fire suppressants. Useful where venting is unacceptable or impracticable e.g. when the dust is toxic.

- Avoid the accumulation of dust (which can be disturbed to form a dust cloud) by the detailed design of equipment, building and working practices.
- Anticipate possible ignition sources and eliminate them, as far as is reasonably practicable, by appropriate equipment design, earthing, maintenance and working practices.
- Take appropriate additional precautions, where practicable, such as inerting, containment, venting or suppression.
- Isolate vulnerable plant as appropriate.

The Factories Act does not specify a size of vessel below which it would not be necessary to take additional precautions but it is generally agreed [PALMER (1973)] that in systems below 0.5 m^3 and for dusts with a K_{st} less than 100 bar ms^{-1} (or a maximum rate of pressure rise less than 345 bars s^{-1} measured in the Hartman apparatus) sufficient vent areas are probably available through inlets and outlets (direct to atmosphere), so special precautions would not normally be required. Every application must however be considered on its merits and specialist advice sought if necessary.

1.2 Venting as a Precaution

The basic principle of venting is that if a dust explosion occurs in a vessel or container a vent of sufficient area should open rapidly allowing unburnt dust and explosion products to escape, thus limiting the pressure rise to an acceptable level. The acceptable pressure rise is determined by the requirement that the vessel should not rupture and in some cases it may be required that it should not deform. Venting is widely used as a precaution because it is relatively simple and cheap to install compared with the alternatives, but it is not always the most appropriate precaution.

Dust explosion venting, by the methods described in this guide, is inappropriate under the following circumstances and alternative precautions should be used and specialist advice should be sought.

- the dust is toxic or corrosive
- the dust explodes violently i.e. $K_{st} > 600$ bar m s^{-1} (see Chapter 2)

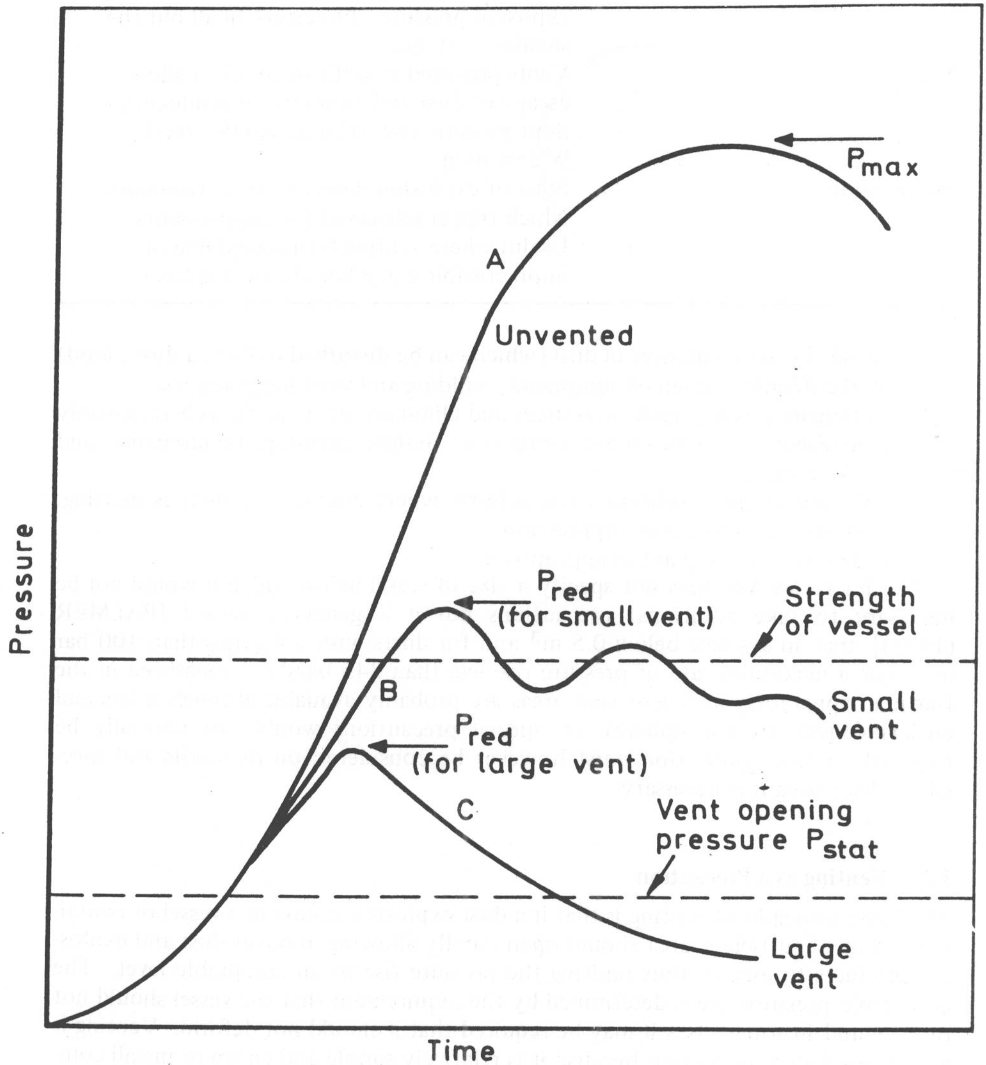

Figure 1.5. Pressure – time characteristics in vented and unvented vessels.