Engineering Practice

To Vent or Not to Vent

Learn from common misapplications in explosion venting and consider alternative strategies

Ralph Foiles
Process Protection Inc.

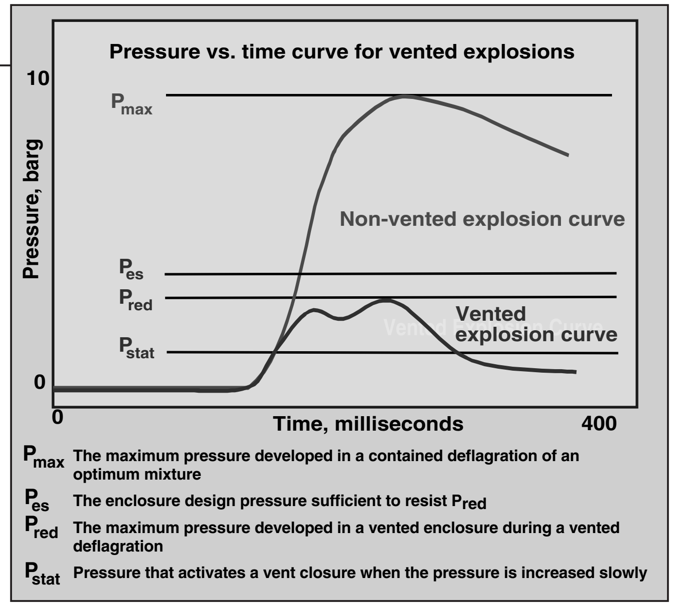

FIGURE 1. If designed and sized correctly, explosion vents reduce the maximum pressure (P_{max}) of a deflagration to a safe level (P_{red}) that the equipment is designed to resist (P_{es})

The most effective explosion protection strategy is one that prevents a blast in the first place. Most plants in the chemical process industries (CPI), however, are fraught with conditions that weaken the fabric of solely preventive measures (box, p. 61). Given the catastrophic consequences that explosions threaten to process equipment and nearby personnel, responsive measures are also vital.

A responsive strategy protects the equipment and personnel after a deflagration* begins. Explosion venting, the most widely used responsive technique in the process industry, has been used for decades to limit or prevent overpressure damage caused by deflagrations in industrial processes. Deflagrations occur most frequently in dust collectors, conveyors, elevators, dryers, mills, storage vessels, and entire buildings or rooms.

If designed and sized correctly, explosion vents reduce the maximum pressure (P_{max}) of a deflagration to a safe level (P_{red}) below that which the equipment is designed to resist (P_{es}) (see Figure 1). The pressure that is developed during a deflagration is released through the vent, and thus, the vessel integrity is not compromised.

The U.S. National Fire Protection Association (NFPA) publication NFPA 68, Guide for Venting of Deflagrations, 2002 edition, provides guidelines for the design and use of explosion venting devices. However, this popular strategy has been misapplied in many applications, resulting in a false sense of security and leaving industrial processes still unprotected.

To reconfirm that the installed explosion-protection strategies adequately protect the process, facilities should be reviewed in context of NFPA guidelines and other applicable industry standards but, more importantly, vis-á-vis industry experience. Consider the following common applications where explosion venting can be misapplied, and consult with explosion protection experts to ensure that your protection strategies are adequate.

Equipment located indoors

When process equipment is located inside a building, vent ducts should be used to direct the flame and pressure from the enclosure to the outdoors (NFPA 68, Section 5.8.1). A vent duct is ductwork connected to the explosion-vent assembly leading to an outside wall, which provides a path directing the flame and pressure to a safe location. The use of a vent duct can, however, significantly increases the pressure (P_{red}) in the equipment during venting.

The old rule of thumb suggested that if the discharge, vent-duct length was less than 3 m. (10 ft), the increase in P_{red} was negligible. But, empirical data have shown otherwise; a new equation in Section 7.5 of NFPA 68 shows how to calculate the effect of the vent duct at various duct lengths (based on the length-to-diameter ratio of the duct). Although the new equation produces lower P_{red} results compared to earlier NFPA 68 editions, there still can be significant increases in P_{red} with the addition of a vent duct.

Consider, for example, an enclosure with various lengths of vent duct (Figure 2 and Table 1). A vent duct of only 3 m (10 ft) would produce a P_{red} that is more than twice that of a vent application that did not utilize a vent duct. So, a typical rectangular dust collector that is rated to resist a P_{red} of 0.2 barg (3 psig) could actually experience pressures that exceed the vessel's ultimate strength — and risk rupture — if a vent duct were added. In general, larger dust-deflagration index (K_{st}) values and smaller vessel volumes will produce the greatest increases in P_{red} when vent ducts are used.

Alternative protection strategies. In the case of equipment located indoors, consider the following alternatives:

- Increase the vent relief area to compensate for the effects of the vent duct and achieve an acceptable P_{red}
- Move the process equipment as close to an outside wall as possible. The duct length is directly correlated to the predicted pressure (Table 1) — the shorter the duct length the lower the P_{red} value. If the vent duct length is less than one hydraulic vent diameter, there is no additional increase in P_{red} (NFPA 68, Section 5.8.2)
- Use explosion suppression in lieu of explosion venting. Explosion suppression is a responsive technique of detecting and extinguishing the deflagration during its incipient stage,

* Deflagration: propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium

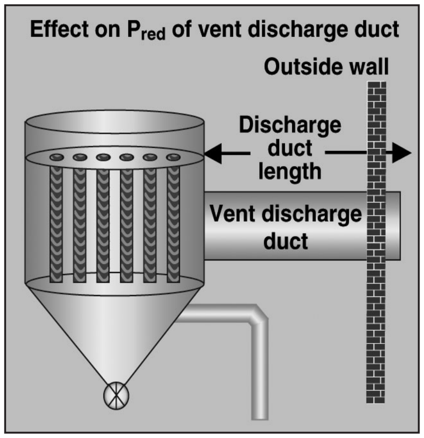

FIGURE 2. As indicated in Table 2, P_{red} achieved with venting increases with an increase in the vent duct discharge length (diagram is not to scale)

resulting in P_{red} values similar to those for explosion venting without vent ducts

- Use a flame-arresting device in conjunction with explosion venting. The flame-arresting device quenches the flame as it exits the explosion vent, and prevents unburned dust from escaping the process equipment. Typical flame arresting applications can provide P_{red} values similar to those achieved by explosion venting without vent ducts

No safe place to vent

As indicated earlier, explosion venting reduces the deflagration pressure but does not stop the combustion process. As pressure is relieved through the explosion vent, unburned dust is pushed outside of the enclosure, ahead of the flame front. The discharged flame and high-pressure material can injure personnel, cause secondary explosions, or result in pressure damage to adjacent equipment or buildings. It is important to take into account the explosion vent location and where the fireball will be directed. The resulting fireball and external pressure can now be quantitatively estimated by Equations 7.8 and 7.9 of NFPA 68.

The maximum flame distance from the explosion vent for a process vessel with a volume of 10 m^3, for instance, is calculated to be 21.5 m (70 ft). The maximum external pressure exists at a distance of about one-fifth of this maximum flame distance. For this specific example (Table 2) the maximum pressure at a distance of 14 ft would be about 0.8 psig; and at 70 ft, it would be about 0.16 psig. As a point of reference, glass windows will fail at approximately 0.15 psig pressure. There goes the neighborhood.

TABLE 1. EFFECT OF VENT DISCHARGE DUCT SIZE ON SAFE DEFLAGRATION PRESSURE

Discharge duct length, m	P_{red}, barg
0	0.2
2	0.4
3	0.5
4	0.6

Calculations based on: Vessel volume = 8 m^3; P_{stat} = 0.1 barg; K_{st} value = 139 bar-m/s; P_{max} = 9 barg; Vent relief area = 0.44 m^2

Alternative protection strategies

If finding a safe place to vent proves difficult, consider the following options:

- Use explosion suppression in lieu of explosion venting. The resulting pressure will be contained in the enclosure and the flame will be extinguished
- Use a flame-arresting device in conjunction with explosion venting. The flame is quenched and prevented from leaving the flame-arresting device

Flame propagation

In process equipment that is interconnected by pipelines, a deflagration that originates in one vessel can propagate to another, even if all the equipment is explosion vented. This propagation results in pressure piling, increased turbulence, and a significant ignition source in the adjoining equipment. Figure 3 and Table 3 show the dramatic increase in explosibility parameters when two vessels are interconnected via a pipeline. With these elevated conditions, the vent area calculated by NFPA 68 equations can be insufficient (NFPA 68, Sections 5.6.7, 7.11).

Alternative protection strategies

For interconnected equipment, consider the following options:

- Provide an explosion isolation device between the interconnected equipment to prevent the flame propagation (refer to NFPA 69, Chapter 9)
- Provide explosion vents along the length of the interconnected ductwork, per Chapter 8 of NFPA 68, to reduce pressure and turbulence. This will not prevent the flame from propagating to the interconnected vessel. It will merely allow standard vent area calculations to be utilized

Processing toxic materials

This matter is somewhat obvious. Due to regulations and environmentally responsible practices, it is not acceptable to emit toxic materials that should be confined to the process equipment. During a vented explosion, however, some unburned material inside the process equipment will be released into the atmosphere.

TABLE 2. EXTERNAL PRESSURE AND DEFLAGRATION FLAME DISTANCE

Vessel volume m^3	Flame distance m	(ft)	External pressure barg	(psig)
5	3.4	11	0.046	0.67
5	17	56	0.009	0.13
10	4.3	14	0.055	0.80
10	21.3	70	0.011	0.16
50	7.3	24	0.083	1.20
50	36.9	121	0.017	0.25

Calculations based on: P_{stat} = 0.1 barg; P_{red} = 0.2 barg; K_{st} = 110 bar-m/s; P_{max} = 8.5 barg

Alternative protection strategy

When toxic materials are present, use explosion suppression in lieu of explosion venting. Explosion suppression maintains the vessel integrity and contains all products within the vessel, eliminating a toxic emission concern.

Inadequate surface area

There are situations in which the venting calculations result in extremely large vent-area requirements that are impractical to apply to the process equipment. Some examples of conditions when the relief area requirement may be impractical are as follows:

- The process material has a high K_{st} or is a hybrid mixture (dust and gas)
- Low P_{red} values are required to maintain vessel integrity
- Vent panels with a relatively high density (mass per unit area greater than 2.5 lb/ft^2) also exhibit relatively higher inertia and, thus, require greater vent relief area to achieve equivalent P_{red} values. To compensate for the slower opening inherent to vents with a larger mass, the vent area needs to be increased comparatively more to achieve the same P_{red} (Table 4).

In those scenarios where the required vent area is impractical, NFPA 68 Section 5.6.10 suggests that lesser venting will at least reduce the potential damage; however, other protection and prevention methods must then be considered (refer to NFPA 69).

Alternative protection strategies

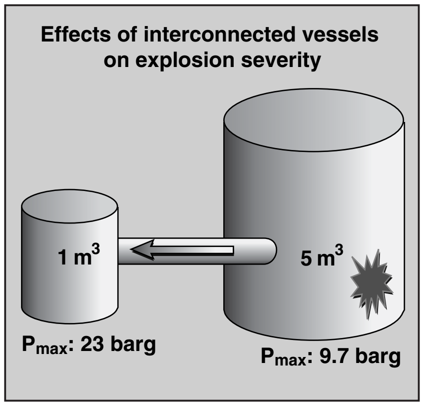

FIGURE 3. As indicated in Table 3, if vessels are interconnected (whether vented or not) during a deflagration the flame and pressure, effects will be exaggerated in both vessels, resulting in inappropriately sized explosion vents

TABLE 3. EFFECTS OF INTERCONNECTED VESSELS ON EXPLOSION SEVERITY (*2*)

Vessel volume, m^3	P_{max}, barg	dp/dt, bar/s
Separate vessels:		
1	7.4	55
5	7.4	32
Interconnected vessels:		
1	23	10,000
5	9.7	645

TABLE 4. EFFECT OF VENT MASS ON SAFE DEFLAGRATION PRESSURE (*3*)

Vent mass		Vent response time	Reduced pressure (P_{red})
lb/ft^2	kg/m^2	m-sec	m-bar
0.073	0.356	14.5	156
0.68	3.32	31.0	199
2.29	11.17	42.6	235
4.26	20.79	54.0	314

Calculations based on:
Vessel volume = $2.6m^3$; Pstat = 0.1 barg;
5% Propane; Vent relief area = 6 ft^2

- Use explosion suppression in lieu of explosion venting. The area required to mount explosion suppression hardware is minimal compared to the explosion vent area
- Reinforce the process equipment to increase the design strength, which will allow for a smaller explosion vent area
- Use venting devices that are 100% efficiency rated (have a mass per unit exposed-surface area less than 2.5 lb/ft^2). If a hinged vent closure (door) is used, be sure to obtain the tested venting-efficiency percentage

PREVENTING EXPLOSIONS IN CPI FACILITIES

Industrial processes will experience an explosion if all four of the following conditions exist:

1. The suspended-fuel concentration is within the flammable range — below the upper explosive limit (UEL) and above the lower explosive limit (LEL)
2. The oxidant (usually air) concentration is sufficient to support combustion
3. An ignition source is present
4. The immediate environment is contained within an enclosure, such as process equipment or a building

Preventive strategies seek to eliminate at least one of these conditions. Unfortunately, conditions 1 (fuel), 2 (oxidant), and 4 (enclosure) are inherently present in many CPI processes during normal operations. The primary preventative strategy comes down to eliminating potential contact with ignition sources.

Ultimately, it is impossible to guarantee that all ignition sources have been identified and prevented. A study [*1*] of dust explosions over a ten-year period identified the ignition sources to include over a dozen different types including these: mechanical sparks, machinery friction, welding, flames, electrical, spontaneous ignition, and electrostatic discharges. ❒.

Obstruction to vent area

There may be obstructions to the explosion-vent relief, either internally to the enclosure (such as dust-collector-bag cages) or externally to the unit (such as duct screens, adjacent equipment, and walkways), which need to be considered.

Dust-collector-bag cages or cartridges can interfere with the venting process. There are essentially two areas where vents can be located as recommended by NFPA 68, Section 7.8:

- The explosion vents should ideally be located entirely below the filters. If this is accomplished, then the bag volume can be subtracted from the volume used for relief area calculations. Unfortunately, most dust collector designs do not provide a space below the bags where the vents can be located (refer to NFPA 68, Figure 7.8.1(a))
- So, the next best positioning is for the bottom of the explosion vent to be no higher than the bottom of the bags as shown in NFPA 68, Figure 7.8.1(b)

Another common obstruction arises from terminating the duct with a screen to prevent the entrance of birds, animals, or debris. This obstruction can reduce the venting efficiency if the "blockage" (surface area of the screen) is greater than 15% of the explosion-vent area.

Even equipment adjacent to or near the protected equipment can sometimes affect the performance of the explosion vent. The explosion vent should be able to fully open without contacting handrails, walkways, or other equipment.

Alternative protection strategies

When obstructions to the vent area are potentially of concern, consider one of the following:

- Mount the explosion vent on the vessel in a location ensuring that the vent is not internally or externally obstructed
- Use explosion suppression in lieu of explosion venting if unobstructed venting is not an option

When explosion venting is applied correctly, it is one of the best responsive strategies to economically and safely protect your personnel, facility, and company profitability. Be safe — the right way. ■

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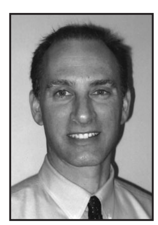
References

1. FM Global, Property Loss Prevention Data Sheet 7-76.
2. Bartknecht, W., "Dust Explosions: Course, prevention protection," Springer-Verlag, 1989.
3. NFPA 68, Guide for Venting of Deflagrations Table 5.6.14.1.

Author



Ralph Foiles is the president of Process Protection Inc. (16134 W 80th St., Lenexa, KS 66219; Phone: 913-481-2587; Fax: 800-760-3987; Email: rfoiles@processprotection.net; Web: www.processprotection.net). Ralph holds a B.S. in chemical engineering from the University of Kansas. He has over 15 years experience in the explosion protection industry, specifically involving hazard evaluation, solution design, code compliance and training seminars. Past positions include product manager, sales manager, and business development manager. He is an AIChE and NFPA member. He also is a frequent presenter at industrial conferences.

Process Protection Inc.

Comprehensive Explosion Protection Solutions
Evaluation | Design | Procurement | Compliance

PPI - a team of professionals with over twenty years of experience in the explosion protection industry; a single source for your industrial explosion protection needs.

We have designed over 500 explosion protection solutions in a variety of industries.

WHAT WE DO

Evaluation

A process or equipment hazard evaluation provides an assessment of the hazard potential and explosion risk for dust or gas handling processes. These evaluations can be performed on existing installations or processes that are in the design phase. Product testing can be conducted as part of the evaluation to quantify explosion risks and assist with the explosion protection design.

Design

Explosion Protection is a very specialized field. Utilizing our expertise to design explosion protection solutions will allow your engineering and operations team to focus on their core competency instead of trying to understand ours. Accessing our experience ensures that you will receive the most effective and economical results.

Procurement

These solutions incorporate all available explosion protection technology; not limiting the design to a single approach assures the correct solution is identified. Continually seeking out new technology and innovative products, as well as evaluating manufacturer performance, positions us to offer the most effective and advanced products, including:

- venting and flameless venting
- suppression
- deflagration/detonation arrestors
- mechanical and chemical isolation
- spark detection and inerting systems

Compliance

Protection strategies are designed in accordance with NFPA and FM Global standards and codes. Compliance reviews can also be conducted on new or existing processes. Compliance with these codes can often help reduce insurance rates.

HOW WE DO IT

Solution Support

Solution support can include any one or all of the following: hazard evaluation and testing, solution design, hardware procurement and system implementation.

Facility and Process Audits

Complete facility or single process reviews can be conducted on a one-time or regularly scheduled basis.

Contract Solution Support

As a contracted part of your team, PPI will serve as an on call explosion protection expert; providing advisory information, design support on projects and a resource for explosion protection information.

Training

Comprehensive education programs are offered through area seminars or customized in-plant training; including topics such as explosion fundamentals, protection strategies and code compliance.

Process Protection Inc.
16134 W 80th Street, Lenexa, Kansas 66219 phone: 913-481-2587
fax: 800-760-3987 website: www.processprotection.net