GOVERNMENT OF WESTERN AUSTRALIA

FESA
Fire & Emergency Services Authority of Western Australia

HAZMAT Articles

Dust Explosions

Introduction

Some of the most destructive explosions have been caused by dust. There is more explosive energy in the dust from grains such as wheat, barley and corn, than in an equal amount of TNT.[1]

While fires are far more common, explosions are far more costly in terms of loss of life, injury and property damage.

Dust explosions have been quite common in the past. For example, there were 645 explosions in the coal mines of England from 1835 to 1850, in which coal dust was the major contributing factor.

There were 1,085 dust explosions resulting in 351 fatalities, in the US from 1900 to 1956. Also in the US, among the 15,000 grain handling facilities from 1958 to 1977, there were 220 dust explosions resulting in 48 deaths and 500 injuries.

The potential for a dust explosion has now become a well recognised hazard.

Which dusts

Any combustible solid material which can be dispersed in air as a dust cloud, is capable of causing a dust explosion. Explosions on record have originated from dusts from the following sources:

- Agriculture - grain dust, flour, sugar, milk powder, wool, paper, and wood.
- Metals - aluminium, magnesium, zinc.
- Mining - coal, combustible sulphide ores.
- Chemical industry - sulphur, most plastics, pesticides, pharmaceutical's including aspirin and vitamin C.

The Bureau of Mines of the US Department of the Interior developed an arbitrary scale, (Table 1) based on tests using small amounts of dusts, as a guide to the degree of hazard of each type of dust.[2]

Explosion	Ignition Sensitivity	Explosion Severity
Weak	<0.2	<0.5
Moderate	0.2 - 1.0	0.5 - 1.0
Strong	1.0 - 5.0	1.0 -2.0
Severe	>5.0	>2.0

TABLE 1. Explosion Hazard Scale for Dusts

There are two terms used on the scale, the ignition sensitivity (how easy to ignite), and explosion severity (how big a bang). The higher the number on each scale the greater the hazard that each dust represents (Table 2).

Type of Dust	Ignition Sensitivity	Explosion Severity
Aluminium	7.3	>10.2
Aspirin	2.4	>4.3
Coal	2.2	1.8
Coffee bean	0.1	0.1
Cotton	<0.1	<0.1
Egg wite	<0.1	0.2
Flour	2.1	1.8
Grain dust	2.8	3.3
Magnesium	3.0	7.4
Milk, powdered	1.6	0.9
Polyethylene	24.0	2.2
Polystyrene	6.0	2.0
Rubber	4.6	1.6
Sugar	4.0	2.4
Sulfur	20.2	1.9
Vitamin C	1.0	2.2

TABLE 2. Explosion Potential of Some Dusts

What is a dust explosion?

A dust explosion is the very rapid combustion of a dust cloud, to produce a flame and a pressure front. The flame front frequently causes loss of life, while the pressure front will often cause extensive damage to buildings. With some dusts, there is sometimes only a flame front and the pressure front is only minimal; with others, the flame spreads with the effect of an explosion.

An explosion occurs as the flame generates heat and combustion products, and expansion from both these sources causes an immediate pressure rise which must then move out as a pressure wave and impact on the surroundings. Pressures of up to 700 to 800 kPa can be generated, and if it occurs in a confined space such as a building, the effects can be devastating, since most buildings can only withstand 2 kPa at most.

Contributing factors

Dust clouds may be ignited by the effects of mechanical friction such as overheated bearings, motors overheating from air cooling vents being clogged with dust, particles of steel or stone caught up in grinding machinery producing sparks, overheated dust coated light bulbs, static electricity, electrical arcing, welding sparks and naked flames.

As a general rule, dusts require 20 to 50 times more energy from an ignition source compared with a flammable vapour, or they need direct contact with surface temperatures ranging from 300 to 600 deg C.

The finer the dust the greater the hazard. Not only can it be more easily blown into the air, it will stay suspended in air much longer. It has a greater surface area per unit volume so that it can burn all the more rapidly, increasing the intensity of the flame front and the violence of the explosion.

Dusts like flammable vapours, have lower and upper explosive limits. The lower limit is the concentration of dust in air to just sustain the flame front. The lower flammability limit ranges from about 10 to 40 gm/m^3 depending on the type of dust. At these concentration it will be quite visible to the naked eye as a fog or cloud.

The upper limit is usually difficult to measure since there appears to be no clear cut-off point. Instead it may, or may not, ignite at a given concentration. If it does ignite, it tends to leave behind increasing amounts of charred residue.

Concentrations of dust which are potentially explosive are intolerable for people to remain in and are not likely to be found in the open, however they can be found around machinery used for crushing, grinding, sanding, milling, filtering, blending, shredding, spray drying, or conveying bulk quantities of solid materials.

Why so dangerous?

Dust explosions are dangerous, because they can set off a chain reaction. The initial explosion is usually small and localised, however it is often sufficient to disturb surrounding dust deposited on floors, roofs, beams, and machinery to form a second much larger cloud, which in turn can lead to a far more devastating explosion.

Further explosions can follow in other parts of the building or even neighbouring buildings. These explosions may occur seconds or even minutes apart, and have been described by those who have survived a dust explosion, as sounding like 'rolling thunder'.[3]

A fire can then follow from scattered burning particles, or from other small dust accumulations that have been ignited.

Incidents involving dust

The initial explosion need not necessarily be caused by dust. It may only be a small gas/vapour explosion, or even a mechanical or man-made disturbance sufficient to create a dust cloud. One incident on record involved an explosion of an air compressor in a wool combers store. It did not hurt anybody, however it triggered a dust cloud, which ignited and the resultant flame shot right across the room with 18 workers being burned, one fatally. In another, a fitter died after being enveloped in flame after walking across a 6 metre grating platform. The vibrations from his footsteps created a cloud of polymethylmethacrylate (a plastic!) dust, which dropped onto a shrink wrapping machine fuelled by an open propane gas flame.

On the 15th March, 1987, in Harbin, China, an explosion of flax dust triggered a chain of explosions that destroyed the whole 13,000 m^2 linen plant, causing 58 deaths and 177 injuries. The strength and time of each explosion was detected at the nearby earthquake monitoring station.

On the 2nd March, 1982, in the UK, an articulated lorry carrying 19 tonnes of powdered resin crashed into a roadside cottage spilling part of its load. A dust cloud was thrown up, which ignited and exploded, setting fire to the entire load. Noxious fumes from the fire affected the driver, occupants of the cottage, workmen at the nearby building site and some fishermen in a boat about 1.5 kilometres out to sea.

In the US on 23rd December, 1977, at Westwego, Louisiana, a series of explosions destroyed 37 grain silos completely and damaged many others, causing 35 deaths and $100,000,000 worth of damage. The facility consisted of 73 silos with a capacity of 150,000 m^3. It was one of 5 grain storage explosions that occurred over an 8 day period, and was attributed to unusually dry weather conditions.

On the 6th February, 1979, in Bremen, Germany, the greater part of the 40,000 square metre Roland Mill complex was destroyed by a series of explosions. The complex included a seven story flour store, six story mill, other silos and administration building. A pressure wave struck a loaded truck, throwing it against a wall spreading its load into the air and believed to have caused an open air explosion. No traces were found of seven of the fourteen killed in the fire, believed to be cremated in parts of the fire where all traces of combustibles were consumed; an estimated 1,000 degrees C for several hours.

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[1] Bowen JE, "An Overview: Grain Dust Explosions." Fire Engineering, 136(1983):22,23,25,27

[2] Fire Protection Handbook, Ed., McKinnon GP, 14th ed., 1976, NFPA, Boston, Mass

[3] Nelson P, "Dust Explosions: The Forgotten Killer." Australian Safety News, 65(1994):51-55

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