Flammable Solids & Dusts			
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DUST EXPLOSIONS IN TOTALLY ENCLOSED SYSTEMS OF INTERCONNECTED VESSELS

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Summary

This Discipline Information Note summarises the results and conclusions of a research project completed during autumn 1994 at Buxton. It was carried out as a collaborative project, with industrial sponsorship from 11 companies, drawn together via the British Materials Handling Board.

Background

A related project involving dust explosions in vented interconnected vessels has been described in DIN 3102. When this project was started, it was felt that there was a need to look also at totally contained systems. These are not particularly common, but are most likely to be found in the pharmaceutical industry, where the scale of production may be relatively small, the product value high, and the health risk from spreading products via a vented explosion unacceptable.

Dust explosions involving organic materials in the standard test apparatus produce peak pressures up to 10 barg, and frequently less. A 10 barg design basis for containment should be satisfactory for explosions in single vessels, but at the outset of the project there was a concern that pressure piling in systems of linked vessels could produce much higher peak pressures.

Experimental Work

Three vessel sizes were used: 2, 4 and 20m^3. The length of interconnecting pipe was kept constant at 5m, but the pipe diameter was varied. Diameters of 0.15, 0.25 and 0.5m were used. Experiments were carried out with coal dust and toner dust, which had measured K_{ST} valves of 168 and 222 respectively.

About 120 experiments with interconnected vessels were completed, but in most cases the explosion did not transmit down the pipe from 1 vessel to the other. Transmission never occurred with the 0.15m diameter pipe, and did not always occur with the 0.5m pipe.

Pressure piling did cause enhancement of the peak pressures in some experiments. The highest peak pressure recorded was 19.7 barg using coal in a 20-4m^3 vessel system and the largest size of pipe. This compares with a P_{max} for the coal dust of 7.7 barg.

Analysis of Results

In most dust explosions, worst case conditions occur in fuel rich systems, ie oxygen supply limits the amount of fuel burnt. This means that in a closed system, although the flow of dust from vessel 1 to vessel 2 following an initial explosion increases the pressure at the start of any explosion in vessel 2, the amount of dust burnt cannot increase. Consideration of the material flows show that peak pressures where pressure piling occurs is not expected to depend on the type of dust. The peak pressure in vessel 2 will however be directly proportional to the pressure in the vessel at the start of an explosion.

After the explosion in vessel 2, flow reversal down the pipe was sometimes observed, and could produce a peak pressure in vessel 1 higher than the initial explosion.

Graph 2 illustrates the range of experimental results.

Practical Conclusions

1. A major problem is that it is never possible to predict with certainty in a system of linked vessels, the vessel in which the primary explosion will occur. The maximum pressures obtainable depend on the volume ratio of the vessels and become very high when this ratio exceeds 4 and ignition occurs in the larger vessel. Such arrangements should be avoided.

2. When the volume ratio is between 2 and 4, pressure enhancement is evident with a pipe diameter of around 0.25m. Use graph 1 to estimate P_{red}, the pressure that could be achieved in vessel 1. A theoretical peak pressure for the system is P_{red} times the normal P_{max} value for the dust.

3. With pipe diameters less than 0.1m, the probability of explosion transmission is low, and may be ignored for design purposes.

4. With vessel volume ratios in the range 1-2, graph 1 again gives a value of P_{red}, from which a theoretical maximum pressure can be calculated. Consideration of graph 2 suggests that with a pipe diameter of less than 0.5m the system should be designed to thus worst case value.

5. Where the pipe diameter is more than 0.5m, a less conservative design pressure is recommended. This should be the mean of normal P_{max} for the dust and theoretical P_{max} for the system.

Two Worked Examples should make this clear

Dust with parameters K_{st} 250, P_{max} 8.5 barg
Vessels of volumes 1.5 and 4.5m^3
Pipeline diameter 0.3m
Vessel ratio = 3
Graph 1 gives P_{red} = 1.32 para
Theoretical P_{max} pressure = 1.32 x 8.5 = 11.2
Design systems to withstand 11.2 barg

Same dust, vessels of 1 and 1.5m^3
Pipe diameter 0.55m
Vessel ratio 1.5
Graph 1 gives P_{red} = 1.5 barg
Theoretical maximum pressure = 1.5 x 8.5 - 12.75
Design pressure = (12.75 + 8.5)/2 = 10.6 barg

A full report has been issued to the project sponsors, and a paper describing the work was published in the Journal of Loss Prevention in January 1996. The information should be offered as best advice where relevant systems are being designed, but it is not enforceable.