Step 2. Find the partial volume vent area for this application as follows:

N **[A.8.4.2b]**

$$A_{v4} = (1.48)\cdot(0.333)^{-0.333}\cdot\sqrt{\frac{(0.333-0.050)}{1-0.050}} = 1.16\ \text{m}^2$$

Step 3. Install vent panels with a total vent area of at least 1.16 m^2 on the conical lower section of the dryer.

A.8.4.3.3.3 The approximate surface density, $\bar{M}/A$, corresponding to these assumed values is 950 g/m^2.

•

Δ **A.8.5** The flow resistance coefficient K for the vent duct correlation is defined on the static pressure drop, ΔP, from the enclosure to the duct exit at a given average duct flow velocity, U:

N **[A.8.5a]**

$$K \equiv \frac{\Delta P}{\frac{1}{2}\cdot\rho\cdot U^2}$$

Another convention used by some reference books is to define K on the total pressure drop or on another velocity scale. The user should ensure that the loss coefficients used in the calculations are consistent with the definition of K adopted for the vent duct calculations. See Ural [114] for additional information.

The user should note that inlet loss can vary depending on the shape of the vent closure attachment to the vessel; however, most typically a flush inlet would be appropriate. Figure A.8.5(a) shows the loss coefficient for two different inlet designs as well as a plain duct outlet. Rain hats or other outlet covers provide additional resistance as in Figure A.8.5(d).

Figure A.8.5(b) shows a round elbow and loss coefficients for various radii of curvature. Figure A.8.5(c) shows a rectangular elbow and loss coefficients for various duct aspect ratios and radii of curvature. Loss coefficients for 45 degree bends and 30 degree bends are proportionally less than the tabulated 90 degree bends. Figure A.8.5(d) provides loss coefficients for a typical rain hat design. [123]

The equations are nonlinear and, under certain combinations of input values, result in two possible solutions for vent area for a given P_{red}. The lower value of vent area is the meaningful solution, and the upper value is an artifact of the form of the equation set. There are certain combinations of P_{red} and vent duct length where no vent area is large enough and no solution is obtainable. When that occurs, it could be possible to vary P_{red} or vent duct length to converge to a solution. If that solution is not satisfactory, NFPA 69 can provide alternatives.

There is a minimum value for P_{red} as vent area increases, beyond which solutions are not meaningful. That value occurs approximately when the volume of the duct exceeds a fraction of the volume of the vessel. When solving the equations, constraining A_{vf} as follows will typically isolate the smaller root:

N **[A.8.5b]**

$$\frac{A_{vf}\cdot L}{V} \le 1$$

For the following input values, Figure A.8.5(e) illustrates the potential solutions:

V = 500 m^3

P_{max} = 8.5 bar-g

K_{St} = 150 bar-m/s

P_{stat} = 0.05 bar-g

P_{red} = 0.5 bar-g

Vessel L/D = 4

ε = 0.26 mm

Straight duct, no elbows, fittings, or rain hats.

Example problem. Given Figure A.8.5(f) and the following conditions, calculate P_{red}:

Enclosure volume, V = 25 (m^3)

Enclosure L/D = 4

Vent diameter, D_v = 1.5 (m)

Duct diameter, D_h = 1.5 (m)

A_v = 1.77 (m^2)

P_{stat} = 0.25 (bar-g)

K_{St} = 200 (bar-m/s)

P_{max} = 8 (bar-g)

Duct length = 12 (m)

Duct effective roughness, ε = 0.26 (mm)

Elbows = 2 × 90 degrees, long radius (R/D = 1.5)

Elbow flow resistance = 2 × 0.39 = 0.78 [see Figure A.8.5(b)]

Rain hat flow resistance = 0.73 [H = 0.5D, see Figure A.8.5(d)]

While Section 8.5 provides the equations in a form to calculate the vent area based on an allowable P_{red}, this example shows how to determine the resulting P_{red} for a given vent area. In general, such calculations will be iterative. These input parameters are provided for demonstration purposes. Ural [114] can be referenced for additional discussion on how they were selected.

Solution:

(1) Compute the friction factor for the problem. For practically all vent ducts, the Reynolds number is so large that a fully turbulent flow regime will be applicable. In this regime, the friction factor is only a function of the ratio of the internal duct surface effective roughness (ε) to duct diameter. The duct friction factor can thus be calculated using a simplified form of the Colebrook equation:

[A.8.5c]

$$f_D = \left\{\frac{1}{\left[1.14 - 2\log_{10}\left(\frac{\varepsilon}{D_h}\right)\right]}\right\}^2$$

The effective roughness for smooth pipes and clean steel pipes is typically 0.0015 mm and 0.046 mm, respectively. Recognizing that the pipes used repeatedly in combustion events could be corroded, a value of Ɛ = 0.26 mm is assumed.
From Equation A.8.5c, $f_D = 0.013$:

Δ **[A.8.5d]**

$$\text{then } \frac{f_D \cdot L}{D_h} = \frac{0.013 \cdot 12}{1.5} = 0.107\text{, and}$$
$$K = K_{inlet} + \frac{f_D \cdot L}{D_h} + K_{elbows} + K_{outlet}$$
$$K = 1.5 + 0.107 + 0.78 + 0.73 = 3.117$$

where:
K = 3.117
K_{inlet} = 1.5 [static pressure loss for flush duct entry, see Figure A.8.5(a)]
K_{elbows} = 0.78
K_{outlet} = 0.73

(2) Assume a P_{red} value of 1 bar-g. The solution is iterative, where the assumed value of P_{red} is replaced with the calculated value of P_{red} until the two values substantially match. A 1 percent difference between iterations is typically considered acceptable convergence.

(3) From Equation 8.2.1.1:

[A.8.5e]

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left[1 + 1.54 \cdot (0.25)^{4/3}\right] \cdot 200 \cdot (25)^{3/4} \cdot \sqrt{\frac{8}{P_{red}} - 1}$$
$$A_{v0} = 0.735 \text{ m}^2$$

(4) From Equation 8.2.2.3:

[A.8.5f]

$$A_{v1} = 0.735 \cdot \left[1 + 0.6 \cdot (4-2)^{0.75} \cdot \exp(-0.95 \cdot P_{red}^2)\right]$$
$$A_{v1} = 1.02 \text{ m}^2$$

(5) From Equation 8.5.1b, and using the intended vent area of 1.77 m^2:

[A.8.5g]

$$E_1 = \frac{1.77 \cdot 12}{25}$$
$$E_1 = 0.85$$

(6) From Equation 8.5.1c, and using the installed vent area of 1.77 m^2:

[A.8.5h]

$$E_2 = \frac{10^4 \cdot 1.77}{\left[1 + 1.54 \cdot (0.25)^{4/3}\right] \cdot 200 \cdot (25)^{3/4}}$$
$$E_2 = 6.37$$

(7) From Equation 8.5.1a, with A_{v4} equal to A_{v1}, assuming no increase for turbulence, inertia, or partial volume:

N **[A.8.5i]**

$$A_{vf} = (1.02) \cdot \left[1 + 1.18 \cdot (0.85)^{0.8} \cdot (6.37)^{0.4}\right] \cdot \sqrt{\frac{3.117}{1.5}}$$
$$A_{vf} = 4.67 \text{ m}^2$$

(8) Because the calculated value of A_{vf} is not equal to the installed vent area, go back to Step 2, and change P_{red} until the A_{vf} calculated in Step 7 is equal to the specified vent area of 1.77 m^2. A trial-and-error process (or the goal seek button in Excel) satisfies the requirement in Step 8 when P_{red} = 2.72 bar-g.

(9) From 8.5.9, Equation A.8.5j and Equation A.8.5k show that there is no deflagration-to-detonation-transition (DDT) propensity for this particular application:

[A.8.5j]

$$L_{eff} \le \min\left[\frac{10{,}000 \cdot 1.5}{200}, \frac{11{,}000}{200}\right]$$
$$L_{eff} \le \min\,[75, 55]$$
$$\le 55$$

Δ **[A.8.5k]**

$$L_{dusty} = (8 - 2.723) \cdot \frac{25}{1.77}$$
$$= 74.5 \text{ m}$$

Because L_{duct} = 12 m, L_{eff} = min [12, 75] = 12 m ≤ 55 m. Therefore, DDT is not expected.

A.8.5.1 This solution of Equation 8.5.1a is iterative, because E_1 and E_2 are both functions of A_{vf}.

A.8.6.1.1 For deflagration venting accomplished by means of vent closures located in the sidewall of the enclosure, the closures should be distributed around the wall near the top.

A.8.6.3 In such cases, design and operating conditions (internal and external pressure, wind loads, and snow loads) can cause the mass of the roof to exceed that prescribed for deflagration vent closure.

A.8.7.1 A key assumption made for the three alternatives in 8.7.1 is that the clean air plenum above the tube sheet is essentially free of dust accumulations.

The prescription for determining the maximum flame length is not the same as in Chapter 6 for general enclosures. Private dust collector test data provided to the committee does not support the general approach for determining maximum flame path length based on vent location in these devices. Flame extension along the entire major axis, beyond the location of the vent, is presumed due to the filter elements providing a gas expansion path to the clean side of the collector.

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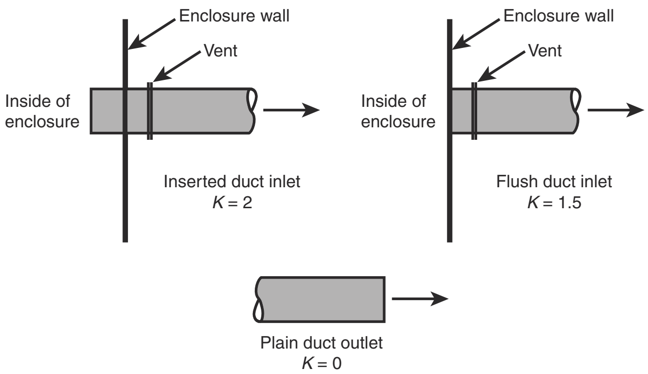
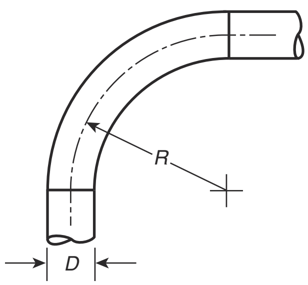
N **A.8.7.1.1** Where a dust collection system is constructed of multiple modules, each independently vented, the flame path length should be determined in each module.

N **A.8.7.1.2** Many flexible and rigid filter elements extend upstream from the tube sheet and retain dust on the outer surface. This section does not subtract the volume of such elements from the effective volume. Pocket filter elements extend downstream from the tube sheet and retain dust on

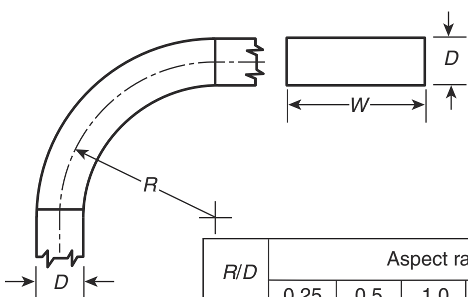


Δ **FIGURE A.8.5(a) Loss Coefficients for Inlets and Plain Duct Outlet.**



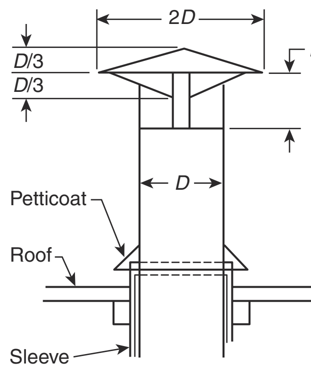
R/D	*K*
2.75	0.26
2.50	0.22
2.25	0.26
2.00	0.27
1.75	0.32
1.50	0.39

FIGURE A.8.5(b) Loss Coefficients for Round Elbows.



R/D	Aspect ratio, *W/D*					
	0.25	0.5	1.0	2.0	3.0	4.0
1.5	0.28	0.18	0.13	0.13	0.12	0.12
2.0	0.24	0.15	0.11	0.11	0.10	0.10
3.0	0.24	0.15	0.11	0.11	0.10	0.10

FIGURE A.8.5(c) Loss Coefficients for Square and Rectangular Elbows.



H No. of Diameters	*K*
1.0 D	0.10
0.75 D	0.18
0.70 D	0.22
0.65 D	0.30
0.60 D	0.41
0.55 D	0.56
0.50 D	0.73
0.45 D	1.0

FIGURE A.8.5(d) Loss Coefficients for Rain Hats.

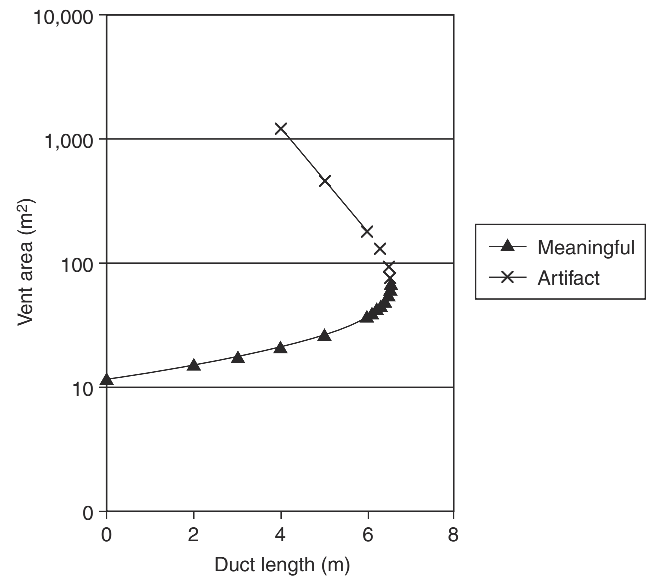


FIGURE A.8.5(e) A_v vs. Duct Length.

their inner surface. This section includes the volume of such elements in the effective volume.

N **A.8.7.2** Figure A.8.7.2(a) and Figure A.8.7.2(b) show situations for flexible filters where additional vent area is not required. Figure A.8.7.2(c) through Figure A.8.7.2(g) show situations for flexible filters where restraints effectively prevent obstruction of the vent and additional vent area is not required. Figure A.8.7.2(h) shows a situation for flexible filters in which the vent is located totally above the free end of the filter, restraints are not provided, and additional vent area is required.

A.8.8.1 A single-casing design has buckets moving both upward and downward within the same casing. A double casing design has one casing enclosing the buckets as they move upward and another casing enclosing the buckets as they move downward.

A.8.8.2 The boot of a bucket elevator is the inlet section at the lower elevation, while the head is the outlet section at the higher elevation.

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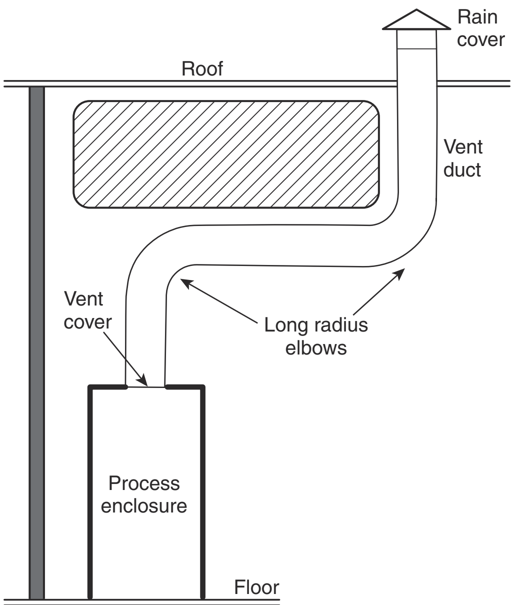
N **A.8.8.3.4** Changing from metal to plastic buckets has been demonstrated to increase the explosion pressures. For example, if designing a double-casing bucket elevator with plastic buckets for a K_{St} of 100–150 bar-m/s, and intending to space vents at no more than 10 m, then the enclosure strength should be based on a P_{red} of 0.5 × 1.35 = 0.68 bar-g.

A.8.8.3.5 The vent area can be located on the bucket face, the sides, or both as suitable for the installation.

A.8.8.4 P_{stat} should be as low as possible.

A.8.9 When dust deflagrations occur, there can be far more dust present than there is oxidant to burn it completely. When venting takes place, large amounts of unburned dust are vented from the enclosure, and burning continues as the dust mixes with additional air from the surrounding atmosphere. Consequently, a very large and long fireball of burning dust develops that can extend downward as well as upward. The average surface emissive power varies greatly between different types of dusts, with metal dusts tending to be much worse than, for example, agricultural dusts [112]. *(See also A.7.6.)*



Δ **FIGURE A.8.5(f) Example Vent Duct Installation.**

A.8.9.2 If the vented material exits from the vent horizontally, the horizontal length of the fireball is anticipated. It is extremely important to note that the fireball can, in fact, extend downward as well as upward [91, 108]. In some deflagrations, buoyancy effects can allow the fireball to rise to elevations well above the distances specified.

Equation 8.9.2 calculates the fireball dimension, but that is not the only factor to consider in evaluating the hazard from an emerging vented deflagration. Other factors to consider include, but are not limited to, environmental matters such as prevailing wind speed and direction, external nearby structures, particle size, vent configuration and weight, and nearby operations. A safety factor should be considered based on an assessment of the risk elements that are present in or near the anticipated path of travel of the emerging flame and unburned dust.

Equation 8.9.2 is based on Bartknecht [101] and also includes an adjustable value *K* that reflects the work of Holbrow et al. [112].

N **A.8.9.2.2** Higher panel inertia slows the panel deployment, extending the time during which the projected flame could be deflected off the vent axis direction. This effect can occur with, but is not limited to, one-petal panels with a hinge on one side or translating panels (no hinge). The deflection of the projected flame can be advantageous in some installations, such as directing the flame upwards, assuming upward is the safer venting direction. For hinged panels, the location of the hinge can thus be important. The deflected flame could extend with length equal to the full predicted flame length.

A.8.9.3 Estimates of external pressure effects for gas venting have been made using validated computational fluid dynamics models. A simpler methodology to estimate downstream external pressures for other situations and other locations is described in T. Forcier and R. Zalosh [116].

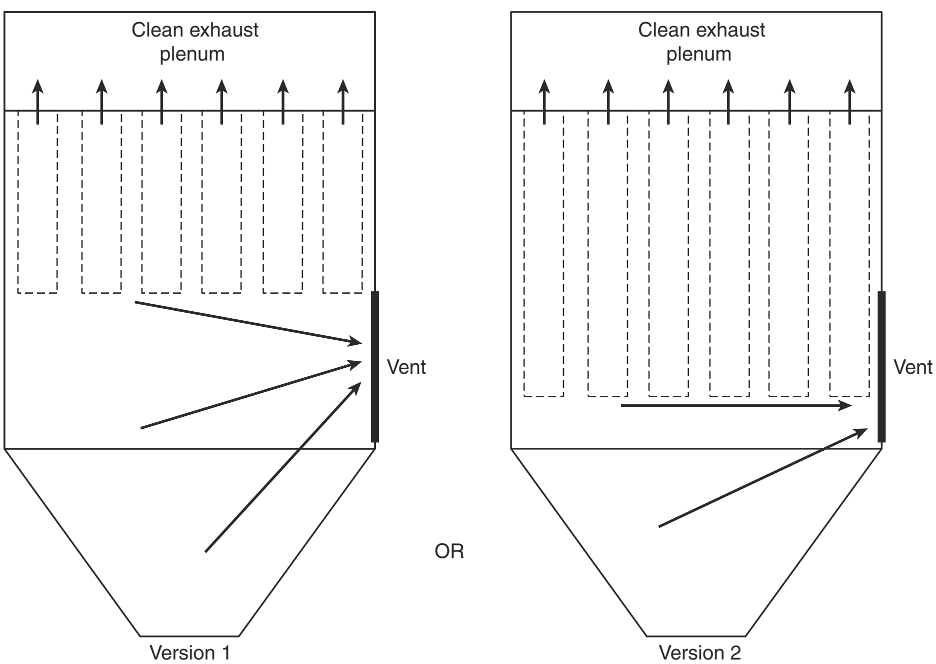
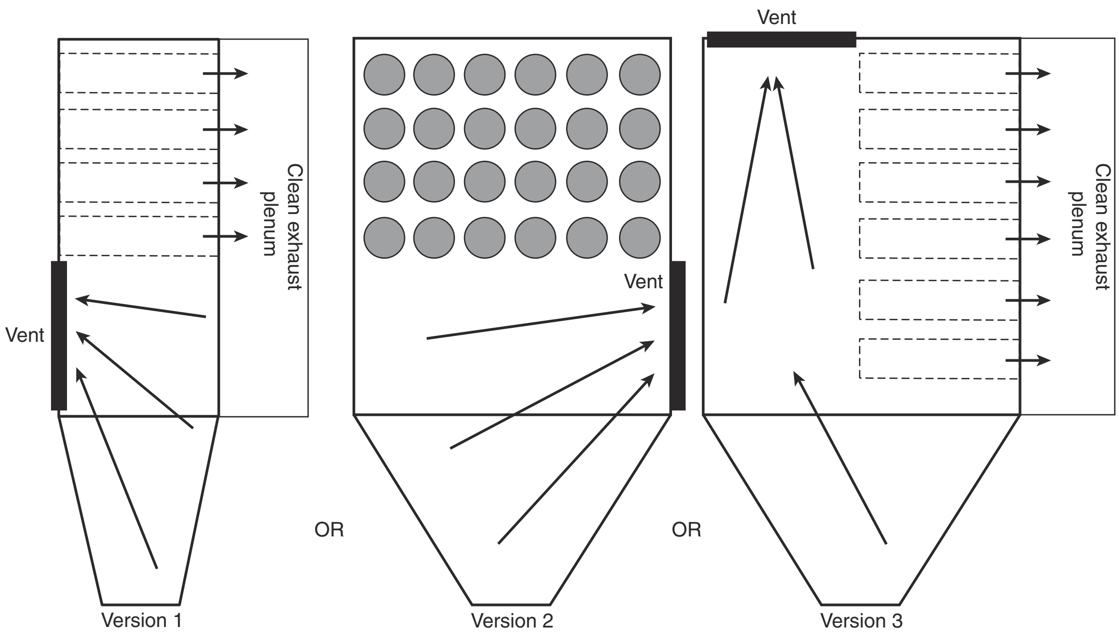


FIGURE A.8.7.2(a) Vertical Element — No Additional Vent Area.



Δ **FIGURE A.8.7.2(b) Horizontal Element — No Additional Vent Area.**

A.8.10 Even with complete extinguishment of flame, the immediate area surrounding the vent can experience overpressure and radiant energy. Venting indoors has an effect on the building that houses the protected equipment due to increased pressurization of the surrounding volume [110].

A.8.11 A bin vent is an air material separator attached to a larger storage vessel but not provided with a physical separation between the two. The collected dust is returned directly to the large storage vessel.

A.8.12 Interconnections between separate pieces of equipment present a special hazard. A typical case is two enclosures connected by a pipe. Ignition in one enclosure causes two effects in the second enclosure. Pressure development in the first enclosure forces gas through the connecting pipe into the second enclosure, resulting in an increase in both pressure and turbulence. The flame front is also forced through the pipe into the second enclosure, where it becomes a large ignition source. The overall effect depends on the relative sizes of the enclosures and the pipe, as well as on the length of the pipe. This phenomenon has been investigated by Bartknecht, who discovered that the effects can be significant. Pressures that develop in the pipeline itself can also be high, especially if a deflagration changes to a detonation. Where such interconnections are necessary, deflagration isolation devices should be considered, or the interconnections should be vented. Without successful isolation or venting of the interconnection, vent areas calculated based on the design described herein can be inadequate because of the creation of high rates of pressure rise [58, 66].

Equation 8.2.1.1 and Equation 8.2.2.3 can give insufficient vent area if a dust deflagration propagates from one vessel to another through a pipeline [98]. Increased turbulence, pressure piling, and broad-flame jet ignition result in increased deflagration violence. Such increased deflagration violence results in an elevated deflagration pressure that is higher than that used to calculate vent area in Equation 8.2.1.1 and Equation 8.2.2.3.

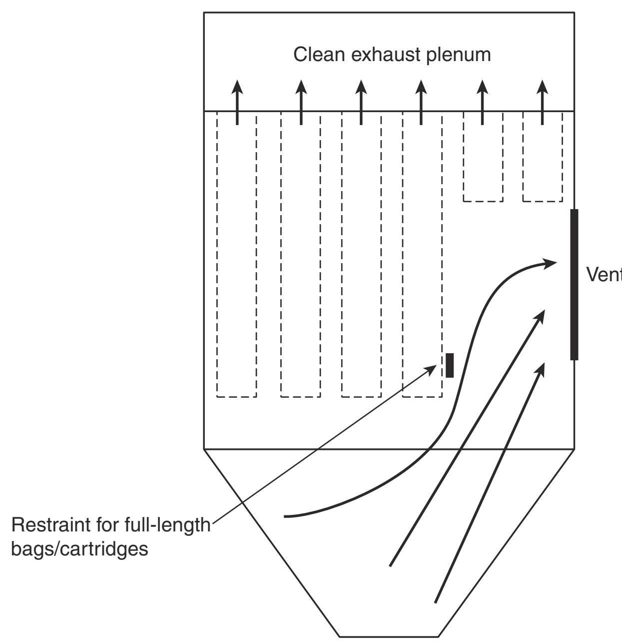


FIGURE A.8.7.2(c) Free Area Normal to Vent for Vertical Filter Elements — Side View — No Additional Vent Area.

Δ **A.8.12.1** Interconnecting pipelines with inside diameters greater than 0.3 m (1 ft) or longer than 6 m (20 ft) are not covered in this standard. Alternative protection measures can be found in Chapter 9 of this document and in NFPA 69.

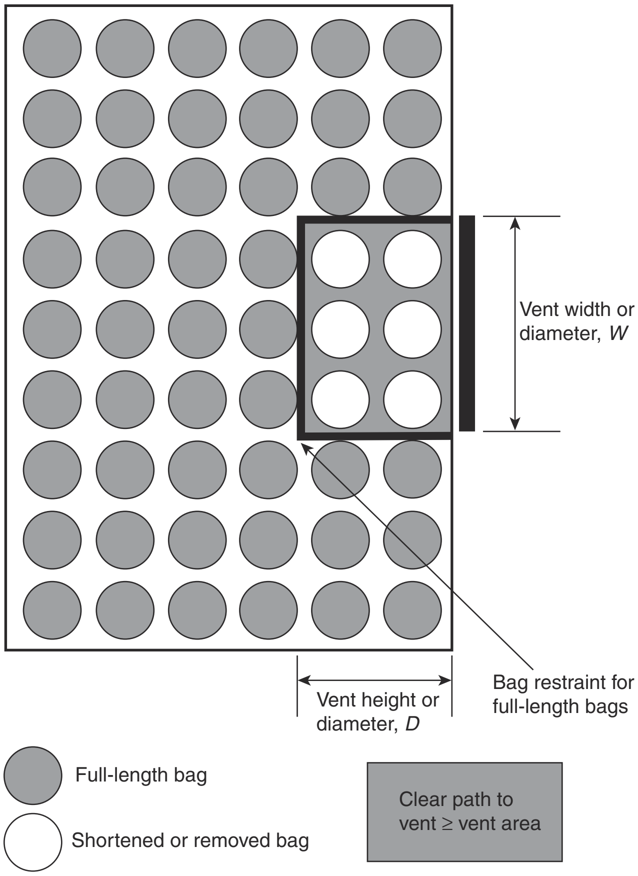


FIGURE A.8.7.2(d) Free Area Normal to Vent for Vertical Filter Elements — Plan View — No Additional Vent Area.

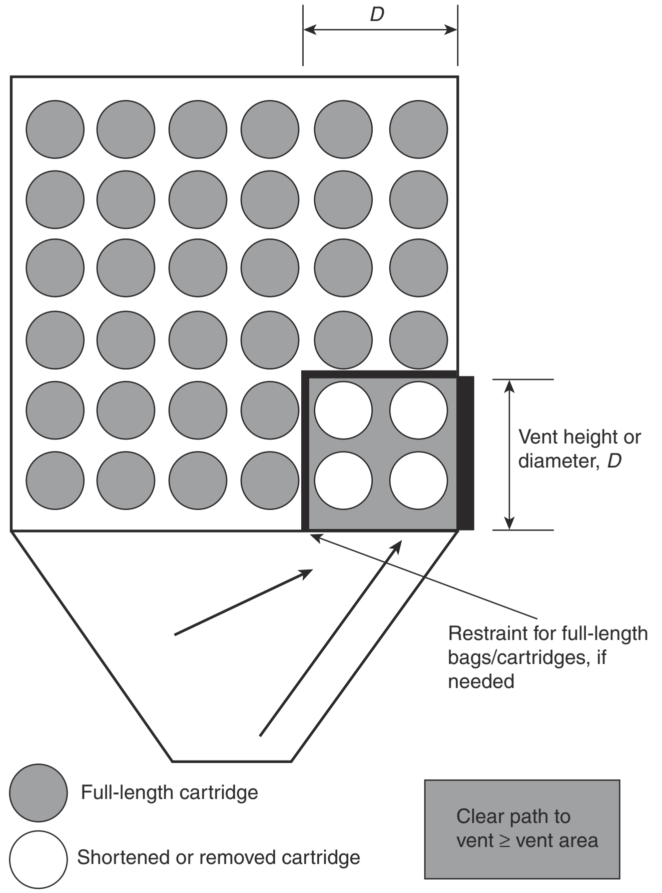


FIGURE A.8.7.2(e) Free Area Normal to Vent for Horizontal Filter Elements — Version 1, End View — No Additional Vent Area.

A.8.12.2 The subject of enhanced explosions in interconnected enclosures is addressed in the following references:

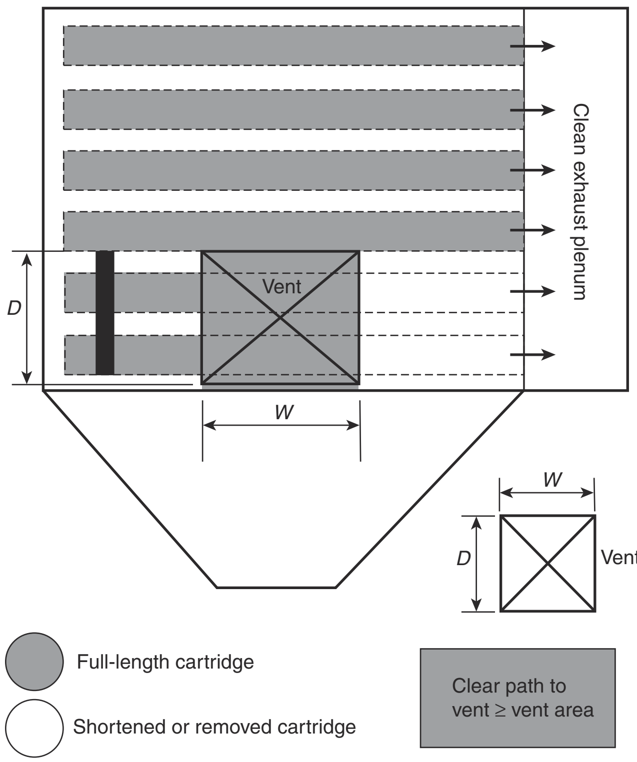
(1) Lunn, Holbrow, Andrews, and Gummer, "Dust Explosions in Totally Closed Interconnected Vessels"
(2) Holbrow, Lunn, and Tyldesley, "Dust explosion protection in linked vessels: Guidance for containment and venting"
(3) Holbrow, Andrews, and Lunn, "Dust explosions in interconnected vented vessels"
(4) Roser, "Investigation of dust explosion phenomenon in interconnected process vessels"
(5) Roser, Vogel, Radant, Malalasekera, and Parkin, "Investigations of flame front propagation between interconnected process vessels. Development of a new flame front propagation time prediction model"
(6) Moore and Senecal, "Industrial Explosion Protection — How Safe Is Your Process?" www.nfpa.org/assets/files/PDF/Foundation%20proceedings/Industrial_Explosion_Protection.pdf

Δ **A.9.1** Relatively little systematic test work is published on the design of deflagration venting for pipes and ducts. The guidelines in this chapter are based on information contained in Bartknecht [3, 68–76, 105, 106].

The use of deflagration venting on pipes or ducts cannot be relied on to stop flame front propagation in the pipe. Venting only provides relief of the pressures generated during a deflagration

Several factors make the problems associated with the design of deflagration vents for pipes and ducts different from those associated with the design of deflagration vents for ordinary vessels and enclosures. Such problems include the following:

(1) Deflagrations in pipes and ducts with large length-to-diameter (*L/D*) ratios can transition to detonations. Flame speed acceleration increases, and higher pressures are generated as *L/D* increases.
(2) Pipes and ducts frequently contain devices, such as valves, elbows, and fittings, or obstacles. Such devices cause turbulence and flame stretching that promote flame acceleration and increase pressure.
(3) Deflagrations that originate in a vessel precompress the combustible material in the pipe or duct and provide a strong flame front ignition of the combustible material in the pipe or duct. Both of these factors increase the severity of the deflagration and the possibility that a detonation will occur.



Δ FIGURE A.8.7.2(f) Free Area Normal to Vent for Horizontal Filter Elements — Version 1, Side View — No Additional Vent Area.

Wherever it is not possible to provide vents as recommended in this chapter, two alternative approaches can be employed as follows:

(1) Explosion prevention measures should be provided as described in NFPA 69.
(2) Piping or ducts should be designed to withstand detonation pressures and provide isolation devices to protect interconnected vessels. Systems that have a design pressure of 10 bar-g are acceptable for St-1 dusts.

A.9.2 *Example.* Deflagration vents should be provided for the ducts in the system shown in Figure A.9.2. The gas flow through the system is 100 m^3/min (3500 ft^3/min), and all ducts are 0.6 m (2 ft) in diameter. The maximum allowable working pressure for the ducts and equipment is 0.2 bar-g (3 psig), and the maximum operating pressure in the system is 0.05 bar-g (0.73 psig). The system handles an St-2 dust. It is further assumed that the dryer and the dust collector are equipped with adequate deflagration vents.

As recommended by 9.2.4, *A* should be located within two vent diameters of the dryer outlet and no more than three vent diameters upstream of the first elbow. *B* and *C* should be located three diameters distance upstream and downstream of the first elbow, as recommended in 9.2.5. *F* should be located at a position approximately two diameters upstream of the dust collector inlet, based on 9.2.4.

Additional venting is needed for the 20 m (66 ft) section. The flow of 100 m^3/min corresponds to a velocity of 6 m/s (20 ft/s). Therefore, Figure 9.3.1 should be used. According to Figure 9.3.1, the vents should be placed at intervals no greater

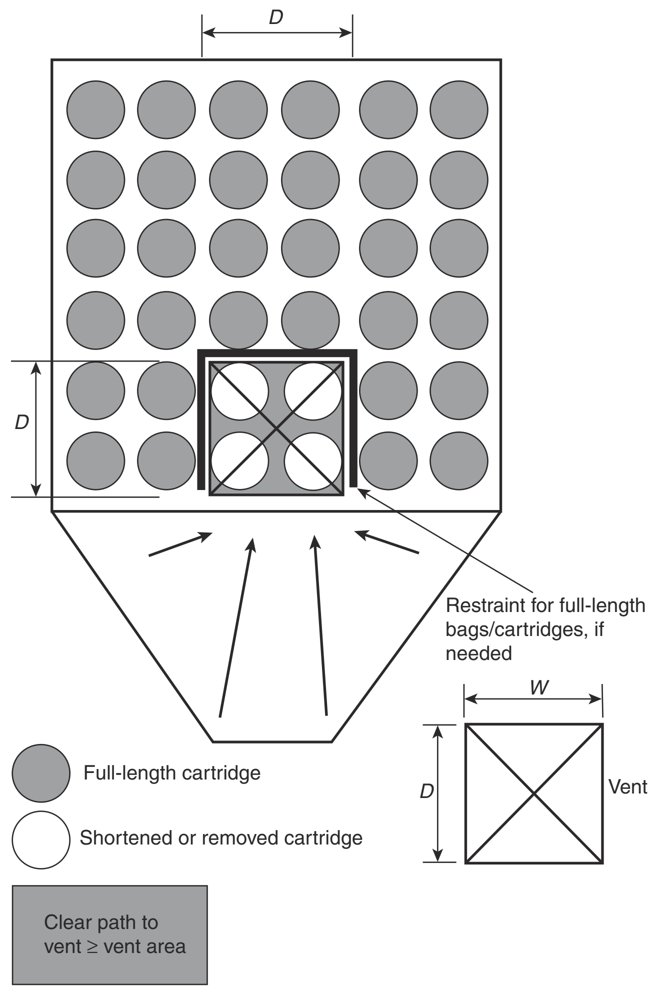


FIGURE A.8.7.2(g) Free Area Normal to Vent for Horizontal Filter Elements — Version 2, End View — No Additional Vent Area.

than 11 vent diameters, or approximately 6.5 m (21 ft), apart. The distance between vents *C* and *F* is 17.2 m (56 ft); therefore, two additional vents (*D* and *E*) at approximately equal spacing meet the need.

The total vent area at each vent location should be at least equal to the cross-sectional area of the duct. This results in a value of 0.2 bar-g (3 psig) for P_{red}. The vent release pressure should not exceed half P_{red} and, therefore, cannot exceed 0.1 bar-g (1.5 psig).

A.9.2.4 See Example in A.9.2.

A.9.2.9.2 The following problem illustrates the requirement in 9.2.9.2. A flare stack is 0.4 m (1.3 ft) in diameter by 40 m (130 ft) in height and is equipped with a water seal at its base. What should its design pressure be in order to protect it from the pressure developed by ignition of a fuel-air mixture that has properties similar to those of propane?

Check the maximum allowable length. From Figure 9.2.10.1, a maximum *L/D* of 28 is allowed. This stack has an *L/D* equal to 100. Therefore, it should be designed to withstand a detonation or should be protected by some other means.

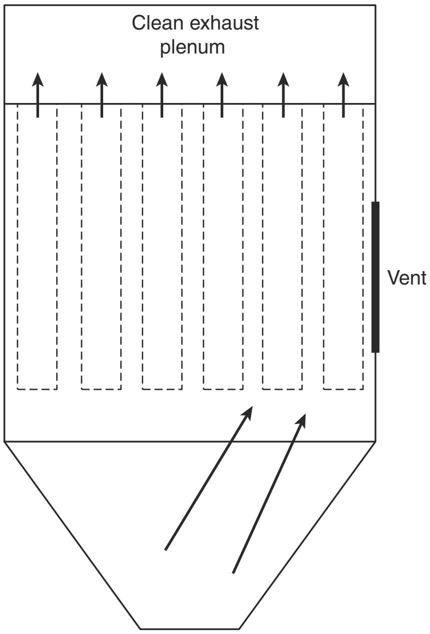


FIGURE A.8.7.2(h) Vertical Element — Additional Vent Area Required.

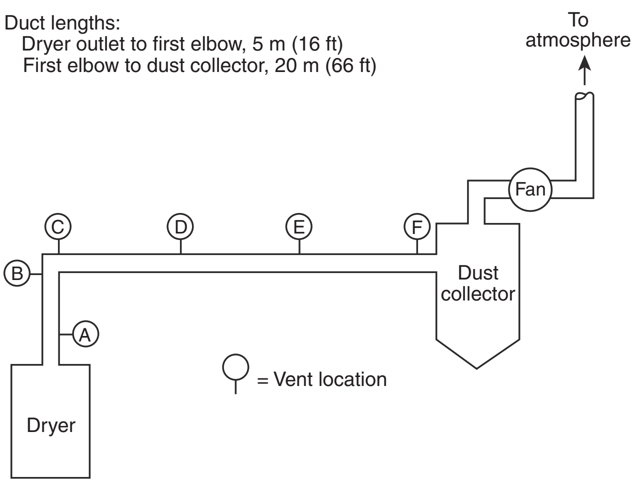


FIGURE A.9.2 Diagram for A.9.2 Example.

The distance necessary for a deflagration to transition into a detonation is described as a length-to-diameter ratio (*L/D* for detonation). The *L/D* is dependent on ignition source strength, combustible material, piping system geometry, roughness of pipe walls, and initial conditions within the pipe.

A.9.2.10.1 The curve identified as "Dusts with $K_{St} \leq 200$" in Figure 9.2.10.1 is based on Bjorklund and Ryason [75] for gasoline vapor deflagrations. The curve identified as "Propane, dusts with $K_{St} > 200$" in Figure 9.2.10.1 is obtained by reducing $(L/D)_{max}$ data for gasoline vapor by 50 percent [75]. Therefore, the Committee has exercised engineering judgment in adapting the data for use with dusts as well as gases.

If the length of a pipe or duct is greater than the *L/D* indicated in Figure 9.2.10.1, a single vent cannot provide enough vent area *(see Section 9.3)*. Figure 9.2.10.1 includes safety factors for typical long-radius elbow systems. While very few conveying pipes are either straight or smooth, Figure 9.2.10.1 can be used for most applications. It does not apply where conveying pipes have sharp elbows or orifice plates along their lengths.

A.9.2.10.2.2.1 The following problem illustrates the requirement in 9.2.10.2.2.1. A dryer that handles a dust whose K_{St} is 190 is 2 m (6.6 ft) in diameter and 20 m (65.6 ft) long and is designed with a single vent. What is the pressure that can occur during a vented explosion?

(1) *Maximum Allowable Length.* According to Figure 9.2.10.1, an *L/D* of approximately 25 is allowable. The dryer has an *L/D* of 10, so this is acceptable.
(2) *Maximum Pressure.* According to Figure 9.2.10.2.2.1, a pressure of approximately 0.5 bar-g (7.3 psig) develops in such dryer equipment by means of the deflagration of the specified dust. Therefore, the equipment should have a design pressure of at least this value.

A.9.3.1 The following problem illustrates the requirement in 9.3.1. A straight duct that is 1 m (3.3 ft) in diameter and 100 m (330 ft) long is to be protected by deflagration vents. It contains a hydrocarbon-air mixture that has properties similar to those of propane. The vent spacing needed to limit the deflagration pressure to 0.17 bar-g (2.5 psig), where the vents are designed to open at 0.05 bar-g (0.73 psig), must be determined. Figure 9.3.1 specifies that the vents should be placed no more than 7.6 m (25 ft) apart. To meet this requirement, a vent should be placed at each end, and 13 additional vents should be evenly spaced along the duct.

A.10.1 Openings fitted with fixed louvers can be considered as open vents. However, the construction of the louvers partially obstructs the opening, thus reducing the net free vent area. The obstruction presented by the louvers decreases the flow rate of gases that pass through the vent and increases the pressure drop across the vent.

A.10.3.2 Specially designed fasteners that fail, under low mechanical stress, to release a vent closure are commercially available, and some have been tested by listing or approval agencies.

A.10.3.2.2 Large panel closures that are installed on buildings or other large low-strength enclosures cannot be tested as a complete assembly.

A.10.4 Where the vent closure panel is a double-wall type (such as an insulated sandwich panel), single-wall metal vent panel restraint systems should not be used. The restraint system shown in Figure A.10.4(a) should be used for double-wall panels. The panel area should be limited to 3.1 m² (33 ft²), and its mass should be limited to 12.2 kg/m² (2.5 lb/ft²). Forged eyebolts should be used. Alternatively, a "U" bolt can be substituted for the forged eyebolt. A shock absorber device with a fail-safe tether should be provided.

The bar washer on the exterior of the panel should be oriented horizontally, should span the panel width (less 2 in. and any panel overlap), and should be attached to the panel with as many bolts as practical (i.e., at every panel flat for a corrugated panel). High-quality wire rope clips should be used to ensure the restraint system functions properly. It is noted that this panel restraint system was developed based on tests in which the peak enclosure pressure achieved was approximately 1 psig or less; hence, its performance at higher explosion pressures might not be reliable.

Where large, lightweight panels are used as vent closures, it is usually necessary to restrain the vent closures so that they do not become projectile hazards. The restraining method shown in Figure A.10.4(b) illustrates one method that is particularly suited for conventional single-wall metal panels. The key feature of the system includes a 50 mm (2 in.) wide, 10 gauge bar washer. The length of the bar is equal to the panel width, less 50 mm (2 in.) and less any overlap between panels. The bar washer–vent panel assembly is secured to the building structural frame using at least three 10 mm (3⁄8 in.) diameter through-bolts.

The restraining techniques shown are specific to their application and are intended only as examples. Each situation necessitates individual design. Any vent restraint design should be documented by the designer. No restraint for any vent closure should result in restricting the vent area. It is possible for a closure tether to become twisted and to then bind the vent to less than the full opening area of the vent.

The stiffness of the double-wall panel is much greater than that of a single-wall panel. The formation of the plastic hinge occurs more slowly, and the rotation of the panel can be incomplete. Both factors tend to delay or impede venting during a deflagration.

The component sizes indicated in Figure A.10.4(a) have been successfully tested for areas up to 3.1 m^2 (33 ft^2) and for mass of up to 12.2 kg/m^2 (2.5 lb/ft^2). Tests employing fewer than three rope clips have, in some instances, resulted in slippage of the tether through the rope clips, thus allowing the panel to become a free projectile.

The shock absorber is a thick, L-shaped piece of steel plate to which the tether is attached. During venting, the shock absorber forms a plastic hinge at the juncture in the "L," as the outstanding leg of the "L" rotates in an effort to follow the movement of the panel away from the structure. The rotation of the leg provides additional distance and time, over which the panel is decelerated while simultaneously dissipating some of the panel's kinetic energy.

The L-shaped shock absorber should be ductile annealed steel and designed for each venting application, such that it does not break. Stronger is not always better. The shock absorber is a one-time use item and should be replaced when the panel is replaced. The wire rope and other attachment items might also need replacement after use.

The panel should be replaced soon after an opening event. Wind will eventually fatigue the tether system and the dangling panel might fall to the ground.

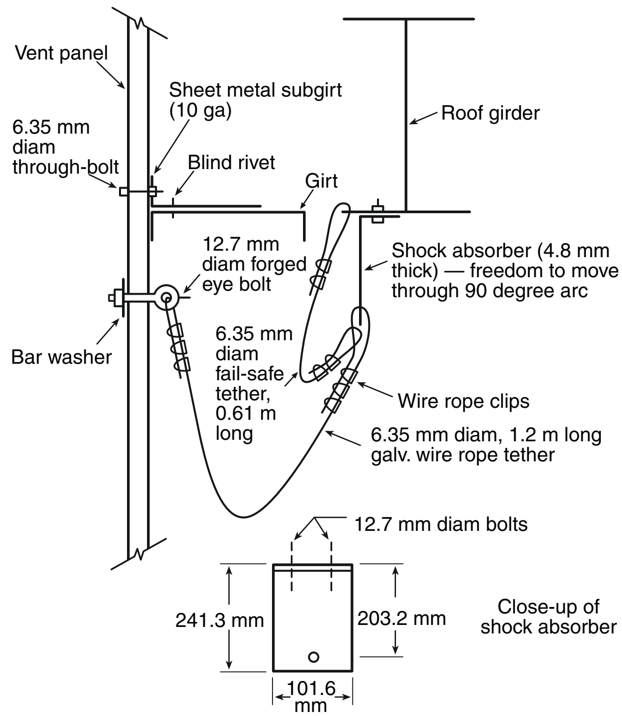


FIGURE A.10.4(a) An Example of a Restraint System for Double-Wall Insulated Metal Vent Panels.

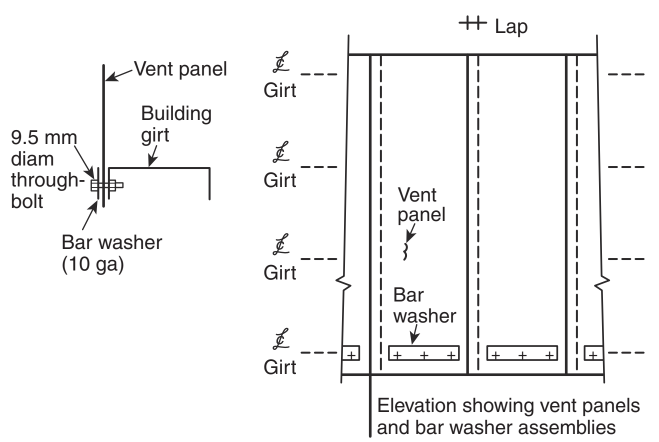


FIGURE A.10.4(b) An Example of a Restraint System for Single-Wall Metal Vent Panels.

A.10.5.1 Closures that are held shut with spring-loaded, magnetic, or friction latches are most frequently used for this form of protection.

A.10.5.1.1 It is important that hinges on hinged vent closures be capable of resisting the expected forces. If hinges are weak, if they are attached weakly, or if the door frame is weak, the vent closures can tear away in the course of venting a deflagration and become projectile hazards.

A.10.5.1.2 It is difficult to vent equipment of this type if the shell, drum, or enclosure revolves, turns, or vibrates.

A.10.5.1.6 If construction is strong, the vent closure can close rapidly after venting. This can result in a partial vacuum in the enclosure, which in turn can result in inward deformation of the enclosure.

Figure 10.5.1.6 shows the vacuum relief vent area, as a function of enclosure size, that is used to prevent the vacuum from exceeding the vacuum resistance of the enclosure, in millibars.

A.10.5.2 Rupture diaphragms can be designed in round, square, rectangular, or other shapes to effectively provide vent relief area to fit the available mounting space. *(See Figure A.10.5.2.)*

Some materials that are used as rupture diaphragms can balloon, tear away from the mounting frame, or otherwise open randomly, leaving the vent opening partially blocked on initial rupture. Although such restrictions can be momentary, delays of only a few milliseconds in relieving deflagrations of dusts or gases that have high rates of pressure rise can cause extensive damage to equipment.

A.11.2 A sample vent closure information form is shown in Figure A.11.2.

A.11.3.4 For symbols, placement, and layout, refer to ANSI Z535.4, *Product Safety Signs and Labels*.

A.11.4 A sample annual inspection form is shown in Figure A.11.4.

A.11.4.2 The frequency depends on the environmental and service conditions to which the devices are to be exposed. Process or occupancy changes that can introduce significant changes in condition, such as changes in the severity of corrosive conditions or increases in the accumulation of deposits or debris, can necessitate more frequent inspection. It is recommended that an inspection be conducted after a process maintenance turnaround. Inspections should also be conducted following any natural event that can adversely affect the operation and the relief path of a vent closure (e.g., hurricanes or snow and ice accumulations).

A.11.6 The vent closure design parameters can include the following items, among others:

(1) Manufacturer
(2) Model number
(3) Identification number
(4) Location
(5) Size
(6) Type
(7) Opening pressure
(8) Panel weight
(9) Material(s)

A.11.9.2 It is recommended that changes be reviewed with life safety system and equipment suppliers.

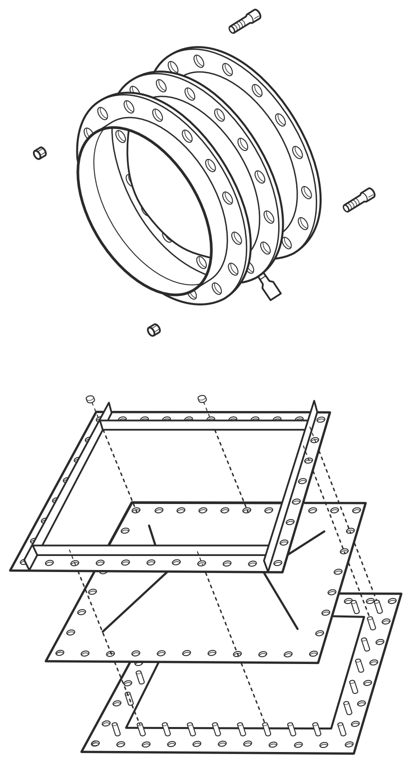


FIGURE A.10.5.2 Typical Rupture Diaphragm.