

Flammable Solids & Dusts

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VENTING OF DUST EXPLOSIONS IN INTERCONNECTED VESSELS

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Summary

This Discipline Information Note provides a summary of completed research done at Buxton in 1994 on the consequences of dust explosions in vessels linked together by a moderate length of pipework. Advice is given on the circumstances in which existing calculation methods for the required area of explosion relief are inadequate.

Existing methods of calculating the area of explosion relief are based on results of tests in single vessels of various sizes and dimensions. Many arrangements of dust handling plant comprise however a series of interconnected vessels, and it is not always practicable to provide a rotary valve, or other means of explosion isolation between the vessels.

Where an explosion starts in one vessel, and propagates down a pipe into a dust cloud in a second vessel, the second explosion may be expected to be more violent than an explosion in a single vessel in otherwise identical conditions. Three factors will influence this. A flow of hot gas down the pipe will raise the pressure in the second vessel as the explosion starts; the same rapid flow of gas along the pipe will raise the turbulence of the dust cloud in the second vessel, and the flame entering the second vessel can act as a large, energetic ignition source for the second explosion. These factors will raise the rate of combustion and hence explosion violence.

Experimental Work

The research project used vessels with explosion vents in each vessel. The vessel sizes were 2, 6.3 and 20m³. Pipe diameters used were 0.15, 0.25 and 0.5m, with lengths 5, 10 and 15m. Dusts used were coal, toner and anthraquinone, as examples of ST1, ST2 and ST3 materials. Dust was injected under pressure into each vessel to create the initial clouds. Piles of dust were placed in the pipe.

It was seen at the outset that there are a very large number of interrelated variables in the system, including dust concentration, ignition delay, vent areas, pipe length and diameter, and which vessel in an unequal system contained the source of ignition. Not every variable could be investigated separately, but the main test programme comprised 600 experiments, and the overall pattern of results is clear.

Qualitative Results

Many experiments showed that the pressure trace in the vessel first ignited (vessel 1) contained two peaks. The second peak resulted from reversal of the initial flow in the pipe, with a burning dust cloud flowing back from vessel 2 into vessel 1. This could produce a higher peak pressure than the initial explosion.

With the smallest pipe diameter, 0.15m many explosions failed to propagate from one vessel to the other, and no transmissions occurred with a 15m length of 0.15m pipe.

Conversely, enhanced peak pressures in the system were most evident with short lengths of pipe and larger diameters.

Pre-compression of the dust cloud is greatest when unequal sized vessels are connected, and ignition is in the larger vessel. Not surprisingly, this arrangement showed large pressure enhancements. Unfortunately, in a real system it is rarely possible to predict with any certainty the likely site of ignition in a system of interconnected vessels.

A most noticeable trend is that pressure enhancement in the system is greater when the vent areas are small. The pressure enhancement is expressed as a ratio, between the predicted peak pressure for a single vessel with a given vent, and the actual worst case peak pressure. The worst case result is used to allow for scatter in experimental results. Conversely in most systems where the designed value of Pred is 0.2 bar no pressure enhancement from the system of linked vessels is evident. This means that for many systems, designed with low values of Pred, no correction to the required vent areas for linked vessels is needed.

Guidance

The full report has been issued to the 19 organisations outside the HSE who jointly sponsored the work. As the results are partly in the public domain, at this stage they should be considered as best technical advice, but they are not enforceable.

Where interconnected vented systems are seen, or planned, the advice should be to use the KST nomograph approach to venting, and then apply the appropriate factor from the table below, to determine the required vent area **for each vessel**.

Where the designer would otherwise use either the ST nomographs or Radandt nomographs (see pages 80-85 and 98-101 of the I Chem E book) it may be reasonable to use this same correction factor.

It is not recommended to combine these new results with any of the other vent sizing calculation methods.

The coal dust data may be used for any other ST1 class of dust, and the toner data for any other ST2 class dust.

Section 31(2) of the Factories Act remains in force, and the provision of one of the established forms of explosion barrier between linked vessels is always good practice and often enforceable.

VENT AREAS REQUIRED FOR INTERCONNECTED SYSTEMS (CONSTANT x Kst VALUE)

Vessels	Vol Ratio	x Kst Vent Area			
		Pred 0.2 bar	Pred 0.5 bar	Pred 1.0 bar	Pred 1.5 bar
Coal 0.5m Diameter Pipe					
2 - 2	1:1	1.10	1.00	1.00	-
20 - 20	1:1	1.00	1.07	1.10	1.43
6.3 - 2	3.15:1	1.00	1.13	1.30	1.57
20 - 6.3	3.17:1	1.00	1.33	1.40	1.57
20 - 2	10:1	1.00	1.33	1.40	1.57
Coal 0.25m Diameter Pipe					
20 - 20	1:1	1.10	1.07	1.00	1.14
6.3 - 2	3.15:1	1.00	1.00	1.20	-
20 - 6.3	3.17:1	1.00	1.20	1.20	1.43
20 - 2	10:1	1.00	1.33	1.20	1.29
Coal 0.15m Diameter Pipe					
20 - 2	10:1	-	1.20	1.00	-
Toner 0.5m Diameter Pipe					
2 - 2	1:1	1.00	1.85	2.30	2.44
6.3 - 2	3.15:1	1.00	1.45	1.69	2.67
20 - 6.3	3:17:1	-	1.50	1.85	2.44
20 - 2	10:1	1.00	1.25	1.61	2.11
Toner 0.25m Diameter Pipe					
2 - 2	1:1	1.00	1.30	1.53	1.89
6.3 - 2	3.15:1	1.00	1.30	1.69	1.78
Toner 0.15m Diameter Pipe					
2 - 2	1:1	1.00	1.00	1.00	1.00
20 - 2	10:1	-	1.00	-	-
Anthraquinone					
2 - 2	1:1	-	1.61	1.32	1.76

Note: The ratio has not been allowed to fall below 1.0 even if the experimental data showed otherwise. Where the experimental data was out of range no ratio is given.