

Flammable Solids & Dusts

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DUST EXPLOSIONS IN PIPELINES

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Summary

This DIN summarises the results of a substantial research project completed in 1997 by HSL which studied the flame and pressure effects of explosions down pipes in which a dust air mixture was flowing.

Background

Earlier work on this topic has been reported from France, Germany, the USA and the UK. Guidance based on a literature review of experiments in the USA and elsewhere is presented in NFPA 68, and these form the basis of the calculations in DUST- EXPERT. The German VDI guidance warns against the possibility of serious explosion pressures, but gives no specific advice concerning the provision of vents. Work by the old CEGB, who were concerned with their pulverised fuel plants, demonstrated circumstances in which detonations in coal carrying pipelines could occur, but some of this work was commercially confidential and was never widely publicised. The NFPA guidance was seen to be restrictive in its application, so further work was commissioned.

The Work

The HSL project used a fan and dust feeding system to produce a continuous cloud of known concentration in pipe lengths up to 45m. Pipe diameters were 0.15, 0.25 and 0.5m, and the cloud was ignited by a charge of black powder in the pipe. Flow rates in the range 17-48 m/s were used, and dust concentrations in the range 0.1-0.5 kg/m³. These flow rates are comparable with those used in lean phase pneumatic conveying, but the concentrations are below those typically found in conveying systems by a factor of about 10. Most of the tests used coal dust, (KST 155) but some were carried out with more energetic toner (KST 222) and cornflour (KST 211) dusts. Early arrangements used a system in which the explosion could only vent at the downstream end of the pipe. Later the ducting was altered to allow the explosion freedom to vent in both directions. Intermediate explosion vents were fitted in some experiments, and the passage of flame and pressure waves were studied.

No explosions transmitted down the smallest size of pipe using coal dust, but it is not clear why this was the case. Smaller scale experiments carried out in Norway have demonstrated flame transmission with dusts of similar reactivity up pipes of diameter 0.1-0.15m where the dust was falling under gravity. Factors such as turbulence, material of pipe construction and type of ignition source are likely to influence flame propagation. In the current work, only low explosion pressures were measured in straight pipes so the programme of tests moved on to pipework arrangements with sharp and swept bends, or orifice plates to mimic turbulence generating features that would be expected to increase the burning rate.

Conclusions

Some of the experimental conclusions can be summarised as follows.

1. Even at the slowest air speed used, the flame front would not travel significantly against the direction of powder flow.
2. With straight pipe and no obstructions, none of the experiments showed pressures exceeding 0.4 barg. Similarly even with turbulence generating features, none of the experiments in the 0.25m diameter pipe showed pressures exceeding 0.4 barg.
3. Flame speeds with coal dust were generally below 200 m/s, and at low speeds there was very little correlation with the pressures measured. Sharp bends and orifice plates did create turbulence and raise the pressures and flame speeds. In a small number of cases flame speeds exceeding 500 m/s were measured, well above the speed of sound at standard temperature and pressure. Earlier work which showed much higher peak pressures used quite different experimental arrangements.
4. With the system open to vent pressure at both ends, but no intermediate vents, the highest pressure measured was 2 bar. In this experiment using coal dust, and an orifice plate to generate turbulence, the peak pressure rose progressively along the pipe, and the flame front had caught up the pressure wave at 45m. This suggests that in significantly longer pipe, much more destructive pressures could arise.

A smaller number of tests carried out with cornflour in the large diameter pipe with an orifice plate and no explosion vents produced markedly higher pressures. Four experiments produced peak pressures in the range 6-15 bar

Practical Conclusions for Systems Handling ST1 Class Dusts, With Systems up to 50m Long

Circular pipework is inherently strong, and pneumatic conveying systems have to be designed to withstand overpressures from the blower used to move the powder. Simple calculations show that even 1mm thick mild steel as a 0.5m diameter cylinder can withstand 5 bar, while 1mm thick aluminium will withstand 2 bar. In practice, thicker walls are usually used, as some allowance has to be made for abrasion by the powder being conveyed. German advice suggests that welded steel pipe with a wall thickness of 2mm is given a pressure shock rating of 10 bar at diameters up to 650mm. They note that suitable support for the pipework is important.

More specifically, in respect of the explosion risk for the pipeline itself, the following advice can be given:

- 1) Dust extraction systems used for plant cleaning, whether mobile or centralised will rarely have a pipe diameter above 0.1 m. The risk of a dust explosion in the pipe is minimal, but an explosion in the collector can vent back through the system. Even if a heap of smouldering dust was rapidly sucked up, it seems unlikely that it would both ignite a dust cloud in the pipe and propagate the explosion.
- 2) Dust extraction systems drawing fine dust continuously from multiple places in a complex plant, e.g. the tops of elevators or bins may have pipework of diameter above 0.15 m, but they should be designed to operate well below the LEL, and in this case there will be no reason to seek venting of the collection ductwork.
- 3) Most pneumatic conveying systems have pipe diameters of 0.15 m or below. Lean phase conveying typically operates at velocities similar to those used in

these experiments, but with dust concentrations higher by a factor of about 10. Such systems may briefly have a dust cloud of the right concentration to propagate an explosion at the beginning or end of a run, but in general they present a low risk, and we have little basis to ask for venting of the pipeline.

4) Dense phase conveying systems typically operate with the powder flowing relatively slowly as a series of discrete plugs. An explosion could not propagate along the pipe in this condition, but at the end of a run the pipe blows partly clear. The degree of risk at this point is uncertain, but we have from these results no basis to ask for explosion venting.

5) Large scale pulverised fuel burning plants, at some power stations or cement works, have long lengths of large diameter pipework. Such systems are likely to need venting or other protective features.

6) It is clear that much higher pressures can be produced with more reactive dusts, but the large majority of installations, particularly in the food and related industries will be covered by the advice above. If examples of long lean phase pneumatic conveying systems carrying ST2 dusts come to the attention of specialist inspectors, details should be sent to TD5.

7) Centralised vacuum cleaning systems for ST3 and other highly reactive dusts have been known to propagate explosions, and precautions to control this risk may be needed. The most important precaution is to ensure there are no dead spots within the pipework where deposits may settle, and later become fuel for an explosion travelling back from the filter system, or start to smoulder or overheat.

8) Earlier work has shown that an explosion that starts in a vessel, and propagates into a pipe can be much more violent. Some grinding installations may have the right geometry and dust cloud conditions. Existing advice in the flour milling code recommends that the pipework leading from grinders should be strong enough to withstand 7 bar. If the pipework extends more than 20 m before the air is separated from the dust, a more detailed study of the explosion risks is needed, and venting may be necessary.

9) None of this advice affects the existing advice on venting process vessels, silos, filters, cyclones and similar items of plant.