DUST EXPLOSION VENTING RESEARCH†

P Holbrow, Health and Safety Laboratory, Buxton, Derbyshire, UK

INTRODUCTION

Dust explosion venting is a well-established method of protecting against damaging explosion over-pressures. The principle is well known; in the early stages of an explosion, weak panels in the walls of the vessel or explosion venting device open at a low over pressure. Much of the explosion is then dissipated outside the vessel and the maximum pressure inside the vessel is reduced. In general there is already guidance available for the application of explosion venting in industrial situations. However, much of this dates back to the mid 90s and before, since then there have been a number of developments in this area.

This paper reports on two of these:

1. Explosion venting of small vessels is claimed to be unnecessary in some cases. The aim of this work is:
   (a) To potentially revise guidance on venting of small vessels (<0.5 m^3) and to confirm the apparent conditions under which it is claimed that venting is not required, and for which types of dust.
   (b) Establish the venting requirements (if any) of small process vessels.
2. Flameless venting devices consist of a flame-arrestor element, closed at one end and open at the other, that quenches the flame as the vent operates. The device is bolted to the clean side of the explosion vent on the vessel. It is claimed that the dust will be retained in the cylinder and, because of heat absorption, the flame from the explosion will be extinguished as it travels through the flame arrestor section. Advantages of flameless venting are claimed to be flame extinguishment, dust retention, potentially eliminating the need for explosion vent ducts to outside the workroom and minimisation of the vent relief area requirements for indoor venting. The aim of this work is to generate greater understanding of the potential and the limitations of flameless venting.

TEST DUSTS

The test dusts were cereal flour and wood dust (Table 1).

EXPLOSION VENTING OF SMALL VESSELS

TEST VESSELS

0.5 m^3 Test Vessel

A test vessel with an internal volume of approximately 0.5 m^3 was specially constructed for this project. It has a diameter of 0.914 m and a length of 0.8 m with a front face fitted with a 0.4 m diameter vent opening capable of accepting smaller vent openings (Figure 1). Two flanged connections are located on the side of the vessel each with nominal bore of 97 mm diameter. The total vent area was varied by closing off the various openings. Screwed ports were located on the vessel to accept instrumentation and ignition equipment. The dust cloud is produced by injection of a pre-weighed mass of dust into the vessel from an external pressurised dust injection system.

The pressure-time history within the test vessel was measured using transducers positioned at the wall of the vessel. The ignition source was located at the vessel centre-line and comprised an electric fuse head inside a polythene pouch containing blackpowder.

Sieve unit

A sieve unit was supplied specifically for the test programme (Figure 2). The vibratory motion eliminates oversize material from the feed via a sieve screen with an appropriate sized mesh. The upper and lower chambers of the sieve unit are separated by the sieve screen. Internal volumes are approximately 0.1 m^3 above and 0.1 m^3 below the sieve screen. The test programme used 140 micron and a 250 micron mesh screens.

Material is fed into the sieve via the 250 mm diameter inlet in the upper chamber. Oversize material travels across the screen and is discharged through a 150 mm outlet in the upper chamber and the undersize material discharged through a 250 mm diameter outlet in the lower chamber. It is in this chamber where a dust cloud is likely to be located and therefore the igniter is positioned centrally in this chamber. The sieve unit is powered by an external vibratory motor and is supported on four rubber mountings which secure the unit to its steel support frame.

Cyclone

A series of tests are planned involving a small medium efficiency cyclone (Figure 3). It is constructed from 2 mm thick steel with dimensions as shown in Figure 4. This type of cyclone is typically used as a pre-separator before a conventional bag filter. Separation efficiency is quoted as approximately 90% for wood dusts but lower for finer dusts. Dust will be pneumatically conveyed into the cyclone from an external fan/dust feed system and ignited using a strong ignition source located within the cyclone.

This publication and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

Table 1. Test dusts

Dust	HSL reference	K_{st} (bar m s^{-1})	P_{max} (barg)	Moisture content (%w/w)	Particle size distribution
Corn flour	EC/084/09	147	7.9	13.5	100% < 63 μm
MDF wood dust	EC/074/09	113	10.4		62.5% < 500 μm
					49.2% < 250 μm
					44.1% < 180 μm
					31.4% < 106 μm
					15.9% < 63 μm
Wheat flour	EC/107/09	138	8.0	11	100% < 180 μm
					65.9% < 106 μm
					10% < 63 μm

The pressure-time history will be recorded using a pair of pressure transducers mounted at the cyclone wall.

TEST RESULTS

0.5 m^3 Vessel

Tests in the 0.5 m^3 test vessel were done without vent covers and with a range of vent areas to simulate small process vessels having open connections. Figures 5 and 6 show the effect of varying the vent area (without vent covers) on the reduced explosion pressure.

Pressures were generally lower than those predicted by the standard venting equation (BS EN 14491:2006). For example with a vent area of 0.07 m^2, BS EN 14491:2006 predicts a P_{red} of 132 mbar and 134 mbar for conrnflour and wood dust respectively, whereas the experimental data indicates that the actual pressures were lower with values of approximately 80 mbar for cornflour and 50 mbar for wood dust.

The venting equation produces higher predicted P_{red} values because it is based on the situation where the vent

Figure 1. Test vessel

Figure 2. Sieve unit

Figure 3. Cyclone

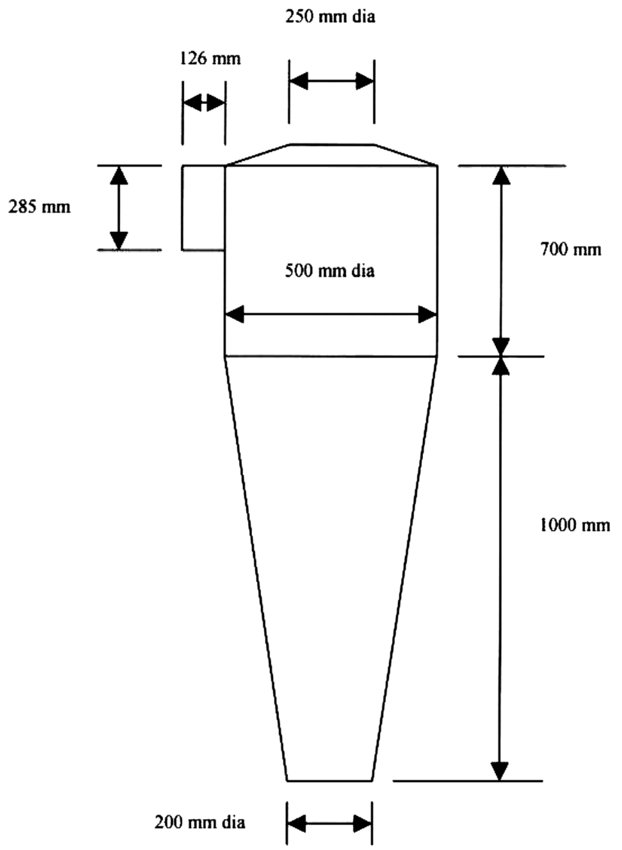

Figure 4. Schematic layout of cyclone

openings are fitted with vent covers. The presence of a vent cover is to increases the P_{red} due to the initial confinement before the cover opens.

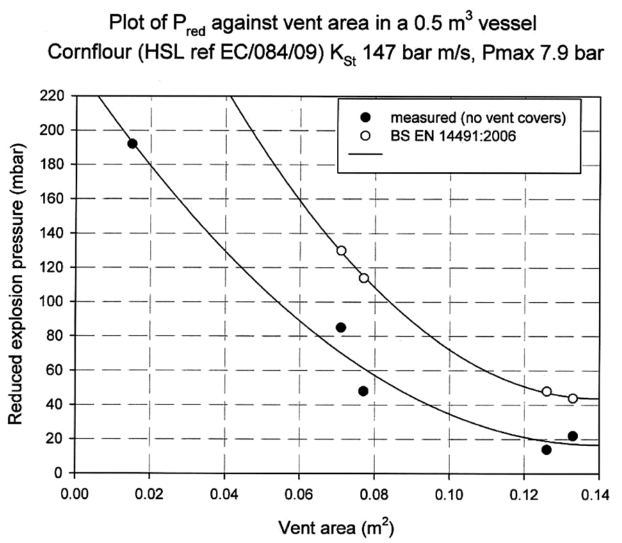

Figure 5. Vent area v P_{red} in the 0.5 m^3 vessel

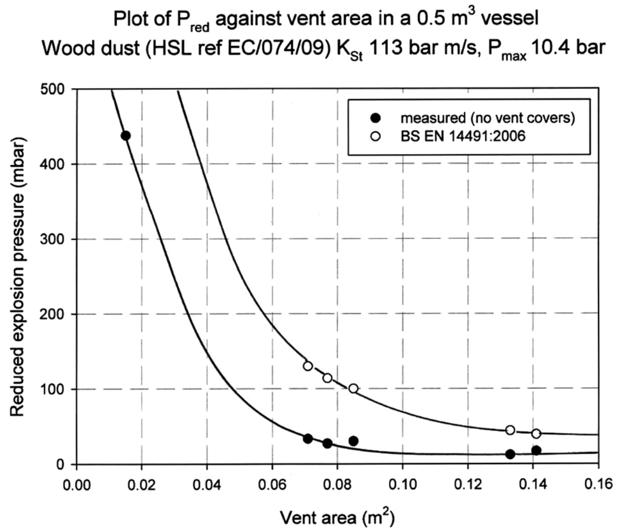

Figure 6. Vent area v P_{red} in the 0.5 m^3 vessel (no vent covers)

As expected the pressures decrease with increasing vent area. Taking a vent area of 0.04 m^2 wood dust and cornflour explosions will produce a P_{red} of approximately 130 mbar. Thus, with an unrestricted opening of 225 mm diameter, the P_{red} will not be much greater than 130 mbar. This assumes that the open connections are able to vent freely without restriction, i.e. if a long length of pipe is attached to the opening, its effect will be to increase the back-pressure. This is clearly demonstrated by the vent duct guidance published by the Institution of Chemical Engineers (Barton 2002).

Reduction of the size of the open connections has also been found to have significant effect. In the case of a vessel with a 0.02 m^2 vent opening, equivalent to a single 160 mm diameter pipe connection, the P_{red} is significantly greater. For cornflour the Pred is 180 mbar and for wood dust the Pred is at 350 mbar, hence the vessel must to be designed to withstand the higher explosion pressure.

Decreasing the effective vent area further will increase the P_{red} significantly with the potential for pressures up to the maximum explosion pressure of the dust typically 7–8 bar.

As a result of the well dispersed dust cloud and high turbulence conditions produced using the 0.5 m^3 test rig, the P_{red} data obtained from the tests is likely to be as severe or greater than similar small vessels found in industry. Real process vessels (a sieve unit and a cyclone unit) were therefore obtained for testing to explore explosion pressure development in real process vessels under typical running conditions.

Sieve Unit

Tests with a range of corn flour dust concentrations and with the inlet and outlet blanked off but with the smallest outlet (oversize outlet) open, generally produced fairly low pressures. The highest P_{red} was 196 mbar. The standard venting

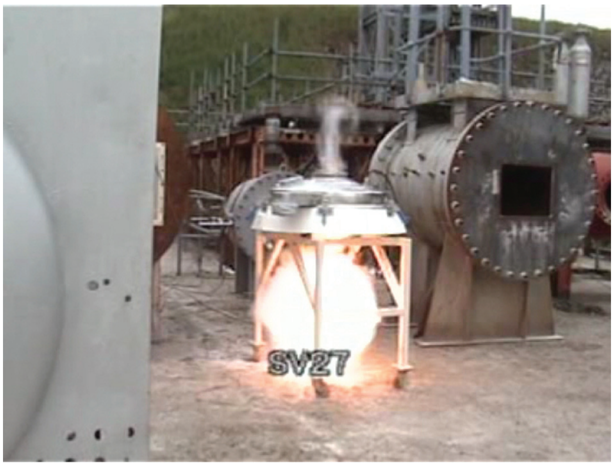

Figure 7. Sieve test 27

equation (BS EN 14491:2006) predicts a relatively high P_{red} 350 mbar for a vessel volume of 0.2 m^3. However, if we assume that the effective volume is only the lower chamber i.e. with a volume of 0.1 m^3 then a P_{red} of 145 mbar is predicted.

The mesh (with residual material on the surface) appeared to prevent flame transmission from the lower chamber into the upper chamber; for example test 27 showed flame venting through the 250 mm diameter undersize outlet but did not propagate though the mesh to the inlet in the top cover (Figure 7). Even with a hole in the mesh there appeared to be no propagation of flame into the top chamber; damage in the form of a hole approximately 30 cm^2 was made in the 140 micron mesh screen during test 34. The damage appeared to be made from the blast from below the mesh.

The difference in the predicted pressure and the maximum measured pressure can be accounted for by the fact that the sieve unit is far from the ideal test vessel and there is no explosion vent cover. Approximately 50% of the vessel volume is above the sieve screen and the flame is vented through the lower outlet but appears to be unable to pass the screen and ignite the dust in the upper chamber. The absence of flame ejected through the top chamber suggests that the screen acts as a flame arrester.

FLAMELESS VENTING

A flameless venting device providing 0.2 m^2 vent area has been tested in conjunction with a 2 m^3 vented test vessel as part of a programme to demonstrate the performance of the venting devices. The front face of the test vessel incorporates a vent opening designed to accept the either weak bursting panel or a flameless explosion venting device of the same vent size. Figure 8 shows the vessel with a conventional stainless steel explosion vent panel attached and Figure 9 shows a flameless venting device attached with the vent panel.

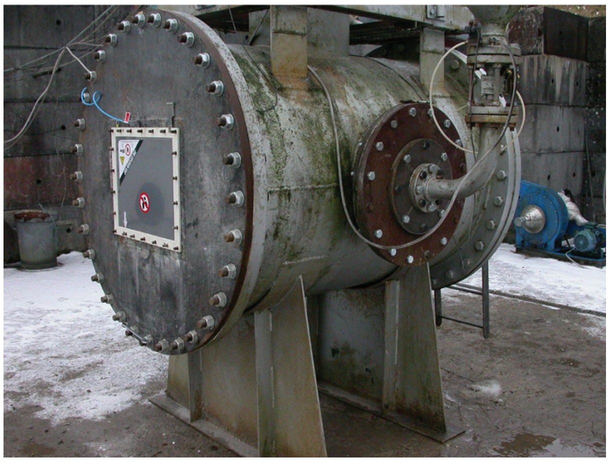

Figure 8. 2 m^3 vessel with vent panel

The explosive dust cloud is produced by injection of a pre-weighed mass of dust into the vessel from an external pressurised dust injection system and ignition is initiated at the centre of the vessel. Pressure transducers are located at the wall of the vessel to record the pressure-time data.

TEST RESULTS

Industrial flameless venting devices are designed to extinguish the flame and prevent the discharge of large quantities of dust from the vented vessel into the surroundings. The tested flameless venting device incorporates several dust retention screens. It was anticipated that the dust trapped inside the flame-arrester mesh would lead to higher reduced explosion pressures in the test vessel when compared with a conventional vent. Unexpectedly, the P_{red} measured in the flameless venting tests with wheat flour (HSL reference EC/107/09) having a K_{St} of 138 bar m/s, did not exceed the pressures measured in tests with simple vent panels fitted to the vessel. A slightly more reactive

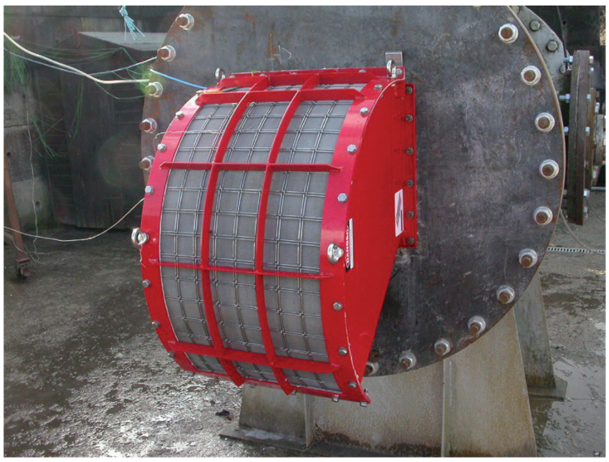

Figure 9. 2 m^3 vessel with flameless venting device

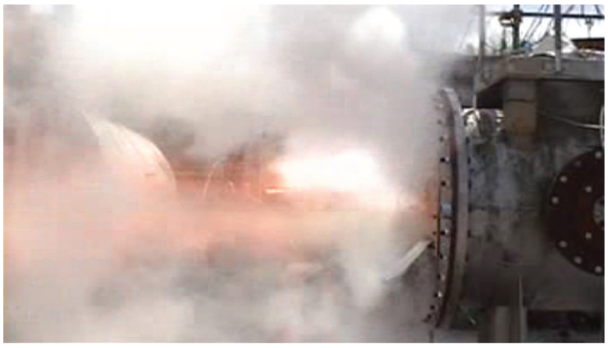

Figure 10. Test 46

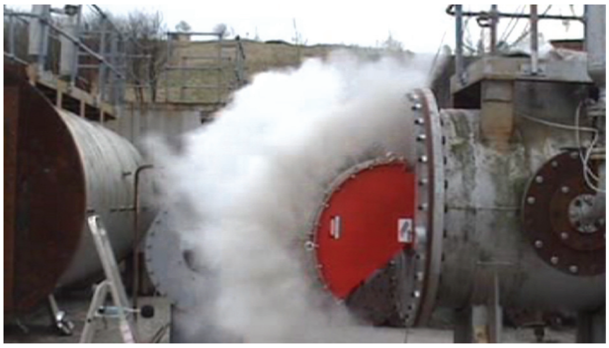

Figure 11. Test 47

corn flour product was tested (HSL reference EC/084/09) having a K_{St} of 147 bar m/s, firstly using aluminium foil vent covers followed by tests using a conventional vent panel and a flameless venting device. Wood dust (HSL reference EC/074/09) was also tested to explore the effects of its different morphology.

Subsequent tests with the flameless venting device produced considerably higher P_{red} values, indicating a reduced venting efficiency when compared with conventional venting. Comparing the two cereal dusts, dust sample EC/107/09 resulted in minimal change to the P_{red} but dust sample EC/084/09 resulted in a marked increase in the P_{red}. Therefore, although the K_{St} of the two cereal flours tested was not significantly different, the two dusts appeared to produce different performances from the flameless venting device.

Figures 10 and 11 show a visual comparison of a conventionally vented explosion and one with a flameless venting device is installed. Identical test conditions were used: corn flour (HSL reference EC/084/09) with a dust concentration of 0.75 kg/m^3, vessel volume 2 m^3 with a vent area of 0.2 m^2 and ignited in the centre of the vessel. The external vented flame from the conventional rupture panel fitted to the vent opening was quite extensive, with several metres of flame. The flame was completely eliminated by the introduction of a flameless venting device with only smoke, dust and water vapour emitted from the device.

CONCLUSIONS

- Tests to date have shown that P_{red} values in small vessels are generally less than predicted by methods described in BS EN 14491(2006) "Dust explosion venting protective systems".
- Flameless venting devices tested to date have demonstrated a high level of flame extinguishment in that no external flame has been observed. The performance of the device appears to be sensitive to dust characteristics other than K_{St}. P_{red} values have been variable and results indicate a reduced venting efficiency when compared with conventional venting.

This project is on-going with a range of tests to be completed; final conclusions will be established at a later date.

REFERENCES

BS EN 14491 (2006). Dust explosion venting protective systems.

Barton J (2002). Dust explosion prevention and protection a practical guide. Institution of Chemical Engineers ISBN 0 85295 410 7.