ARCHIVE

DUST EXPLOSIONS IN FACTORIES

precautions required with combustible dusts

DEPARTMENT OF LABOUR

ARCHIVE

Important Note:
All the publications in the Publications Archive contain the best guidance available at the time of publishing. However, you should consider the effect of any changes to the law since then. You should also check that any Standards referred to are still current.

Published by the Department of Labour
PO Box 3705
Wellington
New Zealand
www.osh.dol.govt.nz

Published: 1985

Contents

Introduction

The explosive properties of many dusts are not widely recognised within industry, and so this booklet sets out to show the problems created by the presence of explosible dusts that commonly occur in New Zealand workplaces.

The dusts created by many materials in everyday use will explode if mixed with air in a cloud formation, and with a source of ignition present.

Dust explosions can occur in grain silos and elevators, flour and icing sugar mills, malthouses, thermal coal dryers, milk spray-dryers and in those industries involved in the manufacture or processing of agricultural products, chemicals,

coal, food products, metals, paper, pharmaceuticals, pigments, plastics, rubber and wood and related products. A comprehensive list of explosible dusts is to be found in Appendix A.

A hazard is present whenever material is produced in the form of a fine dust. This may be a nuisance dust only, but if it is combustible then at the very least it will be a fire hazard and at the worst a severe explosion hazard.

There have been many dust explosions overseas and within New Zealand. One, in a Masterton plastics factory in 1965, killed 4 people and led to an amendment to the Factories Act 1946 to ensure factory occupiers take practicable steps to prevent such explosions.

The Masterton explosion

Today, controls on the hazards of explosive dusts are covered by section 31 of the Factories and Commercial Premises Act 1981.

31. Precautions with respect to explosive or flammable substances — Where there is present in any undertaking dust, gas, mist, vapour, or other such substance, of such a character and to such an extent as to be liable to give rise to an explosion, or explode on ignition, the occupier of the undertaking shall take all reasonable precautions —

(a) To prevent the explosion of the substance by —

(i) The effective enclosure of all plant producing the substance; and

(ii) The removal, or prevention of accumulation, of the substance, wherever situated in the undertaking;and

(iii) The exclusion or effective enclosure of all possible sources of ignition; and

(b) To restrict the spread and effects of any explosion of the substance by the provision of suitable chokes, baffles, and vents, or by other equally effective appliances or measures.

Precautions listed in both parts (a) and (b) of section 31 should be taken by occupiers of undertakings and include all of the following —

(i) effective enclosure of plant;

(ii) removal or prevention of accumulations of explosive materials;

(iii) exclusion of ignition sources;

(iv) means to restrict the spread and effect of any explosion.

What is a dust explosion?

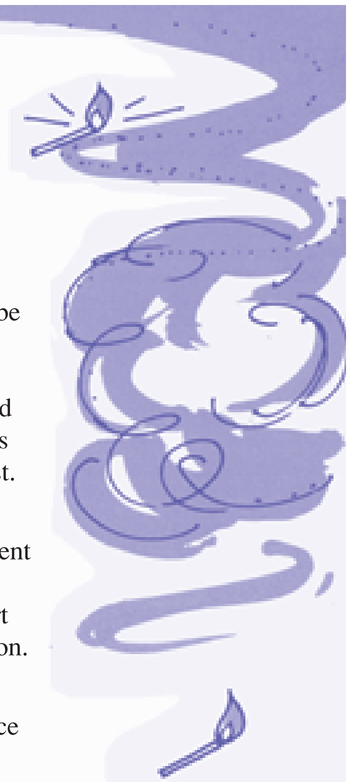
A dust explosion occurs when a fine dust in suspension in air is ignited, causing a very rapid burning and then the release of gaseous products with a subsequent pressure rise of explosive force that will damage plant, property and people.

Dust explosions can be categorised into two types — primary and secondary.

A primary explosion takes place in a confined atmosphere (such as a cyclone or part of the manufacturing plant) and the resulting shock wave will damage and often rupture the plant, allowing the products of the explosion (burning dust and gases) to be expelled into the surrounding area, disturbing any settled dust and initiating a larger secondary explosion. The secondary explosion can cause severe damage to surrounding plant and buildings. All large-scale dust explosions result from chain reactions of this type.

Conditions necessary for a dust explosion

1. The dust must be combustible.
2. The finer the dust the more explosive it is likely to be.
3. The dust cloud must be of explosive concentration, i.e. between the lower and upper explosive limits for that particular dust.
4. There must be sufficient oxygen in the atmosphere to support and sustain combustion.
5. There must be a source of ignition.



Concentration of the dust cloud

Before a combustible dust suspension can explode, its concentration must fall between upper and lower explosive limits. The lower limit for most combustible dusts is fairly well defined, but due to the lack of uniformity of dust cloud concentrations the upper explosive limit is more difficult to establish.

The lower explosive limits for most combustible dusts range from 10g/m^3 air to 500g/m^3.

Atmospheric composition

Oxygen must be present before a dust explosion can happen. The oxygen concentration of air is normally 21%, so any reduction in the oxygen content of an air-dust mixture raises the ignition temperature and therefore reduces the chances of a dust explosion.

There is a limiting concentration of oxygen below which an explosion will not occur. This varies from one dust to another, also with different ignition sources. This factor is used to good effect when designing inciting systems as a method of preventing dust explosions. Dust explosions will occur more readily and violently in an oxygen-enriched atmosphere.

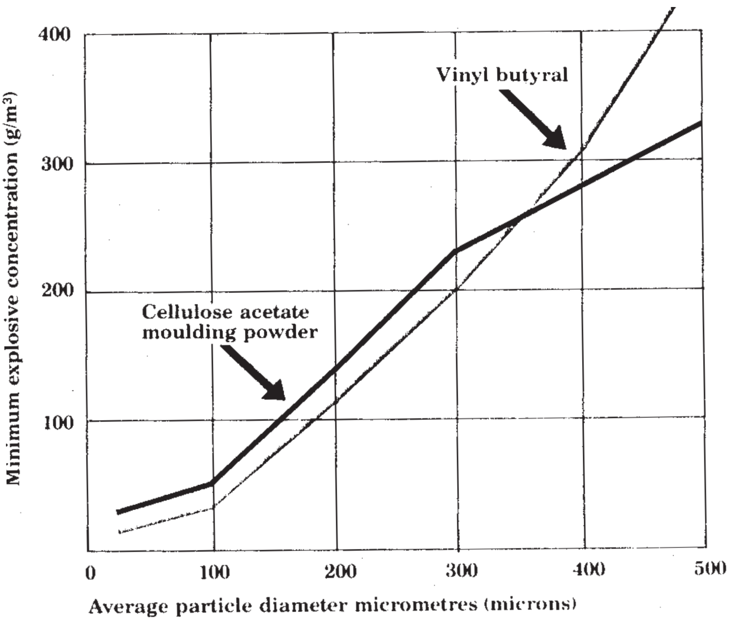
Ignition sources

For a dust explosion to take place (given a dust cloud of explosive concentration) there must be an ignition source of an energy level sufficient to initiate and sustain an explosion. As the strength of the ignition source increases, so too does the severity of the dust explosion.

Ignition sources known to have initiated explosions include electric arcs due to faulty wiring, motors and other appliances, static electrical discharges, open flames, welding, frictional or metallic sparks, overheated bearings and other machine parts, hot electric bulbs, hot dryers and other hot surfaces, and spontaneous ignition.

Particle size of dusts

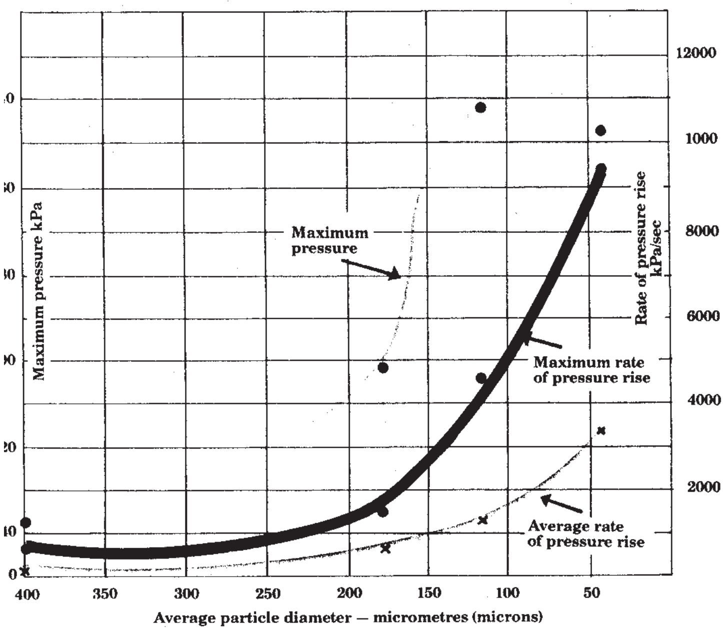
As the particle size of the dust decreases, the available surface area increases, giving a greater capacity for rapid reaction. Therefore, the explosibility of dusts increases as the particle size decreases, and the smaller the particle size the less energy required to ignite the dust cloud. Fine dust can also be thrown into suspension more readily, can remain suspended longer than coarse dust, and will mix more uniformly with air.



Effect of fineness on minimum explosive concentration of dust clouds. Data from US Bureau of Mines' Report of Investigation 3751

Research has shown that dusts of 500 micron (micrometre) diameter or less are capable of exploding. The presence of larger particles helps to reduce the explosion hazard. However, once an explosion is under way, even relatively coarse particles can burn and add energy to the explosion. In New Zealand the DSIR tests dust that will pass through a BSS 60 mesh sieve 1250 micron; to determine its explosibility.

495 g/m³ [grams per cubic metre of air]



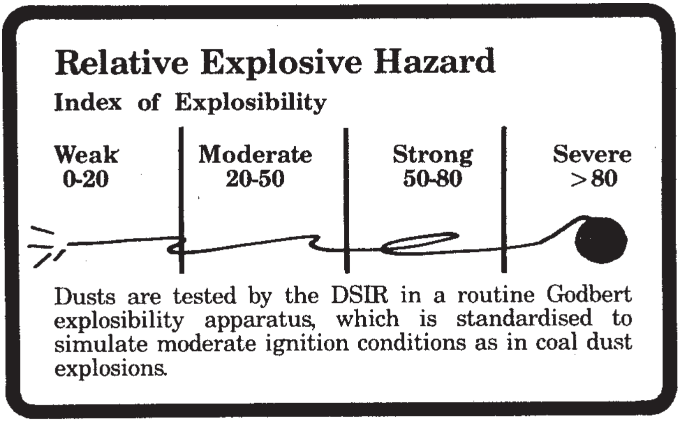
Variation of maximum explosion pressure and rate of pressure rise with fineness of cellulose acetate moulding powder. Data from US Bureau of Mines Report of Investigation 3751.

Hazard rating of dusts

The degree of hazard depends mainly on the type of dust and the processing methods used.

An index of explosibility has been developed by the DSIR to help evaluate the explosibility of dusts. The index is on a scale of 0 - 100. A rating of 0 indicates no explosion hazard exists, while a result of 100 indicates the most severe explosion hazard.

The scale is further subdivided into the categories: weak, moderate, strong or severe. These ratings are correlated with the index of explosibility as follows:



Explosive dusts are classified by the Department of Labour into different classes, depending on their explosibility ratings. Factory inspectors may require different precautions for dusts which fall into the different classes.

Index

> 80 Class 2 dust

20-80 Class 1 dust

< 20 Fire hazard

Classification of hazardous locations for wiring

As electrical wiring or equipment can constitute a source of ignition for dust explosions, precautions must be taken to eliminate this hazard.

Hazardous areas must be clearly defined, including locations where there is dust present in dangerous quantities with electrical wiring and equipment which is not suitable for use in such areas. In New Zealand this classification is usually carried out with reference to MP6105 : 1976 *Electrical wiring in hazardous locations*.

The classifications in this standard are used by electrical power supply authorities to determine the location of hazardous areas and the suitability of electrical equipment in those areas. Compliance with the Electrical Wiring Regulations 1976 or the above standard is required by power supply authorities in undertakings where explosive dust is present.

Factory inspectors can also define these hazardous areas.

Specific points on dust control

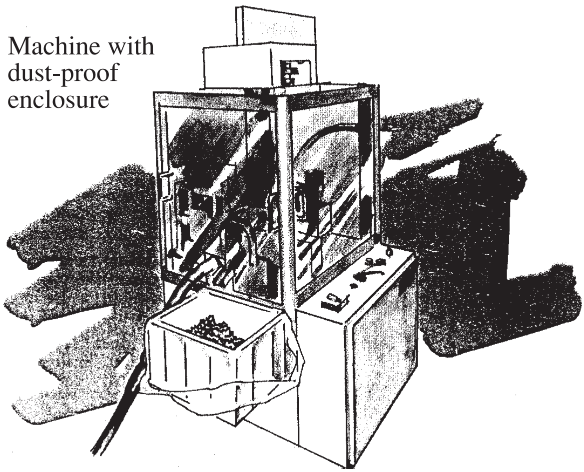
No explosion hazard exists where there is not enough dust to form an explosive concentration in air. Therefore, preventing the escape and dispersion of dust into the air of the workplace is the first step in explosion prevention.

With any process producing dust as an unwanted by-product, the amount of dust produced should be kept as low as possible.

Dust can be generated through many activities such as the handling of dry powder or raw materials and during the machining (grinding, turning, milling or drilling) of solid materials.

1. Where dusts are created or handled, enclosures and equipment should be designed so that unwanted dust drift or spillage is either collected safely or totally avoided.

Machine with dust-proof enclosure



2. Equipment should be constructed so that dust cannot escape.
3. Bulk dust should be handled in such a way or in such containers that accidental spillage or drift is unlikely.

"Dusty" work area isolated from "clean" area

4. Dusty processes should be separated from clean processes so that precautions can be kept to a specific area.
5. If possible, it is better to use wet machining as this converts the dust into a slurry.

Housekeeping

However well plant and equipment is designed or maintained, there is likely to be some seepage of dust over a period, particularly fine dust, which is more dangerous, It is essential to maintain a high standard of housekeeping at all times. Points to remember are:

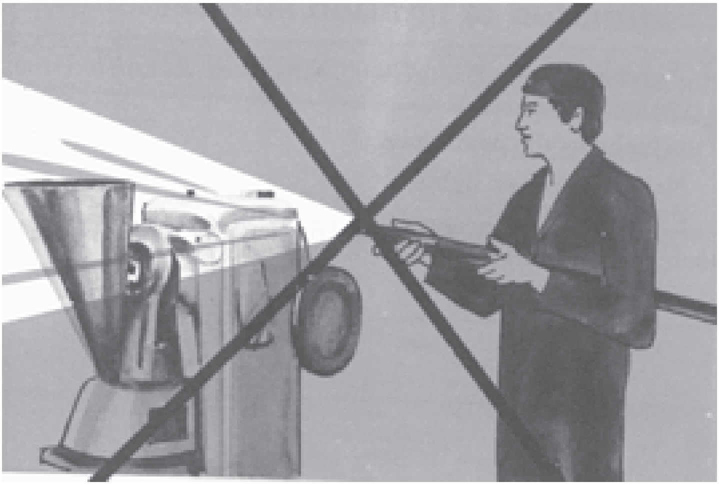
(a) Dust accumulation should be avoided by regular inspection and cleaning down of equipment, rafters, floors, etc.

(b Buildings containing processes involving combustible dusts should be designed so that flat surfaces are avoided and any unavoidable ledges are angled so that dust cannot accumulate on them.

(c) Accumulation of rubbish, oily rags, etc. should be avoided.

(d) Vigorous sweeping, blowing of compressed air, or any other method of cleaning which may raise a dust cloud should be avoided.

Don't use compressed air among dust

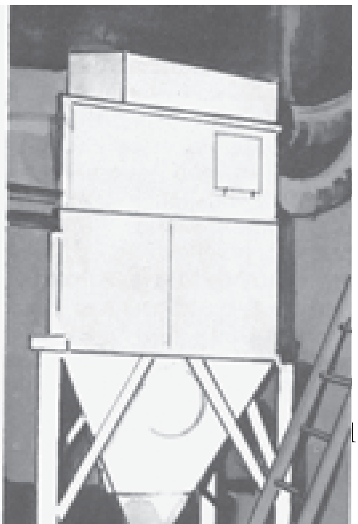


(e) Where vacuum cleaners are used they should comply in all respects with the Electrical Wiring Regulations 1976 or MP 6105: 1976 *Electrical wiring in hazardous locations,* and if not a double-insulated type, they should be adequately earthed.

(f) All dust-producing machines and processes should be provided with efficient dust extraction systems.

Dust collection duct near source

Dust collection hopper



Elimination of ignition sources

It is essential that all sources of ignition are eliminated from a hazardous area.

This includes the *prohibition of:*

Naked flames or lights;

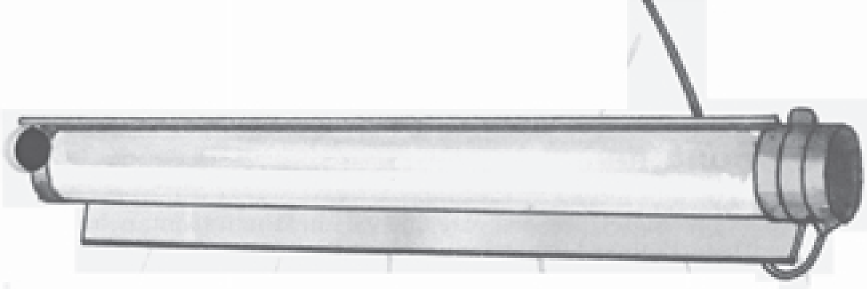
Smoking; and

The use of electrical or gascutting or welding equipment.

Note: The only exception is when all dust-producing machinery is shut down and other precautions necessary for plant maintenance or repair work are carried out. When it is necessary to undertake such work, a “work permit” system should be introduced, and this must be completed prior to beginning any work in the hazardous area. The work permit system should include a suitable checklist which ensures that all precautions have been taken to make the hazardous area safe so that “cold” or “hot” (e.g. welding) work can be undertaken without risk of an explosion or danger to the workers involved. Advice on a suitable work permit system can be obtained from your local office of the Department of Labour.

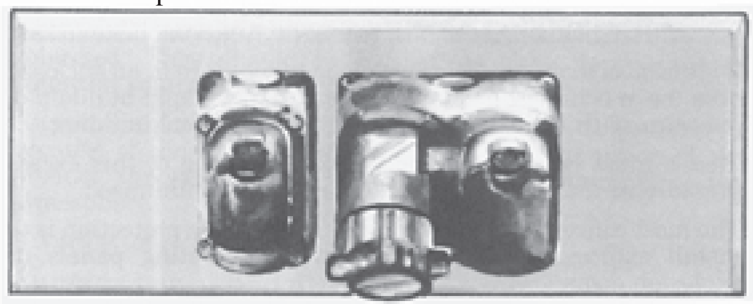
Other precautions include:

(a) Earthing and bonding of all equipment to prevent an accumulation of static electrical charges.



Intrinsically safe light

(b) Ensuring that electrical equipment and wiring complies with the requirements for a Class II Division I hazardous area as specified in MP6105.



Intrinsically safe power socket

(c) Use of magnetic separators to prevent the intake of ferrous materials into dust-producing grinding mills.

(d) Use of non-ferrous blades in fans through which dust passes.

(e) Using non-sparking tools.

(f) Avoiding the use of high-speed shafts and belts.

(g) Eliminating friction sparks.

(h) Eliminating hot surfaces, so that ignition of dust deposits or layers is prevented.

Fire as a source of ignition

When fire fighting it must be ensured that settled dust is not raised into a cloud, as the fire can then become a source of ignition for the explosible dust cloud. In certain circumstances, dry powder fire extinguishers should be avoided as they can add to the dust cloud.

Spontaneous heating

Certain materials are capable of heating spontaneously without the need for an external ignition source. Examples of such materials are cornmeal, fishmeal, fertilizers and rubber.

There is a greater chance that dust which undergoes spontaneous combustion will do so when stored in large quantities.

Relief of explosion pressure

If ignition of a combustible dust cloud takes place in an enclosed area (i.e. machinery or plant) there will be a rapid build-up of pressure, with resulting damage to the plant and building.

Means must be provided for the early release of this excess pressure so that damage to the plant can be minimised.

The most convenient way of providing explosion protection is to install explosion reliefs such as vents, bursting panels or explosion doors.

The relief must be capable of operating almost instantaneously, as usually there is only a very small safety factor between the operation of the vent and the bursting pressure of the plant. The products of the explosion are discharged, hence keeping the explosion pressure at a lower level than the design strength and so protecting the vessel from the worst effects of the explosion.

Care should be taken in the siting of such explosion reliefs, and the products of the explosion must be vented to a safe place in the open air.

Sizing of explosion reliefs

An increase in the area of explosion reliefs reduces the maximum pressure which will develop within the enclosure. The actual size of the explosion relief depends on:

1. The rate of pressure rise of the flammable material.

2. The maximum pressure the plant can withstand.
3. The volume of the plant.
4. The potential strength of the ignition source.

The Department of Labour uses design criteria produced by the National Fire Protection Association (USA): *NFPA No. 68 Explosion Venting Guide 1978*. The determination of the vent size using nomographs is a technical exercise, full details and guidance can be obtained from factory inspectors at all Department of Labour district offices.

Explosion relief vents

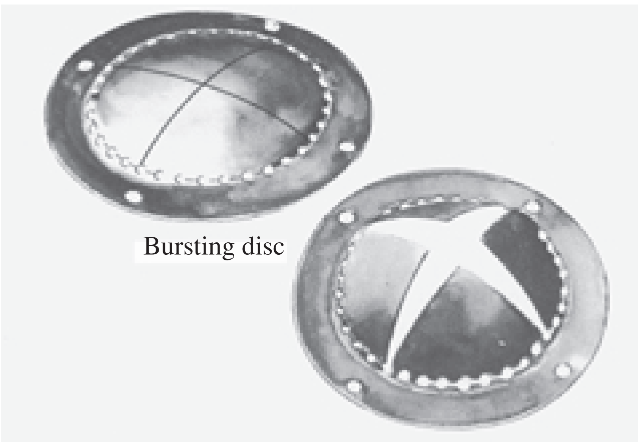
Explosion reliefs must be dust tight and have sufficient mechanical strength to resist the wear to which they are subjected. They should be located as close as possible to potential sources of ignition.

An open vent is the most effective but is usually impracticable because of the need to protect against contamination of the product, the weather, and to stop the dust contaminating the atmosphere.

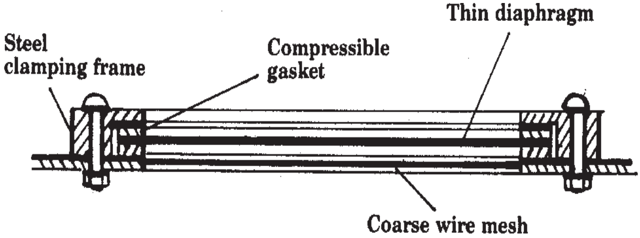
A variety of closures are used instead:

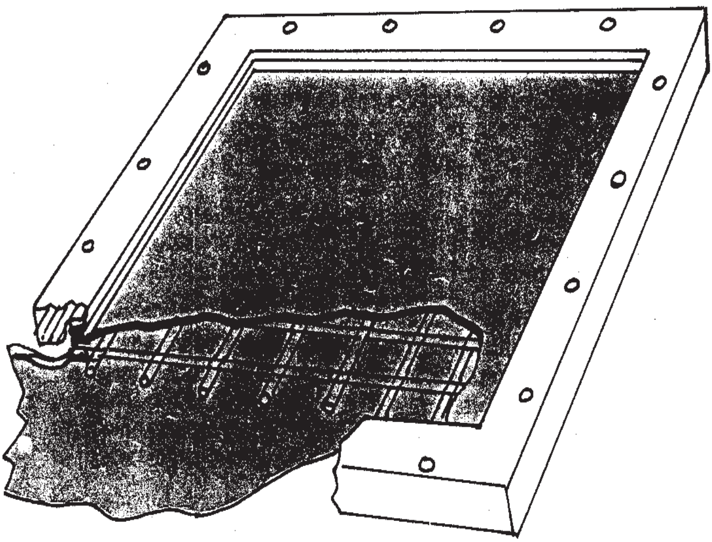
Bursting panels and discs

These panels are made of a wide range of materials, the major consideration being the pressure at which the material will burst and its resistance to pressures from within the plant.



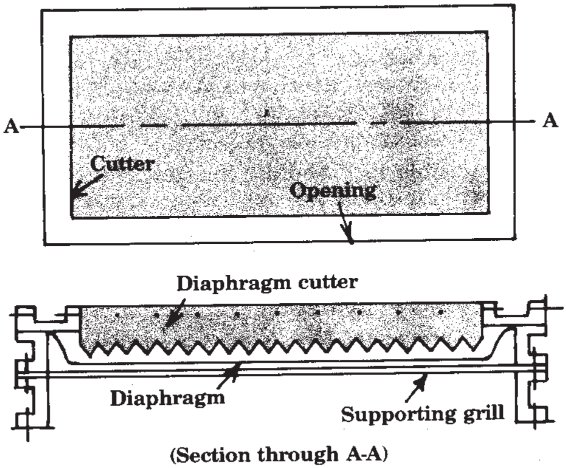
Bursting disc





Bursting panel

Other factors include fire resistance and weather proofing. Materials used include waterproof paper, brown wrapping paper, varnished cloth, polythene sheeting, cellophane, metal foil and rubber. Pressure relief may be accelerated by the provision of knives or cutters at the centre or at the periphery of the panel. (See illustration.)



Explosion relief using a diaphragm cutter

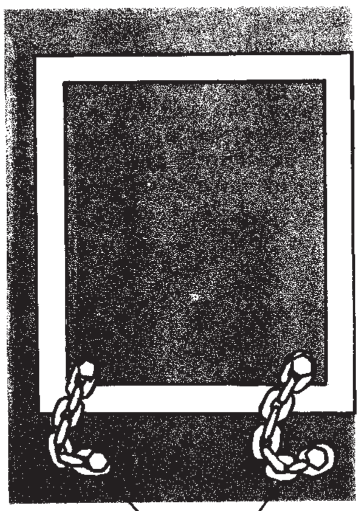
Explosion doors

Light hinged doors have been found to be nearly as effective as open vents for relieving the pressures generated by explosions which do not have a very high rate of pressure rise.

Such doors should be kept as light as possible to reduce inertia which retards operation. Generally the doors themselves should not weigh more than 10 kg/m^2.

Other explosion doors consist of light, rigid covers held in place by magnets, spring clips, friction or thin metal tongues

Vent closures may become dangerous missiles when they operate. To avoid this situation, explosion doors should be securely anchored to the plant by strong chains or other means.



Explosion door with securing chains

Safe venting

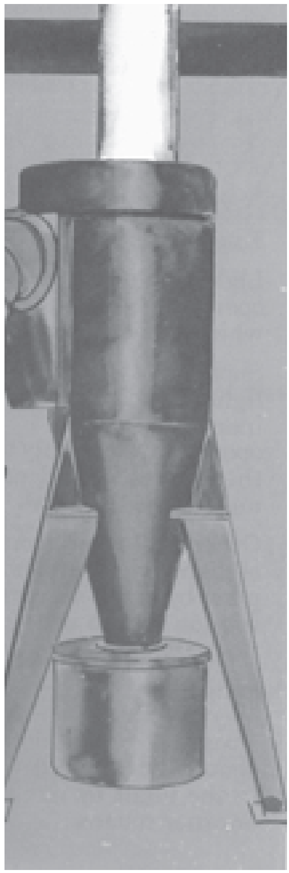
The most effective way of obtaining safe venting is to locate the plant in the open air, or beneath a light waterproof structure, so that the flames, hot gases and burning dust are vented harmlessly away.

If this is not possible, as is usually the case, then the explosion relief vents on plant inside the workroom must be linked to the outside via ducting. This ducting must be strong enough to withstand the maximum pressure to which it is likely to be subjected, and should be as short and straight as possible.

The longer the duct, the less effective it is. Increasing the diameter of the duct as the duct length increases is essential to overcome this problem.

A distance of 6 m is the usual maximum length for an explosion relief vent duct. At 6 m length the cross section of the duct must be twice the area of the vent itself, or the vessel must be capable of withstanding twice the pressure required for that vent area.

The requirement for distances between 2m and 6m is found by proportion, e.g. for a duct 4m in length the area or pressure must be increased by 50%.



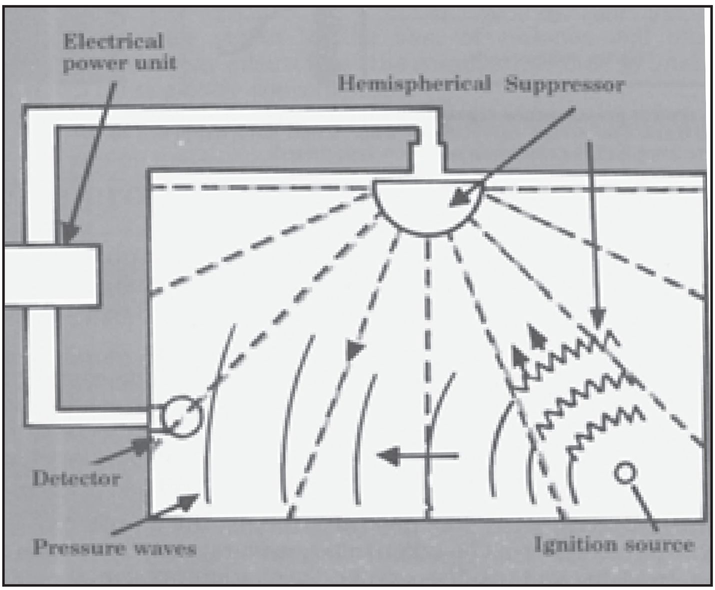
Cyclone with explosion relief duct

Explosion detection and suppression

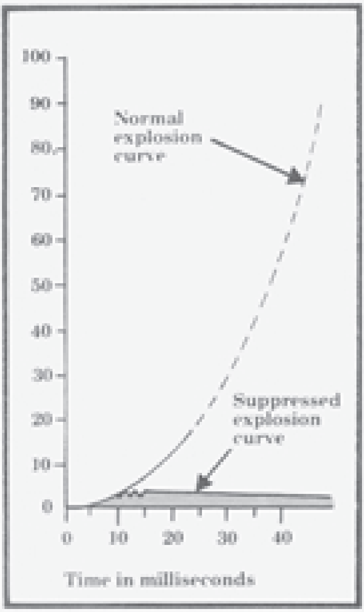
In some cases venting is not practicable as an explosion protection method, and an explosion suppression system may be used as a substitute.

With such systems the initial explosion is picked up by an explosion detector, usually by the detection of a pressure rise. This information is relayed to a control unit and causes a gas suppressant to flow and kill the larger explosion that would follow. The plant will be shut down automatically at this stage by the control unit.

Suppressants usually consist of vaporising liquids such as the halogenated hydrocarbons (halons). To use a suppression system, the plant needs to be able to withstand a pressure rise of about 20 kPa. Care has to be taken where such systems are installed because some suppressants are toxic.



Suppressant container



A typical pressure/time curve for a suppression of an ideal hexane/air mixture. The dotted curve shows what would have happened to the pressure had the explosion not been suppressed.

Inerting

In many plants and processes where the dust is confined within an enclosure, explosions may be prevented by the replacement of the normal atmosphere with an inert gas.

In such a system, oxygen is excluded or the oxygen content in the plant atmosphere is reduced to a level at which combustion cannot be sustained. The use of an inert gas ensures that if a dust cloud does form it will not be able to explode. The inert gas may also extinguish possible sources of ignition.

The reactivity of the dust and the strength and duration of any ignition source must be taken into consideration when choosing an inerting gas, as the oxygen level required for an inert atmosphere will vary considerably from one dust to another. Carbon dioxide is more effective than nitrogen as an inert atmosphere for dust clouds of most carbonaceous materials,

Certain metal dusts will ignite and propagate flame in a carbon dioxide atmosphere. Nitrogen is more suitable in such cases, but at higher temperatures it may be necessary to use argon or a similar gas,

To ensure the exclusion of oxygen, it is best if plant with inerting systems are operated under positive pressure. Places that can benefit from inerting systems are dryers, grinders and silos.

Strength

Strengthening the plant so that it can withstand the effects of any explosion intact can also be used as a method of explosion protection.

Rotary valves

Installing rotary valves at the base of cyclones and other enclosed plant may ensure that the combustible dust is unable to reach an explosive concentration.

Fire protection equipment and facilities

Before beginning construction of new factories in which combustible dust will be produced, handled or processed, the plans should be shown to the fire service for their comments.

Installation of a sprinkler system, with an alarm connected to a fire brigade control room, is strongly recommended. Although fire fighting is primarily the responsibility of fire brigades, a well-designed sprinkler system, in conjunction with first-aid fire-fighting equipment, will help to contain a fire until the arrival of the brigade.

Advice should be sought as to the best type of fire-fighting equipment for the hazard involved, but it should be remembered that actual jets of water should never be played onto burning dust. This could have the effect of raising the dust and hence propagating an explosion.

Further information

Because the type of plant, processes, and dusts which may cause an explosion vary widely, it has only been possible in this booklet to give an outline of the problem and the basic principles involved in explosion prevention.

Factory occupiers are recommended to contact their local factory inspector for additional information and advice. This is particularly important before the construction of a new factory or where major alterations are planned to existing premises where combustible dust may be involved.

Appendix A: Hazard ratings of dust types

The following is a list of some dusts that have been tested by the DSIR. The results give an indication of hazard although there may be variations to these results due to differing composition and particle size of the dust.

For further information see "Hazard rating of dusts" on p 10.

DUST	INDEX	HAZARD
Aluminium/resin mix	50 - 80	Strong
Aqualon fibre	>80	Severe
Bakelite	20 - 50	Moderate
Barley	20 - 80	Moderate to Strong
Barley/maize/lucerne mix	50 - 80	Strong to Severe
Biscuit	>80	Severe
Blood	20 - 80	Moderate to Strong
Blood and bone mix	0-20	Weak
Bread improver	20 - 50	Moderate
Bronzing powder	20 - 50	Moderate
Buttermilk powder	20 - 50	Moderate
Button (plastic)	> 80	Severe
Cane	20 - 50	Moderate
Caramel	20 - 50	Moderate
Carbon black	50 - 80	Strong
Cardboard	50 - 80	Strong
Cardboard/sisal mix	50 - 80	Strong
Casein	50 - 80	Strong
Cheesecake mix	> 80	Severe
Chicken flavouring	50 - 80	Moderate
Chocolate	20 - 50	Strong
Cinnamon	50 - 80	Strong
Clover	50 - 80	Strong
Cloves	50 - 80	Strong
Coal	20 - > 80	Moderate to Severe
Cocoa	50 - 80	Strong
Coconut shells	50 - 80	Strong
Coffee kernels	20 - 50	Moderate
Coriander	20 - 50	Moderate
Cornflour	20 - >80	Moderate to Severe
Cotton waste	50 - 80	Strong
Customwood	50 - 80	Moderate to Strong

DUST	INDEX	HAZARD
Dog biscuit mix	50 - 80	Strong
Drug (mixture of various drugs	50 - 80	Strong
Effluent (freezing works)	80	Severe
Epoxy powder/marble mix	20 - 50	Moderate
Fibreglass	>80	Severe
Fibreglass/plywood mix	50 - 80	Strong
Fibreglass/resin mix	20 - 50	Moderate
Fibreglass/talc mix	50 - 80	Strong
Fibreglass/wood mix	50 - 80	Strong
Fibreglass/wood/MDI foam mix	20 - 50	Moderate
Flax	50 - 80	Strong
Flour	0-20	Weak
Flour/sugar mix	20 - 50	Moderate
Food (mixture of various foods)	50 - 80	Strong
Garlic	20 - 50	Moderate
Grain	20 - >80	Moderate to Severe
Hardboard	20 - 50	Moderate
Icing sugar	50 - 80	Strong
Icing sugar/cornflour/sugar mix	20 - 50	Moderate
Jute	50 - 80	Strong
Lactalbumen	20 - 50	Moderate
Lactose	50 - 80	Strong
Leather.	>80	Severe
Leather (chrome tanned)	50 - 80	Strong
Leather/plastic/wood mix	50 - 80	Strong
Linen	50 - 80	Strong
Lucerne	20 - 80	Moderate to Strong
Maize	20 - 80	Moderate to Strong
Maize starch	50 - 80	Strong
Malt	20 - 80	Moderate to Strong
Malted barley	20 - 80	Moderate to Strong
Malt culms	20 - 80	Moderate to Strong
Meat meal	50 - 80	Strong
Milk powder	20 - 80	Moderate to Strong
Molasses	50 - 80	Strong
Moulding starch	50 - 80	Strong

DUST	INDEX	HAZARD
Oats	20 - 80	Moderate to Strong
Olive flour	20 - 80	Moderate to Strong
Paper	50 - > 80	Strong to Severe
Paper/wood/resin mix	50 - 80	Strong
Particleboard	20 - 80	Moderate to Strong
Peaflour	20 - 80	Moderate to Strong
Pepper (black)	20 - 50	Moderate
Pepper (white)	0-80	Weak to Strong
Pinus radiata	50 - 80	Strong
Pinus radiata/particle board mix	50-80	Strong
Plastic powder	20 - >80	Moderate to Severe
Polyester powder	0 - >80	Weak to Severe
Polyethylene (polythene)	0 - >80	Weak to Severe
Polyurethane foam	0-80	Weak to Strong
Resin	>80	Severe
Resin/marble dust mix	0-20	Weak
Resin/sand mix	> 80	Severe
Rubber	20 - > 80	Moderate to Severe
Rubber/sulphur mix	>80	Severe
Rubber/leather/plastic,’wood mix	>80	Severe
Rye	50 - 80	Strong
Saccharin	50 - 80	Strong
Sausage Meal	50 - 80	Strong
Skim milk	50 - 80	Strong
Sodium caseinate	50 - 80	Strong
Soyabean flour	20 - 50	Moderate
Sphagnum moss (dried)	20-50	Moderate
Spice mix (tumeric,pimento, chillies, cinnamon, ginger mix)	50-80	Strong
Stock feed	50-80	Strong
Sulphur (100%)	>80	Severe
Sulphur (50%)/inert filler	(50%)>80	Severe
Tannaphen (bark extract)	50 - 80	Strong
Toilet soap	>80	Severe
Wheat	20 - 80	Moderate to Strong
Wheat/barley mix	50 - 80	Strong
Wheat flour/gluten mix	0-20	Weak

DUST	INDEX	HAZARD
Whey protein (soluble)	50-80	Strong
Whipping fat (70% coconut fat)	50 -80	Strong
Whiting/emery/wax mix	0-20	Weak
Wholemeal (wheat)	20 - 50	Moderate
Wood	20 -80	Moderate to Strong
Wood/formica mix	> 80	Severe
Wool	50 - 80	Weak to Strong

The following is a list of dusts that have been given a zero rating for dust explosibility:

- Acrofibre insulation
- Alumina
- Amophos (food phosphate)
- Asbestos
- Bronze/aluminium mix
- Cement/woodflour mix
- China clay/urea formaldehyde mix
- “Cosy Fibre” domestic insulation
- Cuprous oxide
- Disprin
- Gluten
- Insul Fluff
- Kelp powder
- Manganese ore
- Nylon flock
- Polyurethane (MDI) fire retardant foam
- Polyvinyl acetate
- Semolina
- Sunflower seeds (70%)/soya bean (30%) mix
- Talcum powder
- Vitreous enamel overspray
- Zinc oxide

Appendix B: Dust explosions in New Zealand

1. A small explosion occurred when damp sulphur clogged ducts and prevented the free flow of carbon dioxide gas which was used to reduce the explosion risk.
2. A worker was using a bucket conveyor to shift sulphur in a fertilizer works when one of the buckets wobbled because of overfilling, struck the side of the conveyor chute and caused a spark which in turn caused a small explosion.
3. A worker was killed when a sulphur store exploded. It is thought that a detonator may have been struck by an elevator and the resultant minor explosion set off a major one. Explosives were used to break down sulphur before shipment to this country.
4. A fire followed by an explosion in a tyre retreading factory occurred when a tyre was being stripped and buffed and a piece of wire reinforcing, which had become red hot, passed through the exhaust system into a bag containing rubber dust.
5. A worker suffered singeing when he was mixing flowers of sulphur in a drum. He accidentally knocked the end of his lighted cigarette into the drum and a minor explosion occurred.
6. A worker suffered severe burns from an explosion in a bulk sulphur store after a patch of sulphur dust started to smoulder. He attempted to put out the fire with a dry powder extinguisher, which agitated the dust and set off a chain reaction.
7. Four people were killed, several people were injured and extensive damage was caused in a factory when an electrical fault ignited plastic dust in the sub-floor area. (See Appendix C.)
8. There was an explosion in a milk plant spray dryer. A partial blockage occurred at the point where the fines are returned to the dryer. As a result, a lump of milk powder

started to burn and eventually ignited the dry fines in the dryer. The explosion vented into the top of the building and caused many broken windows.

9. A worker was injured in a wheat dust explosion. He suffered scorching to the face and loss of eyebrows. Wheat was delivered from the farm to the roller mill by truck. The truck then backloaded gravel to the farm. Consequently gravel became mixed in with the wheat and entered the mill. As a result, the gravel acted as a source of ignition and caused the wheat dust explosion.

10. An employee suffered minor ear injuries when part of an effluent drying plant exploded. The ring dryer was heated by a naked flame and this acted as the source of ignition. In the resulting explosion the classifier and cyclone were badly damaged. A secondary explosion then occurred and an extraction fan and chimney were also badly damaged.

11. A lucerne silo exploded, causing major damage to the silo itself and breaking windows 400 m away. Ten days earlier overheating was detected in the lucerne and it was decided to empty the silo. It is thought a dust cloud was generated inside the silo due to the collapse of an arch of lucerne, and that the explosion was caused when the dust cloud was ignited by some of the smouldering lucerne.

    As a result of the explosion, the conical roof of the silo was forced into the air, settling in the harbour, 100 m away. Also a 7 tonne elevator unit was thrown to the ground, close to 6 employees who were lucky to avoid injury.

12. A coal dust explosion caused major damage to a plant and knocked a worker to the ground, causing minor injuries. Wet coal was conveyed to the mill by a rotary feeder, then forced into the mill by screw conveyor. Hot air was also blown into the mill through the screw conveyor.

    Wet coal clogged in the inlet chute, and, when it released itself, the coal overflowed into the hot air ducting, creating a build-up of coal in the ducting. This coal started to generate its own heat and then, aided by the hot air, began to glow and burn. This released a spark into the pulverized dry coal within the mill and resulted in an explosion.

13. A fire occurred in ducting leading to a coal fired kiln. There were three attempts to put the fire out over a period of 2 days, but eventually the fire acted as a source of ignition for coal dust in the ducting, causing a minor primary dust explosion, and a major secondary explosion. There was major damage to a cyclone, and wall cladding was sprung. No workers were injured.
14. Three men were repairing a flour silo when flour dust dislodged by the release of tension on the silo wall created a dust cloud, which was ignited by a welding torch, and then exploded. The workmen had cleaned flour from beneath the area in the silo where they were working, but had not cleaned the top part of the silo. All the men were injured (two very seriously: resulting in 3-4 months in hospital). There was also some external damage to the building.
15. A fire with a resulting dust explosion in the dust extractor of a plywood sander caused a perspex view port to shatter and injure the operator. The cause of the fire was doubtful but it had been smouldering for at least 2 hours before the explosion. There were two possible causes of ignition:

    (a) occasionally after a new belt of sand paper was fitted, it was incorrectly adjusted and caused sparks; or

    (b) the operator was a smoker, and it was possible for a cigarette to be drawn into the ducting system.
16. A company manufacturing window glass sprayed coconut dust onto the finished product to prevent transit rub from the conveyor system. Any coconut dust build-up was swept into chutes which deposited the waste at ground level. During routine maintenance a welding torch ignited the coconut dust inside the chute, causing a dust explosion. A maintenance worker received burns to his arm.
17. An explosion occurred in an icing sugar milling room when the accumulated dust arising from poor housekeeping was ignited by an exposed electric light filament. Damage was moderate but there were no injuries.

18 An overheated bearing in icing sugar milling equipment resulted in a serious explosion. A worker was injured and major damage to plant occurred.

19. An electrostatic precipitator that was used for coal dust removal did not remove all dust from the plant. Excess dust was ignited by a spark and there was an explosion. There were no injuries but major plant damage resulted.
20. A spark ignited fine milk powder in a fluidized bed, resulting in a severe explosion. There was major property damage but no injuries to workers
21. A light fitting fell onto a dust covered beam and the disturbed aluminium dust then exploded and caught fire. A worker received burns to his forearm.
22. A welding spark ignited fine maize dust while welding work was being carried out on a stock feed elevator. This resulted in a major dust explosion which caused shock and arm burns to a worker.

Appendix C: The Masterton dust explosion

On 13 April 1965 a devastating explosion took place in the factory of General Plastics (NZ) Ltd., Masterton.

The explosion was violent and spectacular. The blast burst floors upwards, blew the roof out of the ornamenting room, practically demolished a locker room, hurled 300 kg machines onto the roof and threw other machinery through a wall. The smoke from the resulting fire could be seen in Martinborough 40 km away.

Four people died as a result. of this explosion and 6 people were injured. Casualties could have been a lot higher, as the explosion took place at afternoon tea time, and most staff were away.

Subsequently the explosion was shown to be caused by a short circuit of an underfloor electrical socket of a button finishing machine. It acted as a source of ignition for plastic dust which had accumulated under the floor of the button ornamenting room and initiated a primary dust explosion in the floor cavity. The burning dust and flames from the initial explosion were driven under the floor of a locker room — causing a further explosion.

The force of these initial explosions burst the floor upwards, taking the unburnt dust, gases and flames into both the ornamenting room and the locker room. These acted as a source of ignition for the secondary explosions that took place in these two areas, causing large-scale damage to the factory.

Although the factory workroom was kept relatively free of accumulated plastic dust, over the years dust had filtered through the floor boards and collected in the floor cavity. This underlines the need to stop the accumulation of hazardous dusts. In this case the provision of solid floors and improved housekeeping would have prevented dust build-up.

As a direct result of this incident, the Factories Act 1946 was amended to require factory occupiers to take practicable steps to prevent dust explosions.