SESSION FOUR - DISCUSSION

EXPLOSIONS PROTECTION

A PROCEDURE FOR DESIGNING GAS COMBUSTION VENTING SYSTEMS.
by W.B. Howard and W.W. Russell (Monsanto Co, St. Louis, Missouri, U.S.A.).

Mr J. Nixon (H.M. Factory Inspectorate):

Have you any information about the venting of centrifuges?

Mr Russell:

We have no information.

Dr N. Gibson (I.C.I., Organics Division):

The cube root law is derived from pressure development due to the advance of a spherical flame front in a closed sphere. Would the author agree therefore that there was no theoretical basis for it providing the correct mathematical relationships in vented dust explosions. The experimental work of Donat is extremely valuable but is it not desirable that the prediction of explosion vent areas should be based on Donat's experimental curves for different vessel volumes, and not on the general application of the cube root law?

Mr Russell:

I believe the cube root law may lead to understatement of vent requirements in some cases. For this reason we prefer to work directly with the Donat data in predicting the effect of volume on vent areas.

EXPLOSION RELIEF PROTECTION FOR INDUSTRIAL PLANT OF INTERMEDIATE STRENGTH.
by P.A. Cubbage and M.R. Marshall (British Gas Corporation, Midlands Research Station, Wharf Lane, Solihull, Warcs).

Mr G. Thomas (I.C.I., Welwyn Garden City):

What K factor does Fig. 4 relate to? Also, in Fig. 5, what are the burning velocities of Manufactured Gas and Natural Gas?

Dr Marshall:

Figure (4) refers to a vent co-efficient of $K = 6$. In Figure (5), the burning velocities are, $S_o = 38$ cm/s for the natural gas-air mixture and $S_o = 75$ cm/s for the manufactured gas-air mixtures.

Mr Thomas:

The strength of many types of vent panels can be affected adversely by weather conditions. Can the authors give any guidance on the design of vents for plant which is located outdoors?

Mr Cubbage:

We appreciate the difficulties of outdoor situation and, other than where protection can be provided, we have applied successfully explosion reliefs of thin stainless steel sheets and of asbestos gasket type materials, suitably secured and painted, to the sides of the buildings and plant.

Dr N. Gibson (I.C.I., Organics Division):

(1) Before ignition the flammable is in a balloon or layer, i.e. only fills part of the volume. Do the data reflext the situation in which the flammable is distributed throughout the volume?

(2) The data are given for particular balloon volume or layer thickness. The parameter "energy density" being used to define the situation. Does your equation cover the two equivalent situations:

(a) Gas concentration A, Gas layer thickness D
(b) Gas concentration A/2 Gas layer thickness 2D

in which the total energy density is the same?

Dr Marshall:

The equation is applicable to situations in which the gas-air mixture to be ignited is contained in a balloon, as a high level layer or completely filling an enclosure. As the volume of mixture ignited is increased, the pressure generated increases but, as figures (3) - (5) indicate, provided that the explosion relief is adequate, once the volume of gas-air mixture to be ignited occupies approximately 1/7 of the enclosure volume, increasing the volume of mixture produces only a marginal increase in the pressure developed.

Mr R.J. Lake (Sandos A.G., Basle):

Could you please comment on the effect of gas detonations, instead of gas explosions, on the venting requirements?
Further, under what circumstances can gas detonations occur?

Cubbage & Marshall:

The most important practical difference between detonations and explosions, in terms of venting requirements, is the time scale of the respective phenomena. In a gas explosion, occurring over a time period of, typically, 100 milliseconds there is sufficient time available for an explosion relief to operate effectively. However, in a detonation the peak pressure is usually developed in at most 1-2 milliseconds; there is therefore no time available in which an explosion vent can operate.

Detonation of gas-air mixtures will only occur under a very limited range of conditions e.g. near stoichiometric conditions and confinement within a physically strong enclosure having a large length to diameter ratio. With natural gas-air mixtures for instance, only near stoichiometric mixtures contained in a pipe having an L/D ratio greater than 300, ignition occurring at a virtually closed end will be likely to detonate.

Mr J.C. Anderson (Marston Excelsoir Ltd):

What types of materials are used for vent panels and what effect do these materials have on relief tolerances?

Mr K.N. Palmer (Fire Research Station, Building Research Establishment, Borehamwood):

The ideal vent closure would open reliably at the lowest pressure consistent with satisfactory normal operation of the plant. The mass per unit area of the cover should also be low, to minimise inertia effects during rapid opening. If the ideal can be approached, the resulting increase in explosion pressure is minimal.

Cover materials commonly used in gas explosion venting can be bursting panels, providing the area is sufficient to permit rupture at the required pressure, or lightweight rigid panels held by springs or magnets. Special types may be used for individual applications.

Mr J.M. Alexander (I.C.I., Petrochemicals Division):

Is it important to determine whether the pressure to which the plant item is designed is for static or dynamic loading?

Dr Marshall:

Very important; the response of a structure to a pressure loading is determined not only by the magnitude of the imposed load but also by its duration. In general, therefore, a structure will be able to withstand higher dynamic pressure loadings than static load tests would indicate. However, the maximum dynamic pressure loading that a particular plant can withstand is difficult to estimate, depending as it does on the dynamic properties of the structure itself and the shape of the imposed pressure-time curve.

Mr Alexander:

This is partly why blast walls are difficult to make strong enough. They must be designed to withstand a higher pressure than simple static loading would indicate.

Dr Marshall:

This is indeed so; depending on the circumstances, the reflected overpressure can greatly exceed the peak pressure in the incident blast wave. The situation is further complicated by the fact that the different surfaces of a structure are subjected to different pressure loadings. A useful discussion of the problem can be found in G.F. Kinney, 'Explosive Shocks in Air' (MacMillan, 1962).

EXPLOSION PROTECTION OF A DUST EXTRACTION SYSTEM.
by K.N. Palmer (Building Research Establishment, Borehamwood):

Mr R.W. Hedge (British American Tobacco Co.):

Is there an equivalent flame velocity for dust clouds which could be applied in equation 2?

Mr Palmer:

No. Very little data is available on the burning velocity of a dust flame, the parameter most widely used is the maximum rate of pressure rise in an explosion in a standard closed bomb.

Dr N. Gibson (I.C.I., Organics Division):

(1) Could the data on duct effect on pressure obtained in the cyclone experiments be applied to ducts from volumes containing uniform distributions of dust?

(2) Is it true that dusts placed in Group (b) 'non-explosible' in the standard tests could produce an explosion at above ambient temperatures, e.g. fluid bed dryer dust cloud at 400-500°C.?

What tests would Mr Palmer recommend to assess whether or not a dust to be processed at above ambient temperatures is capable of producing a dust explosion, i.e. tests for 'explosibility/non-explosibility' at above ambient temperatures (e.g. 100-500°C.)

Mr Palmer:

The effect of a vent duct on explosion pressure could in principle be applied where the dust distribution in the volume being protected is uniform. There is evidence that the total pressure in the duct is the sum of that in the vessel being protected and that generated within the duct itself. Because of the intense turbulence in the duct, which encourages burning throughout the whole volume simultaneously a considerable contribution to the total pressure can come from the ducting itself.

The standard classification tests refer to dust dispersions at ambient temperature, and do not apply to dispersions in a hot environment. A dust which is classified as Group (b) at room temperature may indeed produce an explosion at temperatures quoted. In order to assess the explosibility of a dust under these conditions a non-standard test simulating those conditions needs to be used.

Dr N. Gibson (I.C.I., Organics Division):

Do statutory requirements demand that explosion protection be fitted to a small volume closed vessel (e.g. drum 7-20 cu.ft.) in a powder processing unit that is immediately downstream of a mill when the closed vessel is directly connected to the powder outlet. Two situations that are possible are:

(1) the mill directly in line with the closed vessel.

(2) the mill separated from the container by a rotary valve.

Is there a minimum volume below which an enclosure (e.g. hopper, container) in a plant processing organic powders (maximum rate of pressure rise less than 10,000 psi/sec) is not required to have explosion protection.

Mr Palmer:

Statutory requirements are the province of HM Factory Inspectorate, and in the case quoted not only the volume of the vessel but also the characteristics of the dust and the proximity of operatives, and the type of processes in the immediate vicinity would also have to be considered. In practice, for dusts of average explosibility, and the volumes quoted, venting would not customarily be demanded.

It is also customary, for dusts of maximum rate of pressure rise less than 5,000 $lb/in^2/s$, not to demand venting for vessel volumes less than 20 cubic feet. See below.

Mr J. Anderson (Marston Excelsior Ltd):

Marston are currently developing Reverse buckling discs to operate at 0.5 psig in an 18" NB, what other pressures and bore sizes would be advantageous to the industry in low pressure applications?

Mr Palmer:

The pressures and bore sizes quoted are typical of those required and if each were varied by factors of 2 many industrial applications would be covered.

Mr M. Kneale (Lankro Chemicals Ltd):

Is it possible to predict the explosible properties of powders from a knowledge of their chemical formulae?

Mr Palmer:

Generally it is not possible to predict explosible properties of powders from their chemical composition and it is necessary to resort to explosibility testing. Until the propagation of flame through dust clouds is better understood, direct testing of dusts is likely to continue to be necessary.

Dr K. Gugan (Dr J.H. Burgoyne & Partners):

Re Mr Palmer's comments on the duality of vent factors as applied to dusts and gases, has any correlation been tried, on the same basis as with gases, with dust and how satisfactory is it? A problem naturally arises with mixtures of combustible dusts and gases.

The present vent factor for dusts, being dimensional, requires for very large vessels an excessive vent area - if this rule is applied rigorously. The consequence is that very large vessels receive little attention unless the Factory Inspectorate arbitrarily reduce the vent factor from 1/20 ft to 1/80 ft^{-1}.

A source of disquiet, of course, arises through such arbitrary reductions of the venting standard, although it does enable the installation of vents to become possible. What is the technical justification for such a change and can it be quantitatively related to combustion parameters?

Mr Palmer:

The present situation is untidy, and we certainly suffer from a shortage of experimental data. There are some indications that the different vent factors used with dusts and with gases may be brought together when a fuller understanding is available. If the vent ratio for dusts is combined with the cube root of the vessel volume, as some current venting experiments show to be realistic, then one is approaching use of a K factor. One of the outstanding difficulties is knowing the characteristic burning parameter of the dust cloud With a gas it is relatively easy because the burning velocity can be used, although the rate of pressure rise is greatly increased by turbulence. With dusts we do not have the corresponding burning velocity measurements. Also in order to measure rate of pressure rise it is necessary to disperse the dust, which causes the suspension to be turbulent. Hopefully, all these factors will be brought together in due course.

The vent ratio for dusts is dimensional, and this can mean that on very large volumes the calculated vent area is large. In some instances, it can be unrealistic and exceed the cross-sectional area of the vessel. In practice, there is reduction of the vent ratio for large volumes, but the reduction is arbitrary and not directly related to combustion properties.

Various factors are taken into account such as the whole volume of a large enclosure being unlikely to be full of the most explosible concentration of dust and also that the rate of pressure rise in a large enclosure is less than in a smaller one, if the "cube root" law is taken to apply. There is some justification from experiment for this approach but it is still basically an arbitrary decision.

Dr I.E. Eastham (Rohm & Haas (U.K.) Ltd, Jarrow):

How do we assess the effect of entrainments?

(1) 'Bends in explosion relief vents'; if one has to have them, how can one assess the effect on maximum explosion pressure?

(2) 'Entrainment of solids, liquids or foams by gases being vented following operation of a relief device'; what do we know of their effect on maximum explosion pressure?

(3) I know of an instance where the kinetic energy of relief with entrainment was sufficient to straighten a heavily constructed 24" duct. The energy of the venting fluid, the maximum explosion pressure and the thrust on the vessel should be estimated. Approximate calculation of the 'reaction' has suggested that there would have been a dynamic thrust of 40 tons downwards on the vessel when the 24" bursting disc exploded.

Mr Palmer:

Investigations of the effect on the pressure of bends in ducts attached to vents have been carried out at several laboratories including the U.S. Bureau of Mines and the Fire Research Station. A bed does increase the back pressure and, to restrict the increase, not more than one bend should be installed in a 10 ft length of duct and the angle of the bend should not exceed 45°.

Where another phase is present in the venting of gases through a relief, special considerations apply and these have been subject to very little exploration. There was some German work on the discharge of water/air foams through a vent covered with a bursting disc (STRAUMANN? W. Chemie. Ing. Tech. 1965, 37 (3) 306-16) although this was not a combustion system.

Dr J.H. Burgoyne (J.H. Burgoyne & Partners):

What is the minimum unit volume for which it is desirable to provide dust explosion venting? I am often asked this question and it would be useful to reach some kind of agreement for a dust of average explosion properties.

Mr Palmer:

Twenty cubic feet is a figure often taken for dusts of average explosibility. With dusts of vigorous explosibility such as aluminium, venting should be provided on all volumes. The main justification of 20 cubic feet is that one square foot of vent area is likely to be fairly readily available because of the need to fill the container or ventilate it.

Mr J. Nixon (H.M. Factory Inspectorate):

I would think that the sort of plant of this volume would be the small unit dust collector. Here you have got to have an opening to get rid of the air from your collecting system and the best place for such a unit is up against an outside wall where this air can be vented directly outside the building. This gets rid of the fine dust which must inevitably escape through the filter bag. The vast majority of explosions in a dust collecting system are usually caused by a fire in the bags which then drop giving you a dust cloud with subsequent ignition. On destruction of the bags the unit is effectively vented to the open air.

Dr J.H. Burgoyne:

A vent on the clean side may not be effective unless the bag is first destroyed by fire. It is more appropriate to vent the dirty side of the filter.

Have you any experience of injury to operatives from the open end of ducting due to blowback from an explosion downstream?

Mr J. Nixon:

I do not think that we have had a great deal of trouble from straight extraction systems. We have had blow backs on a rubber grinding system and also fires in collectors on polishing systems where the inflammable material has been mainly fluff and polishing waxes.

Mr Palmer:

There is unlikely to be a flammable dust concentration in the atmosphere breathed by an operative permanently, because the concentration would be too high for comfort. The work he is doing might generate a source of ignition which enters ducting, and may also generate a flammable concentration within the vicinity of the work-piece. It is conceivable that at some specific moment the dust concentration in the duct might be above the lower limit in which case an ignition source could produce a flame, but in most cases involving explosions in dust handling systems the explosion has started in the cyclone or collection equipment. Blowback from the collector into the ducting is then possible.

Mr W.W. Russell (Monsanto Co.):

We have had this experience, accumulation of dust in a dust collection, and the solution we adopted was to keep the duct clean. Housekeeping is the way we have found to get round it.

Dr Burgoyne:

This is probably the answer.

Mr Palmer:

Where there is a branched extraction system it is most important that not only should the air velocity in the main duct be adequate but should also be so in each branch.

Mr R.N. MacLean (Scottish Grain Distillers Ltd):

Pneumatic conveying systems involve high turbulence and concentration. Are normal venting recommendations adequate?

Mr Palmer:

In pneumatic conveying systems particular attention should be given to venting at the collection vessel. Although turbulence and dust concentrations are high in the pipeline experience has shown that any pressure arising from ignition can be contained. However, on delivery from the pipeline into a collector the concentration of dust will vary through the volume and explosion can develop. The normal venting recommendations are customarily used for these collectors.

THE USE OF RETICULATED METAL FOAM AS FLASH-BACK ARRESTER ELEMENTS.
by R.R. Barton, F.W.S. Carver and T.A. Roberts (Ministry of Defence, EM2 (Home Office) Branch, RARDE, London, SE18 6TE).

Mr J.M. Alexander (I.C.I., Petrochemicals Division):

The most frequent use of flame arresters in the chemical industry is in the vents, particularly storage vessel vents. One of the ways in which we can underpressure a storage vessel and suck it in is to allow the flame arresters to become dirty and block up. If we did not inspect the flame arresters regularly and clean them we would have many more vessels being sucked in. Can one easily inspect the reticulated flame arresters and also clean them? The crimped flame arrester is easily inspected by taking it out and looking through it. Is there any pay-off for industry to change over to reticulated foam flame arresters?

Mr T. Roberts:

There are no methods of visual inspection which will allow you to determine whether the paws are blocked or not. However, it is very easy to monitor the flow resistance of the material, and as the material is very easy to clean this can be done as part of a regular maintenance schedule. The advantages of reticulated metal foam arresters over crimped ribbon arresters are that they should be cheaper, easier to mount and can be manufactured to any specification by simply altering the compression.

Mr M. Kneale (Lankro Chemicals Ltd):

Was reticulated foam made specifically for flame arresters? Is it readily available on the market?

Mr T. Roberts:

The material was not made specifically for flame arresters. It is available from the Aviation Department of Dunlops Ltd.

Mr J.M. Alexander (I.C.I., Petrochemicals Division):

Can you see if the foam is dirty or not?

Mr K.N. Palmer (Building Research Establishment, Borehamwood):

You cannot see the foam. We have done trials at Borehamwood. In fact the reticulated foam blocked up less readily than the carbon ribbon but that is in the rural area. I think the safest way is to go for a regular overhaul system. It would be easy to check up on your resistance test.

Mr R.L. Hunter (I.C.I., Agricultural Division):

It is a recommendation in I.C.I. Agricultural Division that 'Amal' crimped ribbon type flame arresters are not capable of dealing with the high flame speed of hydrogen. Have either of the authors any evidence to suggest that reticulated metal foams would be capable of quenching hydrogen flames?

Roberts and Carver:

We consider that a foam with the right compression will quench detonations in hydrogen air mixtures, and in hydrogen oxygen mixtures, although in the latter case the flow resistance will be high.