EXPLOSION PROTECTION OF A DUST EXTRACTION SYSTEM

K N Palmer*

The use of relief venting to protect a dust extraction
system against explosion is considered. A system is
discussed consisting of extraction ducting, fan, cyclone,
and collection bin. The relief venting requirements of
each are considered in turn using data available from the
literature and, for the cyclone, recent research on vent
areas is included.

INTRODUCTION

Many industrial processes involve the polishing, grinding, linishing, etc of
bulk materials which form dusts from the materials being processed and often,
in addition, from the polishing agents. As the processes are usually
supervised by adjacent operatives, it is necessary to continually remove
these dusts to provide a safe and hygienic working environment. A similar
need arises where dusts and powders are transferred from one container to
another under open conditions, as at filling or bagging-off points. An
extraction system with mechanical ventilation is necessary so that the dust
can be removed and collected, and in some cases re-introduced into the
process. One solution to the collection problem is to provide unit dust
collectors for each machine or transfer point, particularly where amounts of
dust are modest and the air throughput is correspondingly small. The
advantage of these collectors is that the length of extraction ducting and the
volume of dust suspension within the collector are minimized and the units
have a reduced dust explosion hazard as compared with centralised systems
having long extraction ducting runs. Where larger throughputs are involved
a centralized collection system is usually installed, and this type of system
has been a traditional method of establishing good working conditions. Large
numbers of such systems have been installed and this paper considers the basic
requirements for dust explosion protection for a typical system, considering
the general case rather than any specific installation.

In a general case, local conditions cannot be covered so that expert
advice should be obtained if it is considered that special factors are
present.

*Department of the Environment and Fire Offices' Committee Joint Fire Research
 Organization, Fire Research Station, Building Research Establishment,
 Boreham Wood, Herts.

There are several methods of protecting dust extraction systems against explosion, but the commonest, and usually the most economic, is to provide explosion relief venting. This method has been selected for the present illustration, but if in a particular case it cannot be adequately applied, then alternative methods must be considered.

Assessing the dust explosion hazard

Before consideration is given to plant design, the explosibility characteristics of the dust or powder involved should be measured. The first question is whether or not the dust is capable of causing a dust explosion. Although, to be explosible, a dust must be combustible, not all combustible dusts are capable of causing an explosion. For present purposes only dust/air suspensions are considered. In order to ascertain whether it is explosible, the dust has to be tested, and many dusts have been so assessed and a list published, HM Factory Inspectorate (1968). For listing purposes the dust must either be chemically defined, or if it is a natural product, it must be a material of consistent characteristics and not a random mixture. Dusts are classified as follows:

Group (a) Dusts which ignited and propagated flame in the test apparatus;

Group (b) Dusts which did not propagate flame in the test apparatus.

The tests are carried out to standard procedures, agreed with HM Factory Inspectorate, at the Fire Research Station, and details of the test apparatus and methods are available, Raftery (1968); some commercial laboratories also carry out tests. Group (a) dusts should be regarded as explosible, and liable to give rise to a dust explosion hazard, whereas Group (b) dusts are non-explosible although they may present a fire risk. These classification tests give little indication of the severity of the dust explosion hazard, being limited to visual observation of the velocity and size of flames produced during the test, as well as the extent of response in the various apparatuses.

The classified list of dusts is on a generic basis and a new formulation of the material may alter its classification. In case of doubt such as this, or where mixtures are concerned, or where the dust is not listed, a classification test should be carried out.

If the dust is shown to be explosible, i.e .is Group (a), further tests can be usefully carried out. There is a series of such tests in which the following explosion parameters can be measured:

(1) Minimum ignition temperature;

(2) Maximum permissible oxygen concentration of the atmosphere to prevent ignition in a dust cloud;

(3) Minimum explosible concentration;

(4) Minimum ignition energy;

(5) Maximum explosion pressure and rate of pressure rise.

All these tests have been described in detail, Raftery (1968), and carried out in small-scale apparatus. For the present purposes those particularly relevant are the minimum explosible concentration and the maximum explosion pressure and rate of pressure rise.

The minimum explosible concentration is that at which there is just sufficient dust in the suspension to enable a flame to propagate through it from a source of ignition. At higher concentrations the flame propagates more readily and the explosions become more vigorous until the concentration is such that so much dust is present that it tends to quench the flame. At a sufficiently high concentration an upper limit is reached beyond which the cloud is too dense for flame to propagate. This upper limit is of lesser practical importance for the present case and will not be considered further. The minimum explosible concentrations of a large range of dusts have been tabulated, Palmer (1973), and many are in the range 0.02 to 0.05 g/l (0.02 to 0.05 oz/ft^3). Some minimum explosible concentrations fall outside this range, and when they are below they can correspond to a suspension which cannot be readily seen under ordinary lighting conditions. For the safe working of industrial plant it is desirable that the dust concentration should be less than the minimum explosible concentration, in order to reduce the likelihood of explosion should a source of ignition appear. The protection given by this measure is not complete, because dust concentrations can change from the average by settling out followed by further dispersion or by the movement of dust-laden air from one vessel into another. However, a design which is such that the air flow through the system is adequate to maintain the average concentration below the minimum explosible concentration is desirable, and a working level of 30 per cent of the minimum explosible concentration has been suggested, Palmer (1973). This requirement is one of several which must be taken into account in the design of the fan for a dust extraction system. It presupposes knowledge of the rate of generation or dispersion of dust at the point of entry to the system, which may be known with inaccuracy but which may be judged on the total dust production over a known length of time. The value of 30 per cent takes some account of such uncertainty.

The other explosion parameters which should be measured are the maximum explosion pressure and the maximum rate of pressure rise. The latter parameter is of particular relevance to explosion relief venting, because it is a measure of the rate at which the dust suspension burns. The higher the rate, the more rapidly the combustion products must be discharged through the vent in order to keep the pressure to an acceptable level. The relation between the maximum rate of pressure rise and the area of vent requires further research, but an ad hoc approach is summarized in Table 1 for a relatively weak plant. The area of vent is described in terms of the vent ratio; that is, the ratio of the area of vent to the volume of vessel being vented. The recommended values are based principally upon tests using vented cubical vessels, see below, and may be used with reasonable certainty up to volumes of 30 m^3 (1,000 ft^3). For much larger volumes a lower value of vent ratio may be acceptable, subject to expert judgement. For many common dusts of vegetable origin the maximum rate of pressure rise is below 35,000 kN/m^2 s (5,000 lbf/in^2 s) but exceptions do arise and many chemicals and plastics give high values, Palmer (1973). Where the maximum rate of pressure rise is in excess of 85,000 kN/m^2 s (12,000 lbf/in^2 s) the use of relief venting becomes questionable, particularly with large volumes of vessel, and a redesign of the plant may be required.

After the explosibility of the dust has been confirmed, and explosion parameters measured, attention can be given to the design of the explosion protection of the plant. A useful practical guide is available, HM Stationery Office (1970), and a full treatment has been given elsewhere, Palmer (1973).

TABLE 1 - Vent ratios for dusts of different rates of pressure rise

Maximum rate of pressure rise		Vent ratio	
kN/m^2 s	lbf/in^2 s	m^{-1}	ft^{-1}
< 35000	< 5000	1/7	1/20
35000 - 70000	5000 - 10000	1/5	1/15
> 70000	> 10000	1/3	1/10

Brief description of plant

The case considered is that of a simple system in which ducting, having an open end for extraction purposes, and whose length is much greater than its diameter, is connected via a centrifugal fan or blower to a cyclone which discharges cleaned air to atmosphere and the separated dust to a connecting bin, via a rotary choke valve. The whole system is assumed to be of the customary sheet metal construction, capable of withstanding an explosion pressure of no more than 15 kN/m^2 (2 lb f/in^2) without serious damage. Indeed, some special precautions may need to be taken to ensure that even this criterion can be attained. Large flat surfaces may need special bracing against internal pressure, and the ducting lengths should preferably be flanged and bolted, and not held only by friction. Seam welded circular ducting is preferred to weaker types, and the supporting struts should be adequate to withstand the explosion stresses.

Basic steps in explosion protection

The extraction system should be of non-combustible construction, e.g. of steel, and it is preferable that much of it be sited outdoors and not in the workroom. In particular the cyclone can often be installed outdoors above ground level, and the top surface of the collection bin can also be external, to facilitate the discharge of combustion products from vents.

Considerable attention should be paid to the airflow through the system to ensure firstly that it is adequate to remove dust suspensions generated by the process, and also that the average concentration of dust is below the minimum explosible concentration as described above. In addition, the linear velocity of air through the ducting should be such that the dust cannot settle out and form a permanent explosion and fire hazard. The required velocity of the air depends upon the physical characteristics of the dust, but is commonly about 25 m/s (80 ft/s), Zenz and Othmer (1960). The optimum diameter of ducting and the performance requirement of the fan can then be estimated.

In the movement of dust it is extremely likely that static electricity will be generated, and all metal parts of the extraction system should be bonded to earth. By this means sparking from metal components to earth is avoided, but there may still be residual charge on the dust in the collection bin which will possibly persist for a long period, depending upon the resistivity of the dust. Hazards due to mains electricity may be minimized by the use of totally enclosed fan-cooled motors, mounted outside the extraction system, with controls situated in a convenient clean area.

Fr i ctional hazards can be reduced by ensuring that all bearings for rotating machinery are outside the extraction system. Temperature sensors such as thermocouples can be used to detect incipient overheating, particularly of inaccessible bearings.

The protection against explosion given by these procedures is not complete. Should an explosion develop, relief venting is required to avoid serious structural damage.

Available venting data

The use of the vent ratio, and the associated rule of thumb values shown in Table 1, are "traditional" but raise questions hitherto unsolved. In particular, the vent ratio is not dimensionless and the possible effects of the scale of plant on the venting requirements have not been studied for the large plant volumes which are commonplace nowadays. The data relevant to the present paper have originated from three main sources: involving tests on compact vessels (box-like enclosures), ducting, and a cyclone. With the compact enclosures and the ducting considerable effort was made to ensure a uniform dispersion of dust throughout the volume under study, whereas the cyclone was operating normally at the time of ignition and the distribution of dust within its volume was concentrated at the walls. The available data on the various systems have been reviewed in detail,Palmer (1973),and the following is only a summary of the principal investigations.

For compact enclosures with open vents (i.e. vents without covers) a systematic series of experiments was undertaken using cornstarch,Hartmann et al (1950),and cellulose acetate,Hartmann and Nagy (1957). The tests with corn-starch were made in cubical galleries, of volumes $0.03 - 6.12$ m^3 $(1 - 216$ $ft^3)$ and showed three features plainly. The scatter of the experimental points was small indicating good reproducibility, the relation between maximum explosion pressure and vent ratio was independent of the volume of the gallery, indicating an absence of scale effect, and the maximum explosion pressure plotted on a logarithmic scale varied directly with the vent ratio. The relationship broke-down at pressures of 20 kN/m^2 (3 lb f/in^2) and below, and the observed pressures were higher than would be predicted. These pressures are of particular interest in the present context and an empirical relation-ship would have been valuable. The maximum rate of pressure rise of corn-starch in the routine test apparatus was reported as 60,000 kN/m^2 s (8,700 lb f/in^2 s). From Table 1 the required vent ratio for plant would be $1/5$ m^{-1} $(1/15$ $ft^{-1})$ and, from the test results, the corresponding explosion pressure would be about 32 kN/m^2 (4.5 lb f/in^2). This value is relatively high but it was measured under experimental conditions deliberately made as severe as possible, and which would be unlikely in practice. However, it indicates that the recommended vent ratios (Table 1) are not excessively cautious. Cellulose acetate dust gave a similar relationship between explosion pressure and vent ratio, but results are only available for the 0.03 m^3 (1 ft^3) gallery. The same equipment was used for tests on a range of other dusts under less severe conditions,Hartmann and Nagy (1957).

The relief venting requirements of long ducting, with open vents, have been reported in detail,Brown (1951). The ducting was horizontal, of length 17 m (55.5 ft), and diameter 1.2 m (4 ft). Uniform dispersion of dust was difficult with this geometry and the method finally used consisted of suspending controlled amounts of dust, in paper bags, at intervals along the ducting. One or two detonators were placed in each bag and fired electrically.

The detonators did not ignite carbonaceous dusts. A check showed that dust dispersed in this way and allowed to settle gave a uniform weight of deposit along the ducting length. The ignition source for the explosions was a small cloud of magnesium dust, ignited by gun cotton, which in turn had been fired electrically. The results available are for wheat, provender (animal feed), and cork dusts with various areas of venting, at different positions along the ducting. The highest pressures were obtained when the dust was ignited remote from the vent, whether or not the full cross-sectional area of the duct was available for venting. A vent near the ignition source was beneficial in reducing pressures, as would have been expected, and the vent halfway along the ducting also gave benefit. The length of ducting was about 14 diameters and so with a single vent equal to the cross-section of the area at the end of the ducting the vent ratio would be $1/17$ m^{-1} ($1/56$ ft^{-1}). This is less venting area than suggested in Table 1, for carbonaceous dusts, and in fact gave pressures up to 60 kN/m^2 (8.4 lb f/in^2). The recommended vent ratio, $1/6$ m^{-1} ($1/20$ ft^{-1}) would require at least three vents in the ducting for the necessary vent area. If these are provided the necessary reduction in pressures can readily be obtained. When considered together the data again indicate that the vent ratios in Table 1 were not unduly cautious.

With a cyclone, becuase the dust is concentrated near the walls, only a fraction of the volume is filled with an explosible concentration. On the other hand the cloud is likely to be intensely turbulent and there are many indications that turbulence can increase burning rates of dust suspensions and gas mixtures, so that higher pressures might be expected in an explosion In order to obtain data specifically applicable to cyclones, some experimental explosions were carried out in an industrial-scale dust handling plant incorporating a cyclone of volume 1.2 m^3 (43 ft^3) provided with a relief vent, Palmer (1974). The test equipment has been described in detail elsewhere, Palmer (1973, 1974), and Fig. 1 shows the relation between explosion pressure and area of vent, for three dusts. The volume of the cyclone was 1.2 m^3 (43 ft^3) and the vents were closed, for experimental purposes, with a diaphragm which burst at a pressure of 4 kN/m^2 (0.6 lb f/in^2) irrespective of the vent area and the rate of pressure rise during the explosion. For each of the three dusts represented in Fig. 1 it was clear that the explosion pressures were lower than would have been expected from results for cubical galleries, Hartmann et al (1950), Hartmann and Nagy (1957), a vent area of approximately 0.07 m^2 (0.76 ft^2) would be required for each of the dusts to reduce explosion pressures to 15 kN/m^2 (2 lb f/in^2). The vent ratio based on the volume of the cyclone alone was therefore $1/17$ m^{-1} ($1/57$ ft^{-1}). The vent ratios in Table 1 for cork and flour would be $1/6$ m^{-1} ($1/20$ ft^{-1}) and for phenol formaldehyde resin would be $1/5$ m^{-1} ($1/15$ ft^{-1}). Alternatively, if the vent ratios in Table 1 were employed the maximum pressures would be below 7 kN/m^2 (1 lb f/in^2) even though the paper diaphragm controlled the lowest explosion pressure A probable explanation of the low pressures in the cyclone was limitation of the size of the explosible dust cloud The distribution of the dust in a cyclone has a complex pattern due to centrifugal action and to vortex formation, and also depends on the individual mass of the dust particles. In order to propagate an explosion the concentration of dust in suspension must exceed the minimum explosible concentration, and for the suspensions used the precipitation of 80 – 90 per cent of the dust initially present would reduce the concentration below the minimum. The variation in concentration of the dusts as they passed through the cyclone was not examined in detail but some broad indications may be given. Direct observations with polypropylene, which was a relatively coarse material (76 per cent between 60 and 72 B.S. mesh) showed that most of the suspension had been precipitated in the first third of the initial revolution in the cylindrical portion of the cyclone. The efficient separation obtained with all

dusts indicated that a negligible quantity was in suspension in the conical part of the cyclone where it could have been entrained by vortices and delivered to the outlet. The height of the cylindrical part was such that a suspension would on average undergo two complete revolutions before reaching the conical portion. For the dusts listed in Fig. 1 it was estimated that an explosible concentration would not be present for more than two revolutions of the cylindrical portion of the cyclone tapering over this distance from a width equal to that of the inlet duct (300 mm, 1 ft) to zero. On taking this as a basis for calculation of explosible volume, the derived pressures were in much closer agreement to those obtained with cubical vessels. This approach indicated that even an approximate estimate of the actual volume of the explosible suspension was helpful. The turbulence of the suspension which may have caused some increase in burning rate, did not compensate for the reduced volume.

Unlike other compact vessels the position of the vent in a cyclone can noticeably affect the explosion pressure. Considerable benefit can be obtained by using a vent near to the dust inlet on the cyclone rather than at a further position. Use of the axial air outlet for venting, although convenient, is less effective but still may be practicable An axial vent would require the explosion products to be drawn to the centre of the cyclone, and is likely to increase the volume of burning dust suspension and hence the explosion pressure.

So far the cyclone has been assumed to be working normally before arrival of the explosion, so that the dust suspension would be near the wall. In many industrial .plant systems a cyclone dust collector may be followed by a fabric filter unit to remove any carry-over of fines. In this system, if explosion should start in the fabric filter, where the finer fractions of dust are collected, then dust could be blown back from the filter into the cyclone or, alternatively the pressure may itself interfere with the distribution of the suspension in the cyclone. This dust is then likely to be ignited by a relatively large flame coming from the filter and the dust suspension in the cyclone may have been disturbed to fill the whole volume. Under these conditions a more violent explosion would be expected, and vent ratios given in Table 1 should be used.

Application of data to plant

The relief venting requirements of the ducting, fan, and cyclone and collection bin will be considered in turn. Other important factors common to each of these plant units will be considered subsequently.

If the ducting is not of sufficient strength to withstand the explosion pressure, and relief venting is used for protection, the ducting should still be as strong as possible. The area of each vent preferably should equal that of the cross-section of the duct, and they should be spaced in accordance with the vent ratio requirements of the dust (Table 1). The open end of the duct may be regarded as a vent. The other vents should discharge to the outside atmosphere, and not into the workroom, and their fitting should not permit dust deposition within the ducting. It is good practice to avoid a large number of ducting systems being serviced by a single dust separator; the number should be small commensurate with economic working. If an ignition should occur in the separator, the explosion could propagate along all ducting attached to the unit and flame could blow back as far as the dust entry points. The number of ducts attached to a single separator unit should therefore be minimized. The number of branches in the ducting should also be minimized because explosion originated in one branch can be transmitted back into others.

Although the provision of separate exhaust and collection systems for individual machines or groups of machines entails a higher initial capital expenditure than with a common system, the advantage obtained should an explosion occur in one of the systems is that the companion systems can continue to run after the incident and the total shut-down of production is avoided. If branched ducting is installed, dampers should be provided to balance the system. They should be correctly adjusted and then locked in position, otherwise dust may deposit in the ducting because the air flow may be insufficient to transport it.

The design of an extended ducting system should prevent fire or explosion leading to disruption of the ducting, but burning material may deposit. Facilities should be provided for inspecting the ducting throughout its length and for enabling burning material to be readily removed after an incident. The extinguishing of fires in deposits in ducting, with inadequate access, can be difficult. Even if the fire is detected quickly and the extraction fan is shut-off, air will continue to move for a period unless stopped by a damper. This air movement would intensify the fire. It also removes extinguishing agents so that they may not have sufficient residence time to extinguish burning deposits. Injection of water is difficult in long and complicated duct systems, and may not be permissible if the dust can react with it. Injection points for extinguishing agents can be useful in long ducting. If an inaccessible fire develops its extinguishing may only be possible by breaking into the ducting and, as this is frequently running overhead, damage to underlying plant is probable.

The vents in ducting may need care in positioning, or may need to be increased in number, to ensure that vents are situated near bends, junctions, or fans in the system. Also where the ducting enters a dust collector, a vent should be installed near the point of entry, either on the ducting or in the wall of the bin.

Fans or blowers inevitably contain fast moving parts which have two effects relevant to explosion problems. One is that the rapid motion can generate sparks if foreign material should enter, or a component may break off the impellor and the resulting friction and impact can cause ignition of a dust suspension. Also, because of the high turbulence within a fan an explosion is likely to propagate throughout its entire volume, giving the most severe conditions. Vents should therefore be provided for the fan, but because of the design of the casing it is often not possible to install vents on it. In such cases vents should be installed each side of the fan, in the connecting ducting, as closely as possible. Even so, in the event of explosion, the fan frequently suffers sufficient mechanical damage and distortion for repairs to be needed. A complex extraction system, with branched ducting serviced by one fan can be put out of commission entirely by an explosion.

For the venting of the cyclone, the experimental results described above indicate that vent ratios in Table 1 will provide a generous area. Frequently, however, because of the surface areas of the cyclone taken up by ducting and other attachments this vent ratio cannot be achieved and, as a compromise, for dusts of maximum rate of pressure rise not exceeding $35,000 \, kN/m^2 \, s$ ($5,000 \, lb \, f/in^2 \, s$) a vent ratio as low as $1/5 \, m^{-1}$ ($1/50 \, ft^{-1}$) may be acceptable if the vent is situated at the optimum position. This is near to the dust/air inlet, and can conveniently be on the top surface of the inlet ducting to the cyclone. Alternatively, the vent can be on the top surface of the cyclone itself, but should then be as near as possible to the dust inlet. If the vent is so positioned that the dust suspension must travel more than half a revolution within the cyclone to reach it, then the lower vent ratio is not advisable. The vent may be installed on the wall of the cyclone, but can

result in abrasion of the vent cover Alternatively, the vent may be on the top of the vortex pipe (ie the exit from the cyclone) but the vent ratio given in Table 1 may not be attainable, and the higher pressures expected may require strengthening of the top of the cyclone. In the present example, where no subsequent dust collector is employed, the vortex pipe would discharge directly to atmosphere and no vent cover would be of course used.

The dust separated by the cyclone would be delivered to a collecting bin, and a choke, such as a rotary valve, should be used to separate the cyclone from the bin. It is good practice to arrange that the electric motor for the rotary motor is switched-off immediately a vent cover on the cyclone or adjacent ducting is displaced by an explosion. A dust-tight micro-switch attached to the vent cover, operating a relay, can perform this task. By stopping the rotary valve, burning dust is prevented from being delivered into the collecting bin, thereby avoiding transmission of explosion.

Collecting bins are of compact shape, cylindrical, conical, etc, and the vent ratio given in Table 1 for the dust can be applied directly. If the bin is emptied with an operative in attendance nearby, it is again important to prevent transmission of explosion and a rotary valve should be installed at the delivery point from the bin. This is particularly important if the contents of the bin are put into bags or drums, as this operation requires the presence of an operative whilst the plant is running.

A plant system protected with vents in the above way should be capable of withstanding the effects of explosion without severe damage, and providing certain further precautions are taken, without endangering operatives. The example described is of a general nature, and with specific installations additional local factors may be present.

Additional explosion protection measures

Burning dust, hot gases and flames will be ejected from vents and must be discharged safely. If the plant is indoors, ducting is usually attached to a vent to ensure discharge to the open air. The usual requirements are that the duct should be short, not more than 3 m (10 ft) in length, straight, and of sufficient strength to withstand the explosion pressure; i.e. it must be at least as strong as the plant being vented. If the vent is provided with a cover it should be on the vent and not at the far end of the duct. It is good practice to avoid accumulation of dust within the duct. A port should be provided in the dust so that the vent cover can be inspected regularly. After inspection it is important that the cover to the port is replaced and properly secured.

When a duct is fitted over the vent the maximum pressure in an explosion in the plant is increased. The amount of increase cannot at present be calculated but information is available from experiments,Palmer (1973). There is some indication that the increase in explosion pressure caused by the duct is proportional to the square of its length. On this basis the additional pressure due to the duct would increase rapidly with its length; this topic is being currently investigated.

Vent covers are required to open at a preset pressure reliably, and should not open accidentally. In some situations such as when the vent cover may be exposed to mechanical shocks it should also be as robust as possible.

Common types of vent cover are:

Hinged covers or doors

Magnetic covers

Pop-out panels

Bursting diaphragms.

The characteristics of each type, with their advantages, and the importance of adequate seating or fixture, have been described in detail, Palmer (1973).

With some types of cover, such as doors, it is possible for the vent to close again after an explosion. In the present case the plant is open to atmosphere at its inlet and outlet so that development of damaging negative pressures is unlikely. Closing of vents after an explosion could reduce the severity of any subsequent fire within the system.

On no account, after an explosion, should operatives attempt to enter or clean-out the plant until all the burning material within it has been extinguished and the atmosphere has been tested to show that it is safe to enter. Danger can arise if the oxygen level is below that in air, or if gases such as carbon monoxide or carbon dioxide are present, as a result of the explosion.

After an explosion or fire the plant should not be restarted until all burning material has been removed. A detailed inspection of the interior is necessary. Failure to follow this course can result in dispersion of burning material on restarting the plant, and the initiation of a second, and possibly more severe, dust explosion.

In designing the vents, and their discharge path, attention should be paid to neighbouring risks. If the plant is in a congested area, or cannot easily be vented to atmosphere, venting may be unsuitable as a method of protection or the plant may need to be transferred. Difficulty can also arise if flammable materials are stored or processed in the vicinity, or if roads, footpaths, or fire escape routes run nearby. In protecting the plant against dust explosion it is important that other installations and facilities are not hazarded.

Even though the design of the plant and its construction are adequate, problems still arise where training and supervision of operatives and maintenance staff are inadequate. It is important that operatives using the plant should be instructed as to its safe running, and that the instructions should be renewed at appropriate intervals and also when new operatives are employed. Fires and explosions in dust extraction systems, particularly in the collection unit, have been caused by the thoughtless disposal of smoking materials into the ducting. There are legal requirements concerning welding and other hot working on dust handling plant, of which maintenance staff or contractors should be made specially aware. For maintenance a 'permit to work' system is desirable. The plant management must ensure that adequate training, control and supervision are provided, even though the plant has been designed to incorporate sufficient dust explosion protection to prevent injury to operatives or damage to the plant. Detailed advice on legal, insurance, and company requirements should be obtained from the appropriate authorities.

Acknowledgment

References

BROWN, K C. SMRE Research Report No. 22, 1951.

HARTMANN, I, COOPER, A R, JACOBSON, M. US Bureau of Mines. RI4725, 1950

HARTMANN, I. NAGY, J. Ind. Engng. Chem., 1957, 49, 1734 – 40.

Dust explosions in factories. Classified list of dusts that have been tested for explosibility in the form of a dust cloud. Department of Employment. HM Factory Inspectorate SHW830, London, HM Stationery Office, 1968.

Dust explosions in factories. Health & Safety at Work, No. 22. Department of Employment. London, HM Stationery Office, 1970.

PALMER, K N. Dust explosions in fires. Chapman & Hall. London, 1973.

PALMER, K N. Relief venting of dust explosions in a cyclone. (To be published 1974).

RAFTERY, M M. Ministry of Technology and Fire Offices' Committee. Fire Research Technical Paper No. 21. London, HM Stationery Office, 1968.

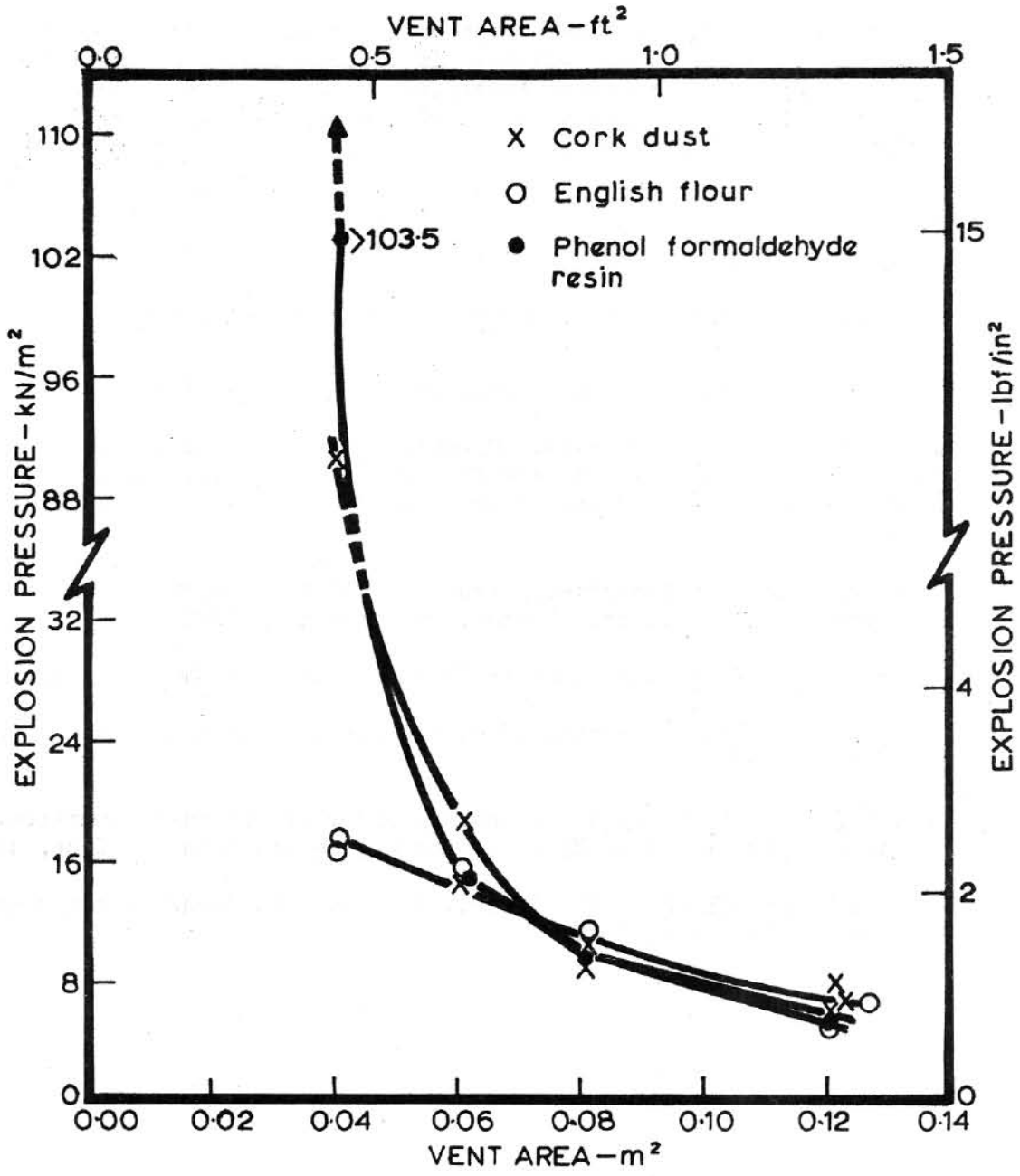ZENZ, F A and OTHMER, D F. Fluidization and fluid–particle systems. Rheinhold. New York, 1960.

Fig. 1 : The effect of vent area on explosion pressure
in a cyclone