INDUSTRIAL EXPLOSION PROTECTION - VENTING OR SUPPRESSION?

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This paper describes, compares and contrasts dust explosion venting with dust explosion suppression systems. It is shown that these two explosion protection methods are largely complimentary, and that in practice, cost effective safety is achieved using the most appropriate technique, or combination of techniques. Two case studies are presented to illustrate the specific considerations which led to the selection of the safety measures installed.

Keywords: Explosions, Venting, Suppression, Safety

1. INTRODUCTION

For the process industry combustible dust clouds and layers present a significant safety hazard. Thus design engineers and plant operators must tackle the issue of industrial explosion protection. In practice this usually means that it is necessary to install an explosion vent or an explosion suppression system on all plant components that present a potential explosion hazard, and take appropriate measures to prevent propagation of the combustion wave from one component to adjacent components. This paper compares and contracts explosion venting with explosion suppression, and seeks to demonstrate that the two technologies complement each other to provide for effective overall plant protection.

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2.   EXPLOSION VENTING

Explosion relief venting requires that a lightweight pressure
relief device of sufficient surface area is incorporated into
the wall of the plant component at an appropriate location.
This vent closure is opened under the rising pressure of an
incipient   explosion,   thus   intentionally   ejecting   the
enveloping fireball into the surrounding environment.

A vented dust explosion is a very significant event. The
vented firebali is liable to be some 5-10 times the free
volume of the plant component. Incorrectly located vent
closures can initiate a far worse secondary dust explosion or
start a catastrophic fire. The danger to personnel in the
proximity of a vent closure from both flame and blast is
considerable. Hence explosion relief devices must be sited
such that the fireball, combustion products and unburned
material are released into a safe area. It is usually
unacceptable to site venting devices such that the explosion
is released into a building, or in close proximity to other
plant components. Explosion venting is normally inappropriate
if the plant product is toxic, as is the case with many
pharmaceuticals,   fungicides   and   pesticides,   or   where   its
release is liable to contaminate the environment as can happen
with pigments and dyestuffs.
Explosion venting is often the most cost effective means of
providing industrial explosion protection. Provided that a
vent closure of sufficient area can be installed on the plant
component such that the explosion can be safely vented, this
protection measure is likely to be the operator's first choice
in industrial safety. After a vented explosion incident it
usually is necessary to douse the plant with water, clean down
and reinstate the vent closure device before production can
continue. Typical down time of some 3 - 6 hours should be
expected.

2.1 Types of Vent Closure

     Explosion vent closures must be of low inertia, and must
     have a low opening pressure, P_{stat}. Although explosion
     vent closures can be fabricated from simple materials it
     is more usual to install a proprietary explosion relief
     device, since its operation and venting efficiency can be
     assured.

     A typical proprietary rupture panel is shown in Figure 1
     (a). It is a slotted thin stainless steel/PTFE/stainless
     steel   sandwich,   designed   to   fail   at   a   specific
     overpressure - thus providing an unimpeded route for
     explosion relief. These types of circular or rectilinear
     rupture panels are particularly appropriate where the
     explosion is to be ducted from the plant component to a
     safe area. A proprietary "pop-out" panel is shown in
     Figure 1 (b). It comprises a low inertia stainless steel

panel held in place by calibrated release catches. It is restrained by chains and, unlike the rupture panel, is essentially a reuseable device. The venting efficiency of "pop-out" panels is similar to that of rupture panels.

Thermally insulated versions of both rupture and "pop-out" panels are available. These would be used where condensate build-up on the cold surface of a standard vent closure could cause process difficulties. For the food industry vent closures with hygienic seals are available to ensure no biological contamination. Most proprietary explosion vent closures can be supplied with a "break wire" sensor to initiate plant shut-down and/or post explosion fire extinguishing measures as appropriate.

Vent panels leave the plant component with an opening to atmosphere after an explosion incident. The ingress of air can sustain a significant fire after a vented explosion in plant components such as silos and bag filters that have a high fire load. Post explosion fire extinguishing measures should be installed on such components. An alternative vent closure device, the explosion door or hinged panel, reduces this fire load. Explosion doors are particularly appropriate for process plant that operates under reduced oxygen, perhaps by feeding combustion gases back into the plant, or for processes involving either flammable gases, or gases with extreme odours. The explosion door is a less efficient vent than the rupture panel. It is designed to self close, thus resealing the plant after an explosion incident. Figure 2 shows a proprietary door that does not transmit any significant reaction forces to the plant component as it operates.

As an alternative to the passive explosion vent closures described above, in some applications an active explosion vent is more appropriate. This comprises an explosive catch fitted to an explosion door, or a glass bursting panel that is explosively opened when an incipient explosion is annunciated by some explosion detection device. One such active explosion panel is shown in Figure 3.

2.2 Design of Explosion Venting Measures

Explosion venting devices must be designed and installed such that they effectively relieve the explosion pressure from a plant component. The effectiveness of the explosion vent is dependant on a number of factors:

- free volume of component to be protected - V

- explosion intensity of the combustible dust: P_{max} - maximum explosion pressure, K_{St} - explosion rate constant.

- static opening pressure of the vent closure device - P_{stat}

- unimpeded surface area of the vent opening - F

- inertia/venting efficiency of the vent closure device

- length and geometry of any duct used to direct the vented explosion to a safe area.

The vent closure must be located such that the explosion has an unimpeded passage to the vent opening. From the above parameters an estimation of the reduced (vented) explosion pressure, P_{red}, can be made by reference to an appropriate design code. Explosion protection by explosion relief venting demands that:

$$P_{red} < P_s$$

where P_s is the pressure load corresponding to the minimum yield stress for the plant component. The plant component must be constrained such that it can withstand the transient reaction force P_{red}/F incident on the vent aperture.

The accepted means of sizing explosion relief vents is based on a collection of published nomograms of the type shown in Figure 4. Selection of the nomograph appropriate to the vent opening pressure P_{stat} enables the minimum vent area, F, to be determined for a plant component of volume V and dust of explosion intensity, K_{St}. These nomograms form the basis of UK(1), German (2) and U.S.(3) codes. Lunn (4) has recently extended these nomograms to account for dusts with low K_{St} (K_{St} < 50 bar m s^{-1}) and for vent closures with low opening pressures (P_{stat} < 0.1 bar g). These nomograms are all based on turbulent hydrocarbon dust explosions with P_{max} = 10 bar. Barthnecht (5) has published alternative nomograms for P_{max} = 9 bar dusts, and Siwek (6) has established an alternative means of sizing vents for low turbulent pneumatic filling type operations. All of these codes refer to vent panels with a defined opening pressure, P_{stat}. Explosion doors have a stated venting efficiency WE%. The explosion doors can be sized by reference to the same nomograms where

$$F_{(Door)} = \frac{F_{(Panel)} \times 100}{WE}$$

The use of a duct to direct an explosion away from a hazardous area (e.g. to outside of a building) has a significant detrimental influence on the venting efficiency. Typically the pressure load on a plant component will increase from say 0.2 bar to 0.4 bar for a straight duct of 3m length, and to 1.1 bar for a straight duct of 6m length. Lunn (7) has recently published a very comprehensive guide which quantifies the influence of straight ducts, and ducts with one or two bends on the resultant pressure load of a plant component.

3.   EXPLOSION SUPPRESSION

Explosion suppression is a procedure whereby the incipient explosion is detected and extinguished with a suitable suppressant before the explosion pressure exceeds the plant component pressure shock resistance. Thus, like explosion venting, the design criteria for explosion suppression requires that the reduced (suppressed) explosion pressure:

$$P_{red} \ < \ P_s$$

where P_s is the pressure load corresponding to the minimum yield stress of the plant component.

An explosion suppression system comprises explosion detector(s), explosion suppressor(s) and a central control unit. The detector senses the incipient explosion and triggers automatic high rate discharge explosion suppressors. The suppressant charge is discharged into the enveloping fireball to extinguish all combustion. Thus the explosion incident is completely contained within the plant component, and is suppressed before a significant pressure load or heat flash excursion occurs.

The suppressant discharged into the component renders the conditions within the plant inert for a time, thus ensuring that there is no re-ignition — provided that the plant is rapidly shut-down to reduce suppressant purging. In some cases it is necessary to install fast acting dampers across fans and/or blowers to attain this design requirement. After a suppressed explosion incident, it is usually necessary to clean down the plant, remove product contaminated with suppressant, and reinstate the suppression system before production can continue. Typically, down time of some 6-12 hours should be expected.

An explosion suppression system is an active system. Its effectiveness depends on the reliability of the installed components. Thus high quality hardware with assured reliability is a requirement for such measures. Nuisance activations will result if sufficient care has not been taken

at the design stage to ensure a significant margin of safety
between detection pressure threshold and normal or abnormal
process pressure excursions. Sensors must be of the highest
reliability, tolerant to shock and vibration. Their preset
pressure threshold must neither drift with time on the plant,
nor as a result of process temperature excursions.

Explosion suppression hardware is normally bolted onto flanges
or stub pipes that are welded into the plant component.
Suppressors must be located to deploy suppressant into the
explosible volume and the fixings must be designed to
withstand the reaction force of the suppressor discharge, and
to support the weight of the suppressors.

Explosion suppression is usually selected where it is either
impractical or too costly to install explosion relief venting.
It is particularly appropriate for plant components that are
located in buildings and where the release of product could
contaminate the environment if vented. For a large industrial
process, the explosion suppression system would be divided
into discrete zones. Each zone would have a dedicated control
unit, and would be designed to suppress and contain the
explosion incident within its zone boundaries.

3.1 Types of Explosion Suppression Measures

For dust explosions, explosion detection is normally by
threshold membrane detectors of the type shown in Figure
5. Such detectors provide an electrical contact when the
pressure load exceeds a preset value. It is normal
practice to install two such detectors mutually at 90°,
and to require that both detectors operate to activate
the explosion suppressors. This procedure essentially
eliminates nuisance activations arising from shock,
vibration or mechanical damage of the detector membrane.
In process plant that operates under positive pressure it
is advisable to fit an overpressure sensor adjacent to
the explosion detectors. The purpose of this
overpressure sensor is to trip out the blower if the
plant pressure begins to rise, for example, because of a
blockage in a downstream duct. In some circumstances a
"rate of rise" pressure sensor, or a more sophisticated
analogue pressure sensor with electronic signal
processing may be appropriate, but optical sensors are
unlikely to be applicable to most particulate explosion
hazards.

There is a wide range of explosion suppression hardware
available to the application engineer. Selection of the
most appropriate hardware and configuration for a
particular application, and effective deployment of the
explosion suppressant will effect system performance.
Figure 6a shows a range of hemispherical explosion
suppressors. This type of explosion suppressor is

mounted inside the plant component and can discharge liquid suppressant within 2ms of detection at a velocity 200 m s^{-1}. An explosive charge petals the scored frangible dome of the hemispherical suppressor, thus thrusting suppressant at the enveloping fireball. This type of suppressor is particularly suited for ducts, elevator legs and small volume plant components. They are unsuited to erosive or high temperature environments.

Single exit and dual exit explosion suppressors are shown in Figure 6b. These suppressors use a high speed valve to release their stored charge of suppressant, which is expelled under pressure of dry nitrogen through a flexible hose or other plant connector to a dispersion nozzle mounted on the plant component. Typically, such suppressors use non-explosive actuators but have only a limited rate of suppressant delivery. They would be deployed against the less intense dust explosion hazards, or for rapid fire extinguishing or advance inerting measures. For the more violent dust explosions, high rate discharge suppressors (HRDs) of the type shown in Figure 6c are more appropriate. These suppressors use a 75 mm diameter or a 125 mm diameter explosive valve to release their charge of suppressant, typically 4 kg, 16 kg, or 35 kg into the plant component at 100 kg s^{-1}. Such suppressors are directly mounted onto the plant component. The high propelling agent pressure, typically 60 bar dry nitrogen, expels the suppressant through either fixed or telescopic nozzles into the plant component. This type of explosion suppressor is suited to all applications. High plant temperature (maximum 250°C) and hygienic plant seal versions are available. A typical telescopic nozzle arrangement - see Figure 7 - ensures that the suppressor nozzle does not intrude in the normal flow conditions of the process plant.

Explosion suppression systems are available with alternative explosion suppressants. Table 1 summarises the commonly available suppressants, and comments on their application. In practice, powder suppressants have a much greater range of application against dust explosions than other suppressant agents.

Table 1:   Choice of Explosion Suppressant

Suppressant	Application
Water	- Most hydrophilic hydrocarbon dusts.
	- Antifreeze required for low temperature applications.
	- Limited inerting time after explosion suppression.
	- Unsuitable for gas or dust/gas hybrid explosions.
Halons	- Most gases and hydrocarbon dusts with moderate or low explosion intensity.
	- Only applicable with very low detector pressure settings.
	- Good inerting properties after explosion suppression.
Powders	- All hydrocarbon dust and gas explosions.
	- Applicable with range of detector pressure settings.
	- Good inerting for dust explosions, limited inerting with gas and hybrid explosion hazards.
	- Water soluable and food grade compatible powders available.

Table 1: Choice of Explosion Suppressant - continued

Gases [CO_2, N_2]	- Unsuitable for explosion suppression
	- Can be used for inerting and post vented fire extinguishing measures.
Halon/ Powder Hybrid mix	- Efficiency between that of Powders and Halons
	- Good inerting, characteristics.

3.2 Design of Explosion Suppression Measures

Explosion suppression measures must be designed and installed such that their operational effectiveness is assured. The effectiveness of a suppression system is dependent on many factors:-

- Volume and geometry of the component to be protected

- Explosion intensity of the combustible dust:
  P_{max} - maximum explosion pressure
  K_{St}^{max} - explosion rate constant

- Process conditions - airflow and turbulence

- Detection pressure threshold, P_A

- Type and efficiency of explosion suppressors

- Number, and geometric deployment of suppressors

- Suppressant propelling against pressure.

Design of explosion suppression for a given application is based on an estimate of the worst case explosion pressure/time characteristic in the component. The corresponding suppressant concentration requirement in the combustion kernel can be estimated from this explosion characteristic and knowledge of suppressant effectiveness (8). Super-imposition of the suppressant delivery characteristic into the plant component, defined by detection pressure and the discharge characteristics of explosion suppressors defines the resultant worst case reduced explosion pressure P_{red} - see Figure 8. This calculation of P_{red}, based on worst case assumptions, defines system effectiveness. If the suppressant delivery characteristic does not intersect the suppressant requirement characteristic a "failed suppression" is predicted. The author recommends the following safety margin for suppression system design:

i) $P_{red} < P_s$

ii) Rate of suppressant delivery at suppression should be greater than twice the requirement rate

iii) Mass of suppressant delivered should exceed mass of suppressant required by 50%.

For given suppression system hardware the number of explosion suppressors required follows a basic cubic law relationship

$$n = n_o \, V^{2/3}$$

where n is the number of suppressors required to suppress an explosion in the volume V and n_o is the fictitious number of the same suppressors required to suppress an explosion in a volume of $1m^3$. This relationship leads to a simple design nomogram of the type shown in Figure 9 for specific hardware and suppressant — here mono-ammonium phosphate suppressant in the HRD suppressors shown in Figure 5c.

Experimental data has quantitfied suppressant and suppression system effectiveness against both gas and dust explosions in a range of test volumes. Such data (9-12) demonstrates system effectiveness. Halons are limited to small volume and low intensity explosion hazards, but powders have been shown to be effective against the more intense dust explosion and applicable to volumes up to $1000m^3$. The recent introduction of a large volume suppression system now makes explosion suppression a cost effective option for these large volume plant components.

4.   VENT/SUPPRESSION HYBRID SYSTEM

Vent/suppression hybrid systems combine the technology of explosion venting with explosion suppression. They are applicable when neither venting nor suppression alone can provide the required level of explosion protection. Vent/Suppression hybrid system could be selected to meet the following explosion protection criteria:

(i)   Minimise flame ejection out of an explosion vent panel that is sited such that the fireball will be ejected into a hazardous area.

(ii)   Provide adequate protection for weak plant components that cannot accommodate a sufficient vent area to attain the criteria P_{RED} (vented) < P_s.

(iii)   Provide adequate protection of plant components fitted with explosion suppression alone where P_{red} (suppressed) does exceed the plant component pressure shock resistance P_s.

(iv)   Attain acceptably low P_{red} values with the more intense St3 dust explosion hazards such as metal dust.

For some applications vent/suppression hybrid systems can provide the most cost effective means of explosion protection.

5.   EXPLOSION ISOLATION

When designing explosion protection by venting or suppression, it is usually necessary to isolate the explosion event to as small a part of the process as is reasonably practical. This is particularly important when a component with a high probability of ignition, such as a mill, is connected to a component that will have a severe consequence from a dust explosion such as a bulk storage silo. The most common types of explosion isolation techniques are:

(i)   Physical barriers, such as explosion proof rotary gate valves and explosion chokes in screw conveyors or triggered slam-shut valves are used to prevent an explosion wave from propagating down inter-connected ducts.

(ii)   Chemical barriers, such as the injection of an inerting extinguishant ahead of the combustion wave to ensure that flame or burning material does not pass into a more hazardous area.

6.   EXPLOSION PROTECTION - THE CHOICE

For most applications there is no one unique solution for a particular explosion hazard. The choice between explosion venting and explosion suppression will depend on both technical and economic factors. In practice, it would be usual to select the most cost effective means of providing adequate explosion protection. This choice may be influenced by a corporate policy, perhaps influenced by employee relations, whereby a fireball release is judged to be unacceptable, even though such release is not hazardous.

In most applications, it would be usual to assess the practicality and cost consequence of installing an explosion venting system. Determination of the vent area requirements, selection of the most appropriate vent closure, estimating the cost of installation of the vent device and any vent ducting, together with any requirement for plant strengthening to withstand the pressure load P_{red} and the reaction force P_{red}/F can lead to an estimate of the cost of such a system. To this cost must be added the requirement for post vented fire extinguishing and any explosion isolation requirement such as slam-shut valves and plant shut down.

The cost of explosion protection by venting can then be compared with the cost of purchase, installation and life cycle maintenance of an explosion suppression system. In most cases suppression is selected where it is either impractical or expensive to install explosion vents, or where venting is not an appropriate safety measure. Thus practical constraints associated with the plant component, its location and the type of product being processed would lead to the selection of explosion suppression, rather than explosion venting.

In most process plants, the consequence of such considerations is likely to result in a mixture of venting, for those plant components that can be readily vented, and of suppression for other components where venting proves to be either impractical, inappropriate or very expensive to implement.

CASE STUDIES

7.   Case Study 1.

Part of an animal feed milling process is shown
schematically in Figure 10. Explosion protection was by
explosion relief venting using explosion doors fitted to
the 6m long bypass chute on the en masse conveyor, and to
each of the bins. The vent areas installed on the bins
were the largest that could be practically fitted such
that the explosion could be ducted through < 3m long
ducts to a safe discharge point. A survey of the plant
identified the following features:

(i)   The ignition probability was greatest in the
      vicinity of the mills where the product was
      being mechanically worked.

(ii) The explosion consequence was greatest in the bins,
      particularly if a bin was nearly empty, since the
      vent area installed was inadequate, and the bin was
      mounted inside a large building where the prospect
      of a secondary dust explosion existed if a bin were
      to rupture.

(iii) An explosion incident in any one bin could
      communicate to the adjacent bin via the en masse
      conveyor, but explosion propagation via the bin
      outlet through the screw conveyor was unlikely.

The most immediate safety enhancement to this process is
to establish effective explosion isolation between the
mills and the bins. This was achieved by installing an
explosion isolation extinguishing barrier on the en masse
conveyor between the mills and the bins. Detection of an
explosion propagating down the conveyor results in the
suppression of the combustion wave before it reaches the
bins. This system was installed as a first step to
improve explosion safety. Since installation, the system
has operated twice, on both occasions preventing known
dust explosion events in the mills from propagating into
the bins.

Since the explosion vents fitted to the bins are
undersized it is necessary to increase the vent areas,
such that a worst case explosion incident in any bin is
protected. The cost consequence of installing explosion
vents, using proprietary panels and of both ducting the
vented explosion to a safe area and increasing the bin

pressure shock resistance was contrasted with the alternative of fitting explosion suppression to these bins. For this application explosion suppression turned out to be the most economic option, and this safety measure has been selected to protect the two bins, thus providing a full explosion protection safety package - as shown in Figure 11.

7.2 Case Study 2. (reference 13)

A large spray drying plant producing a wax product had suffered a history of fire and explosion incidents. Explosion relief had been installed on several components - but in one major incident these had only partially relieved the force of the explosion and extensive damage occurred. The explosion vents installed were based on the belief that the dust had a moderate explosibility quotient as adjudged by Hartmann explosibility data. A re-evaluation of the product in accordance with BS6713 (14) proved this to be wrong. The material was an intense dust with a very low minimum ignition energy. Thus ignition by electrostatic discharge was a prospect with this product. These results explained the ineffectiveness of the installed venting measures and indentified that ignition must be anticipated at all locations in the process. Thus a complete re-evaluation of the plant was undertaken. Since the installed venting was into buildings, which is not an acceptable practice, it proved appropriate to protect this process by explosion suppression.

Figure 12 indicates the hazardous section of plant and the various protection methods incorporated. Some of the component volumes are very large - spray dryer ($320 \, m^3$); main filters ($110 \, m^3$) - and in the past this has meant that explosion relief venting was the only practicable solution. However, a new suppressor configuration recently introduced by Graviner has extended the limit of explosion suppression to volumes of $1000 m^3$ (15). Ten of these new suppressors, each filled with 35kg of powder suppressant, were needed to protect the volume of the dryer. The geometry of the main filters and the obstruction imposed by the filter bags meant that a sufficient number of suppressors were required to introduce suppressant into all the explosible voids - two 35kg suppressors and three 16kg suppressors sufficed. In order to cater for the low plant strengths involved and the increased violence of the potential explosion, a combination of explosion relief venting and explosion suppression was selected. This hybrid protection system relies on the suppression system to extinguish the explosion, and the vents to further relieve any explosion

overpressure - achieving a very low final pressure of 0.05 bar in the spray dryer. Because the explosion will have been extinguished, flame will be ejected through the vents. In fact, one or two suppressors on each component were arranged to discharge their contents directly across the vent apertures, to ensure that virtually all flame is extinguished.

The action of explosion suppression within components will extinguish burning material within the plant component. However, the ducting between components will contain combustible products and thus provide a path for the flame to travel ahead of the explosion and so on to the next part of the plant. Rotary gate valves, which can be stopped on detection of an explosion, were already installed on the outlets of all the filters - these form an effective mechanical barrier to burning material - however, the inlet ducts need some form of protection. Additional suppressors were arranged to discharge their contents along the ducts, directed into the filters, thus forming chemical barriers preventing the propagation of an explosion. The duct between the drier and the main filters need a total of three suppressors, because of its size and length.

The suppressors for this plant were filled with a water soluble powder suppressant Dessikarb,such that, following an activation, suppressant could be easily removed from the process and separated from the non-soluble process material - thus ensuring minimal loss of product.

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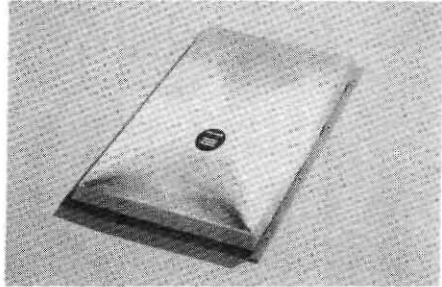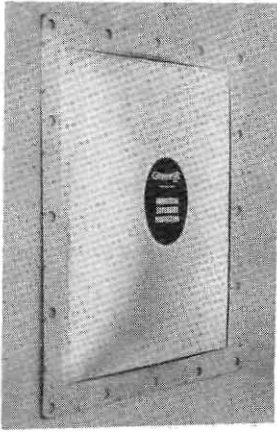
(a)

(b)

Figure 1:   Explosion vent panels   a)   Rupture panel   b)   "pop-out" panel
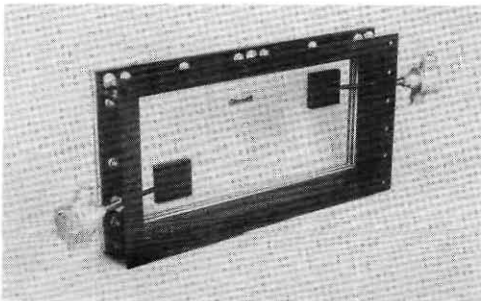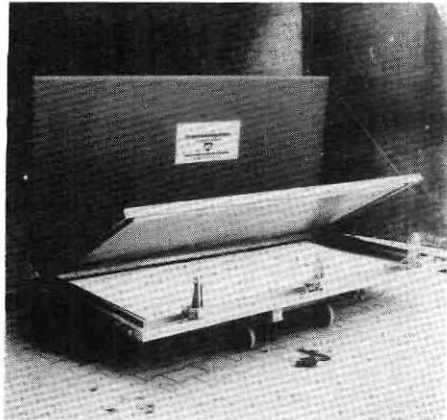

Figure 2:   Explosion door
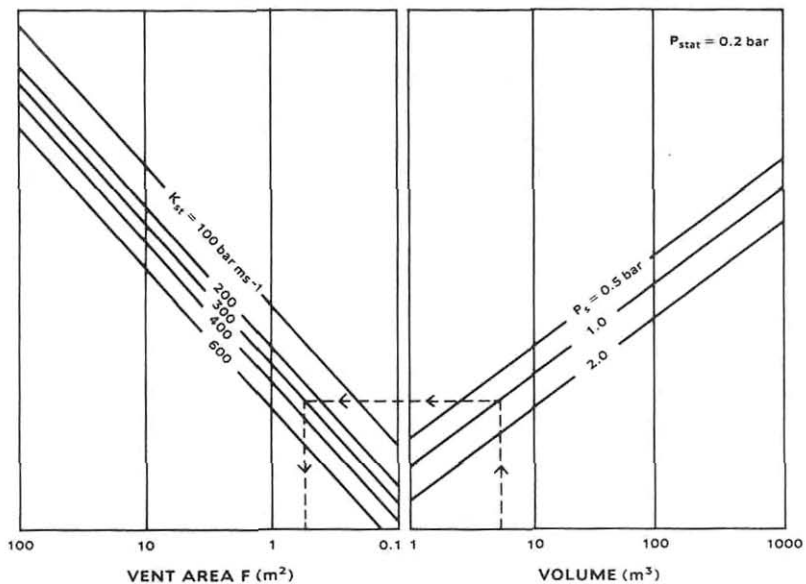

Figure 3: Active Explosion
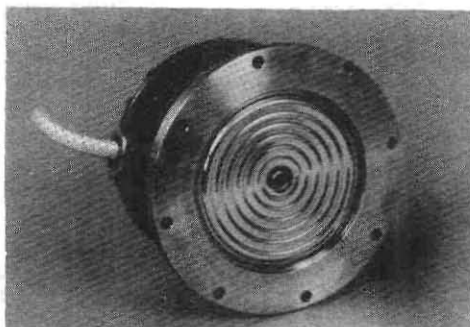Vent Panel

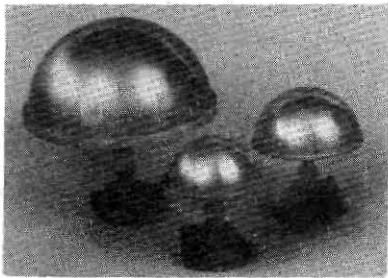Figure 4: Typical nomogram for determination of vent area.
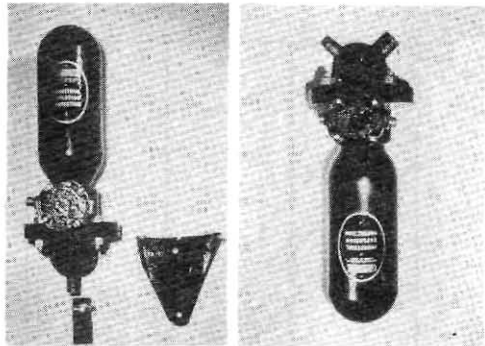

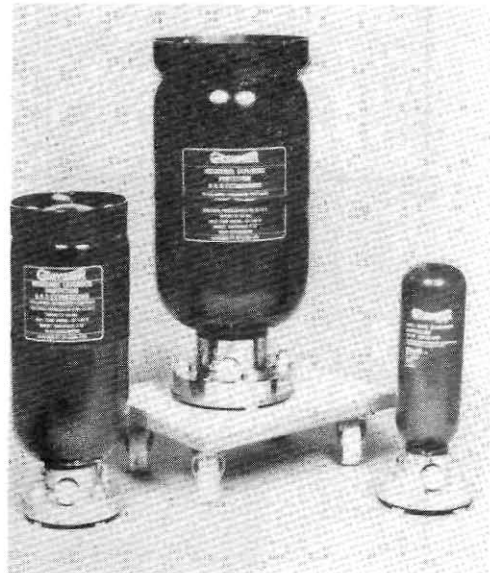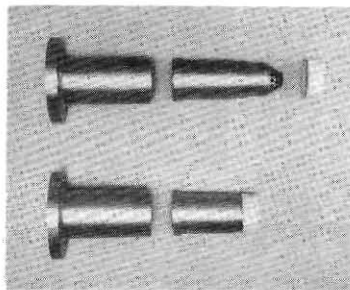Figure 5: Membrane Pressure Detector

(a)

(b)

Figure 6: Explosion Suppressors
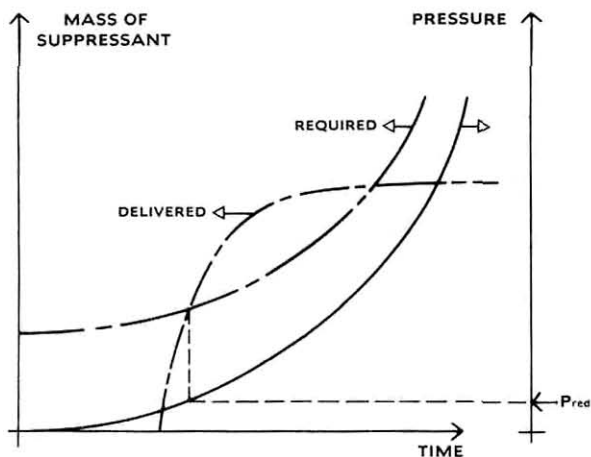
(c)

Figure 7: Telescopic Nozzel

Figure 8: Design Basis for an Explosion Suppression System

Explosion Suppression System Design Guide

Detection pressure $P_A \leqslant 0.1$ bar   Suppressant: Ammonium phosphate

Plant strength $P_s \geqslant 1.0$ bar   Suppressor pressure $P_{N_2} = 60$ bar
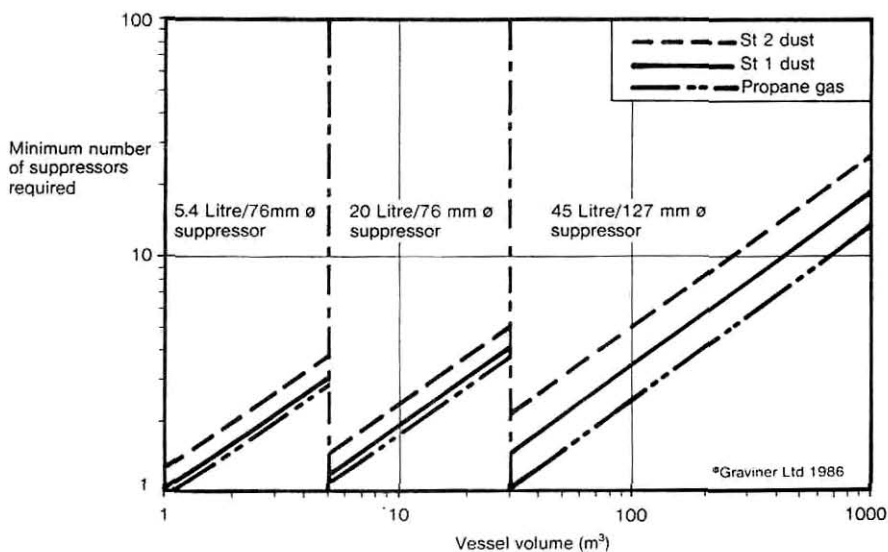

Figure 9: Explosion Suppression System Design Nomogram

PAIR OF EXPLOSION PRESSURE DETECTORS
16 kg HRD SUPPRESSOR
EXPLOSION RELIEF VENT
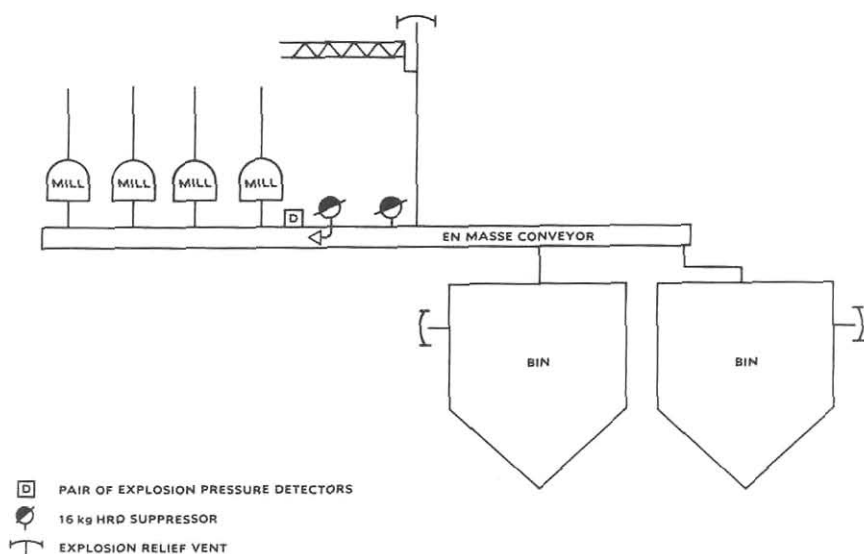
Figure 10: Case Study 1 - Explosion Isolation

PAIR OF EXPLOSION PRESSURE DETECTORS
16 kg HRD SUPPRESSOR
EXPLOSION RELIEF VENT
45 kg HRD SUPPRESSOR
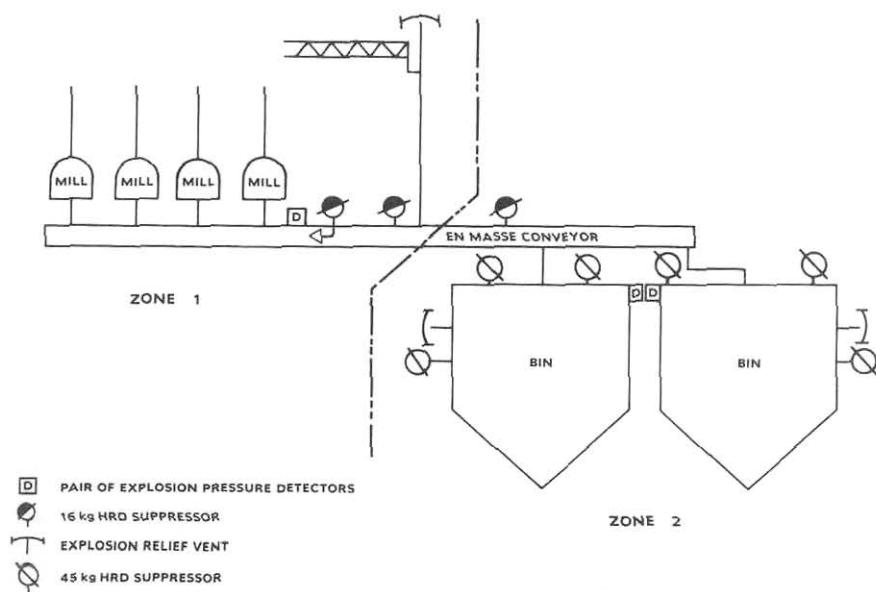
Figure 11: Case Study 1 - Total Explosion Protection

ZONE 3

ZONE 4

SPRAY DRYER

MAIN FILTER

MAIN FILTER

ZONE 2

ZONE 5

ZONE 1

FINES FILTER

CLASSIFIER

FEED HOPPER

CLASSIFIER

FINES FILTER

COARSE FILTER

ZONE 6

ZONE 7

☐D PAIR OF EXPLOSION PRESSURE DETECTORS

4 kg HIGH RATE DISCHARGE SUPPRESSOR

16 kg HIGH RATE DISCHARGE SUPPRESSOR

35 kg HIGH RATE DISCHARGE SUPPRESSOR

EXPLOSION RELIEF VENT
(DESIGNED IN ACCORDANCE WITH VDI 3673)

INDICATES DIRECTION OF INJECTION
OF SUPPRESSANT (WHERE APPLICABLE)

MATERIAL — PARAFFIN WAX

EXPLOSIBILITY RATE CONSTANT — $K_{st} \leqslant 239 \text{ bar ms}^{-1}$

PRESSURE DETECTOR SETTING — $P_a = 0.035 \text{ bar g } (0.5 \text{ p.s.i.g.})$
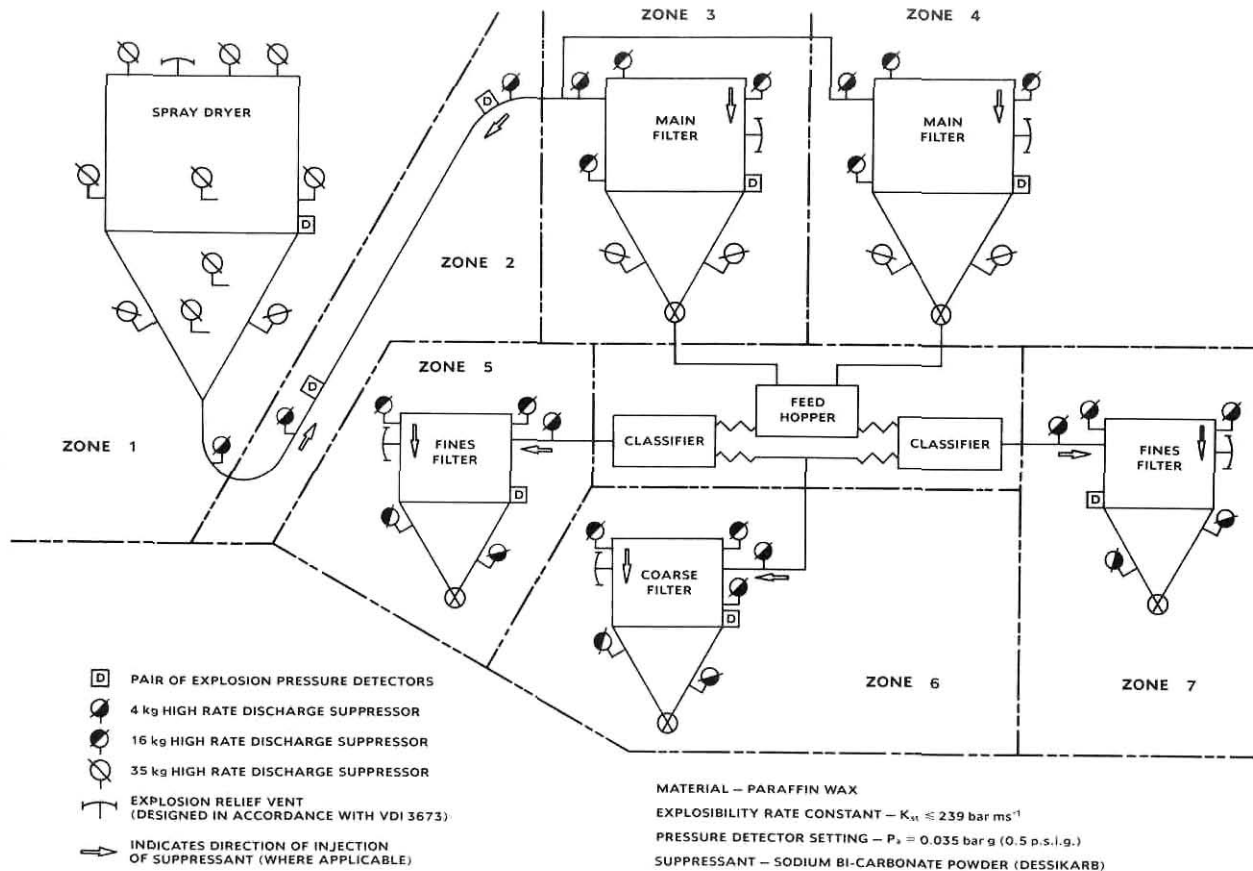
SUPPRESSANT — SODIUM BI-CARBONATE POWDER (DESSIKARB)

Figure 12:   Case Study 2 — Total Explosion Protection