

NFPA® 68

Standard on Explosion Protection by Deflagration Venting

2023 Edition



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NFPA® 68

Standard on

Explosion Protection by Deflagration Venting

2023 Edition

This edition of NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, was prepared by the Technical Committee on Explosion Protection Systems. It was issued by the Standards Council on November 29, 2022, with an effective date of December 19, 2022, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See “Codes & Standards” at www.nfpa.org for more information.

This edition of NFPA 68 was approved as an American National Standard on December 19, 2022.

Origin and Development of NFPA 68

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, started out as a tentative standard in 1945, titled NFPA 68T, *Explosion Venting Standard*. In 1954, the temporary standard was replaced with NFPA 68, *Guide for Explosion Venting*, which brought together all the best available information on the fundamentals and parameters of explosions, the data developed by small-scale tests, the interpretation of the results of those tests, and the use of vents and vent closures that were current at the time. The information was then related to “rules of thumb” vent ratio recommendations, which were used for many years. Some of the vents that were designed using those rules of thumb functioned well, while others were never put to the test.

Beginning in 1954, extensive experimentation was carried out in Great Britain and Germany and added to the existing information. The U.S. Bureau of Mines also did some work in this area. However, the work was not completed because the group involved was reassigned to different programs.

In 1974, NFPA 68 was revised, and the work done in Great Britain and Germany was included with the hope that the new information would provide a means for calculating vent ratios with a greater degree of accuracy than that provided by the rules of thumb. The 1978 revision included substantial data that were more valuable in designing explosion relief vents.

In 1979, the committee began a major effort to rewrite the guide in order to incorporate the results of the test work done in Germany. In addition, the 1988 edition, titled *Guide for Venting of Deflagrations*, contained rewritten text that more clearly explained the various parameters that affect the venting of deflagrations.

The 1994 edition of NFPA 68 was completely rewritten to more clearly explain the principles of venting deflagrations. Revisions to each chapter improved the organization of information within the document without changing the venting methodology. The thrust of this revision was to improve the user friendliness and adoptability of the guide and to clarify this complex technology.

The 1998 edition introduced updated terminology to be consistent with current industrial practice. New information was added on the effects of vent ducts, calculation methods for evaluating those effects, and the effects of vent discharge. The revision also incorporated the “weak roof-to-shell” joint design as a means of venting silos and bins and provided new information on explosions in elongated vessels. It also clarified the provisions for securing restraint panels.

The 2002 edition represented a complete revision of the guide and included updated and enhanced treatment for deflagration venting design for dusts and hybrid mixtures. The revision also included new vent design equations based upon the methodology developed by Factory Mutual Research Corporation. In addition to the generalized correlation for dusts were new methods to evaluate the effects of vent ducts, partial volumes, vent panel inertia, and initially elevated pressures.

All design guidelines for gas mixtures were combined into a single chapter, and the document was revised in accordance with the NFPA *Manual of Style for NFPA Technical Committee Documents*.

The 2007 edition represented a complete revision, including a change from guide to standard. The new standard, titled *Standard on Explosion Protection by Deflagration Venting*, provided mandatory requirements for the design, location, installation, maintenance, and use of devices and systems to vent combustion gases and pressures from deflagrations.

The Committee incorporated a new chapter on performance-based design that enabled users to present alternative design methods to satisfy the requirements for gas and mist mixtures, for dusts, and for hybrid mixtures. The Committee also revised the generalized correlation for dusts on the basis of a review of additional experimental data. That review enabled the Committee to support revisions to the basic equation, along with changes to the equations for low-inertia vent closures, panel inertia, partial volume, initially elevated pressures, and vent ducts. The Committee also added a new chapter on inspection and maintenance.

The 2013 edition introduced a revised calculation method for venting of deflagrations of gas mixtures. The chapter on venting of deflagrations in dust mixtures was revised to address differences between translating vent panels and hinged vent panels, to permit sub atmospheric initial pressures, and to incorporate new research on the entrainment of accumulated dust in a building. New sections addressed bucket elevators and grain silos, and new annex material provided guidance on designing vent ducts and estimating the fundamental burning velocity of a fuel.

In the 2018 edition, a requirement was added to adjust the K_{St} values for certain metal dusts if the K_{St} value was obtained in a vessel smaller than 1 m³. An equation was added to determine the hydraulic diameter for rectangular enclosures. The chapter on venting gas mixture and mist deflagrations was reorganized to clarify the order and applicability of the various adjustments and corrections to required vent area. A new annex was added to implement the equations and calculation procedures, including partial volume effects. The requirements for determining K_G were replaced with requirements for determining P_{max} , and the equations to determine the turbulent flame enhancement factor were revised.

The chapter on venting dust and hybrid mixture deflagrations was also reorganized in order of intended execution. The equation for determining the vent area for elevated or subatmospheric pressure was revised, and an example calculation was added to the annex. The method of determining enclosure volume for dust collectors was revised, and a definition for *flexible filter* was added. Requirements for the use of plastic buckets in bucket elevators were moved from the annex to the body of the standard.

For the 2023 edition, the fireball and hazard distance requirements for gases and dusts have been combined and moved into Chapter 6 for consistency in application. The partial volume calculations for both gases and dusts have been revised to account for solid objects reducing the open-air volume available for mixing and to account for possible dust concentrations below the worst case concentrations. The fundamental burning velocity values in the annex have been updated based on current available data, and an annex on vent sizing for hydrogen mixtures has been added.

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Standard on

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Information on referenced publications can be found in Chapter 2 and Annexes H, L, and M.

Chapter 1 Administration

1.1* Scope. This standard applies to the design, location, installation, maintenance, and use of devices and systems that vent the combustion gases and pressures resulting from a deflagration within an enclosure so that structural and mechanical damage is minimized.

1.2* Purpose. The purpose of this standard is to provide the user with criteria for design, installation, and maintenance of deflagration vents and associated components.

1.3* Application. This standard applies where the need for deflagration venting has been established.

1.3.1 This standard does not apply to detonations, bulk auto-ignition of gases, or unconfined deflagrations, such as open-air or vapor cloud explosions.

1.3.2* This standard does not apply to devices that are designed to protect storage vessels against excess internal pressure due to external fire exposure or to exposure to other heat sources.

1.3.3 This standard does not apply to emergency vents for pressure generated during runaway exothermic reactions, self-decomposition reactions, internal vapor generation resulting from electrical faults, or pressure generation mechanisms other than deflagration.

1.3.4 This standard does not apply to venting of deflagrations in oxygen-enriched atmospheres or other oxidants unless supported by specific test data.

1.4 Retroactivity.

1.4.1 The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.1.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.1.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.4.2 This standard shall apply to facilities on which construction is begun subsequent to the date of publication of the standard.

1.4.3 When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1.5 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.6 Conversion Factors. The conversion factors in Table 1.6 are useful for understanding the data presented in this standard.

Table 1.6 Conversion Factors

Parameter	Unit	Equivalent
Length	1 m	3.28 ft 39.4 in.
	1 in.	25.4 mm
	1 ft	305 mm
	1 μm	1.00×10^{-6} m
Area	1 m ²	10.8 ft ²
	1 in. ²	6.45 cm ²
Volume	1 L	61.0 in. ³
	1 ft ³	7.48 U.S. gal
	1 m ³	35.3 ft ³ 264 U.S. gal
	1 U.S. gal	3.78 L 231 in. ³ 0.134 ft ³
Pressure	1 atm	760 mm Hg 101 kPa 14.7 psi 1.01 bar
	1 psi	6.89 kPa
	1 N/m ²	1.00 Pa
	1 bar	100 kPa 14.5 psi 0.987 atm
	1 kg/cm ²	14.2 psi
	1 kg/m ²	0.205 lb/ft ² (psf)
	1 J	1.00 W-s
	1 Btu	1055 J
	1 J	0.738 ft-lb
	1 bar-m/s	47.6 psi-ft/s
K_{St} conversion	1 psi-ft/s	0.021 bar-m/s
	1 oz	1000 g/m ³
Concentration	avoirdupois/ft ³	

Key to abbreviations:

atm = atmosphere
 Btu = British thermal unit
 cm = centimeter
 ft = foot
 g = gram
 gal = gallon
 Hg = mercury
 in. = inch
 J = joule
 kg = kilogram
 kPa = kilopascal
 L = liter
 lb = pound
 m = meter
 mm = millimeter
 N = newton
 oz = ounce
 Pa = pascal
 psf = pounds per square foot
 psi = pounds per square inch
 s = second
 W = watt
 μm = micron (micrometer)

1.7 Symbols. The following symbols are defined for the purpose of this standard:

A = area (m², ft², or in.²)
 A_s = internal surface area of enclosure (m² or ft²)
 A_v = vent area (m² or ft²)
 C = constant used in venting equations as defined in each specific use
 dP/dt = rate of pressure rise (bar/s or psi/s)
 F_r = reaction force constant (lb)
 K_{St} = deflagration index for dusts (bar-m/s)
 L_n = linear dimension of enclosure [m or ft ($n = 1, 2, 3$)]
 L_x = distance between adjacent vents
 L/D = length to diameter ratio (dimensionless)
 LFL = lower flammable limit (percent by volume for gases, weight per volume for dusts and mists)
 MEC = minimum explosible concentration (g/m³ or oz/ft³)
 MIE = minimum ignition energy (mJ)
 p = perimeter of duct cross-section (m or ft)
 P = pressure (bar-g or psig)
 P_{es} = enclosure strength (bar-g or psig)
 P_{ex} = explosion pressure (bar-g or psig)
 P_{max} = maximum pressure developed in an unvented vessel (bar-g or psig)
 P_0 = initial pressure (bar-g or psig)
 P_{red} = reduced pressure [i.e., maximum pressure actually developed during a vented deflagration (bar-g or psig)]
 P_{stat} = static activation pressure (bar-g or psig)
 dP = pressure differential (bar or psi)
 S_u = fundamental burning velocity (cm/s)
 S_f = flame speed (cm/s)
 t_f = duration of pressure pulse (s)
 UFL = upper flammable limit (percent by volume)
 V = volume (m³ or ft³)

1.8 Pressure. All pressures are gauge pressure unless otherwise specified.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 69, *Standard on Explosion Prevention Systems*, 2019 edition.

NFPA 70®, *National Electrical Code*®, 2023 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2020 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2022 edition.

2.3 Other Publications.

2.3.1 API Publications. American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001-5571.

API STD 650, *Welded Tanks for Oil Storage*, 13th edition, 2020.

2.3.2 ASME Publications. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, 2021.

2.3.3 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2019.

2.3.4 ISO Publications. International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

ISO 6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dust in air*, 1985.

2.3.5 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

▲ 2.4 References for Extracts in Mandatory Sections.

NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, 2021 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, 2019 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of

products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. An NFPA **standard**, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA **manuals of style**. When used in a generic sense, such as in the phrases “standards development process” or “standards development activities,” the term “standards” includes all NFPA **standards**, including **codes**, **standards**, **recommended practices**, and **guides**.

3.3 General Definitions.

3.3.1 Burning Velocity. The rate of flame propagation relative to the velocity of the unburned gas that is ahead of it.

3.3.1.1 Fundamental Burning Velocity. The burning velocity of a laminar flame under stated conditions of composition, temperature, and pressure of the unburned gas.

▲ **3.3.2 Combustible Dust.** A finely divided combustible particulate solid, **including combustible fibers/flyings**, that presents a flash-fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. [652, 2019]

3.3.3 Combustion. A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame.

3.3.4 Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.

3.3.5 Deflagration Index. Value indicated by the use of the variable *K*. (See 3.3.20, *K_{st}*.)

3.3.6 Detonation. Propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium.

3.3.7* Enclosure. A confined or partially confined volume.

3.3.8 Equivalent Diameter. See 3.3.19, Hydraulic Diameter.

3.3.9 Explosible. A material with a pressure ratio (maximum pressure/pressure at ignition, in absolute units) equal to or greater than 2.0 in any test when tested using the explosibility or Go/No-Go screening test described in Section 13 of ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

3.3.10 Explosion. The bursting or rupturing of an enclosure or a container due to the development of internal pressure from a deflagration.

3.3.11* Flame Speed. The speed of a flame front relative to a fixed reference point.

3.3.12 Flammable Limits. The minimum and maximum concentrations of a combustible material, in a homogeneous mixture with a gaseous oxidizer, that will propagate a flame.

3.3.12.1* Lower Flammable Limit (LFL). The lowest concentration of a combustible substance in a gaseous oxidizer that will propagate a flame, under defined test conditions.

3.3.12.2 Upper Flammable Limit (UFL). The highest concentration of a combustible substance in a gaseous oxidizer that will propagate a flame.

3.3.13 Flammable Range. The range of concentrations between the lower and upper flammable limits.

3.3.14* Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitable mixture with air near the surface of the liquid or the solid.

3.3.15 Flexible Filter. A filter that is rigidly mounted and deflects a distance at least equal to the distance between adjacent outer perimeters when subjected to a lateral force of 89 N (20 lb_f) or greater at the free end of a filter that is supported at only one end or the midpoint of a filter that is supported at both ends, or a filter that is not rigidly mounted and can swing freely with very little force.

3.3.16* Friction Factor, f_D . A dimensionless factor relating pressure drop in a straight duct to velocity and wetted surface area.

3.3.17 Fundamental Burning Velocity. See 3.3.1.1.

3.3.18 Gas. The state of matter characterized by complete molecular mobility and unlimited expansion; used synonymously with the term *vapor*.

3.3.19* Hydraulic Diameter. A diameter for noncircular cross sections that is determined by $4(A/p)$, where A is the cross-sectional area normal to the longitudinal axis of the space and p is the perimeter of the cross section.

3.3.20* K_{St} . The deflagration index of a dust cloud.

3.3.21 Maximum Pressure (P_{max}). See 3.3.27.1.

3.3.22 Minimum Explosible Concentration (MEC). The minimum concentration of a combustible dust cloud that is capable of propagating a deflagration through a uniform mixture of the dust and air under the specified conditions of test.

3.3.23* Minimum Ignition Energy (MIE). The minimum amount of energy released at a point in a combustible mixture that causes flame propagation away from the point, under specified test conditions.

3.3.24 Mist. A dispersion of fine liquid droplets in a gaseous medium.

3.3.25 Mixture.

3.3.25.1* Hybrid Mixture. An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥ 10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥ 10 percent of the minimum explosible concentration (MEC).

3.3.25.2* Optimum Mixture. A specific mixture of fuel and oxidant that yields the most rapid combustion at a specific measured quantity or that yields the lowest value of the minimum ignition energy or that produces the maximum deflagration pressure.

3.3.25.3 Stoichiometric Mixture. A balanced mixture of fuel and oxidizer such that no excess of either remains after combustion. [53, 2021]

3.3.26* Oxidant. Any gaseous material that can react with a fuel (either gas, dust, or mist) to produce combustion.

3.3.27 Pressure.

3.3.27.1 Maximum Pressure (P_{max}). The maximum pressure developed in a contained deflagration of an optimum mixture.

3.3.27.2 Reduced Pressure (P_{red}). The maximum pressure developed in a vented enclosure during a vented deflagration.

3.3.27.3 Static Activation Pressure (P_{stat}). Pressure that activates a vent closure when the pressure is increased slowly [with a rate of pressure rise less than 0.1 bar/min (1.5 psi/min)].

3.3.28 Rate of Pressure Rise (dP/dt). The increase in pressure divided by the time interval necessary for that increase to occur.

3.3.28.1* Maximum Rate of Pressure Rise $[(dP/dt)_{max}]$. The slope of the steepest part of the pressure-versus-time curve recorded during deflagration in a closed vessel.

3.3.29 Reduced Pressure (P_{red}). See 3.3.27.2.

3.3.30 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item. [652, 2019]

3.3.31 Static Activation Pressure (P_{stat}). See 3.3.27.3.

3.3.32 Strength.

3.3.32.1 Enclosure Strength (P_{es}). Up to two-thirds the ultimate strength for low-strength enclosures; for high-strength enclosures the enclosure design pressure sufficient to resist P_{red} .

3.3.32.2 Ultimate Strength. The pressure that results in the failure of the weakest structural component of an enclosure.

3.3.33 Vapor. See 3.3.18, Gas.

3.3.34 Vent. An opening in an enclosure to relieve the developing pressure from a deflagration.

3.3.34.1* Hinge Vent. Vent closure that is hinged on one or more sides.

3.3.34.2* Translating Vent. Vent closure that detaches from the vent opening during a vent actuation and travels downstream as one or more pieces with the venting flow.

3.3.35 Vent Closure. A pressure-relieving cover that is placed over a vent.

Chapter 4 General Requirements

4.1 Goal. The goal of this standard shall be to provide effective deflagration venting for enclosures where there is the potential for a deflagration.

4.2 Objectives.

4.2.1 Life Safety.

4.2.1.1* Deflagration venting for occupied enclosures shall prevent the structural failure of the enclosure and minimize injury to personnel in adjacent areas outside of the enclosure.

4.2.1.2 Deflagration venting for unoccupied enclosures shall prevent the rupture of the enclosure.

4.2.1.3 Deflagration venting shall be arranged to avoid injury to personnel by the vent discharge.

4.2.1.4* If the process material has a degree of health hazard (health hazard rating) of 3 or 4 according to NFPA 704, deflagration venting directed inside buildings shall not be permitted even when flame-arresting and particulate retention devices are used.

4.2.1.5 Where explosion protection is required and the process material has a degree of health hazard (health hazard rating) of 3 or 4 according to NFPA 704, alternative protection measures described in NFPA 69 shall be applied unless deflagration venting is supported by a risk assessment suitable to the authority having jurisdiction.

4.2.2 Property Protection.

4.2.2.1 Deflagration venting shall be designed to limit damage of the vented enclosure.

4.2.2.2* Deflagration venting shall be arranged to avoid ignition of adjacent property.

4.2.2.3 Deflagration venting shall be arranged to avoid blast damage to adjacent property.

4.2.2.4 Deflagration venting shall be arranged to avoid projectile damage to adjacent property.

4.2.3 Hazard Analysis.

4.2.3.1 The design basis deflagration hazard scenario shall be identified and documented.

4.2.3.2 A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided.

4.3 Compliance Options.

4.3.1 Options. Deflagration venting meeting the goals and objectives of Sections 4.1 and 4.2 shall be provided in accordance with either of the following:

- (1) Performance-based provisions of 4.3.2
- (2) Prescriptive-based provisions of 4.3.3

4.3.2 Performance-Based Design. A performance-based design shall be in accordance with Chapter 5 of this standard.

4.3.3 Prescriptive-Based Design. A prescriptive-based design shall be in accordance with Chapters 6 through 11 of this standard.

Chapter 5 Performance-Based Design Option

5.1 General Requirements.

5.1.1* Qualifications. The performance-based design shall be prepared by a person with qualifications acceptable to the authority having jurisdiction.

5.1.2 Design Documentation. The design methodology and data sources shall be documented and maintained for the life of the protected enclosure.

5.1.3 Maintenance of Design Features.

5.1.3.1 To continue meeting the performance goals and objectives of this standard, the design features required for each deflagration vent shall be maintained for the life of the protected enclosure.

5.1.3.2 Any changes to the design shall require approval of the authority having jurisdiction prior to the actual change.

5.2 Performance Criteria.

5.2.1 Deflagration vent design shall be based on the documented hazard scenario.

5.2.2 Deflagration vents shall limit the reduced pressure (P_{red}) within an enclosure and any attached vent ducts to meet the objectives in 4.2.1.1 and 4.2.1.2.

5.2.3 Deflagration Vent Discharge.

5.2.3.1 Combustible materials outside the enclosure shall not attain their ignition temperature from flame or hot gases discharged from a deflagration vent.

5.2.3.2* Blast load from deflagration vent discharge shall limit the risk of damage to exposed structures.

5.2.3.3* Access to spaces into which deflagration vents discharge shall be restricted so as to minimize, to a level acceptable to the authority having jurisdiction, the risk of injury from flame, hot gases, hot particles, or projectiles.

5.2.4 Inspection and Maintenance.

5.2.4.1 Deflagration venting shall be regularly inspected and maintained to confirm the ability of the venting to perform as designed.

5.2.4.1.1 If no guidance is given from the performance-based design documents, the requirements of Chapter 11 of this standard shall apply.

5.2.4.2 Inspection and maintenance shall be documented and retained for at least 1 year or the last three inspections.

Chapter 6 Fundamentals of Venting of Deflagrations

6.1* Basic Concepts.

6.1.1* The deflagration index, K , shall be computed from the maximum rate of pressure rise attained by combustion in a closed vessel with volume, V , and shall be defined by the following equation:

[6.1.1]

$$K = \left(\frac{dP}{dt} \right)_{\max} \cdot V^{1/3}$$

6.1.2* For dusts, K_{St} and $P_{\max}$ shall be determined in approximately spherical calibrated test vessels of at least 20 L capacity per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

6.1.2.1* It shall be permitted to determine K_{St} and $P_{\max}$ per ISO 6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dusts in air*.

6.1.2.2 The owner/user shall be permitted to test the dust with moisture content and particle size that deviates from the recommended conditions established by the method described in 6.1.2 or 6.1.2.1, provided a documented assessment acceptable to the authority having jurisdiction has been performed prior to using these K_{St} and $P_{\max}$ values to determine vent sizing.

6.1.2.3* For aluminum, hafnium, magnesium, tantalum, titanium, zirconium, and similar alloys or mixtures with adiabatic flame temperature higher than 3300°C, unless K_{St} and $P_{\max}$ are determined in nominal 1 m³ or larger calibrated test vessels, the K_{St} value shall be multiplied by a factor of 2 for application of the design methods.

6.1.3 For gases, $P_{\max}$ shall be determined in approximately spherical calibrated test vessels of at least 5 L (1.3 gal) capacity with initially quiescent mixture with low energy ignition source (i.e., less than 100 J).

6.2 Mixtures.

6.2.1 Gas Mixtures.

6.2.1.1 Where the hazard consists of a flammable gas mixture, the vent size shall be based on the fundamental burning velocity of the mixture.

6.2.1.2 Where the gas mixture composition is not certain, the vent size shall be based on the component having the highest fundamental burning velocity.

6.2.2 Dust Mixtures.

6.2.2.1 Where the hazard consists of a dust mixture, the vent size shall be based on the K_{St} and $P_{\max}$ of the mixture.

6.2.2.2 Where the dust mixture composition is not certain, the vent size shall be based on the highest K_{St} of all components and the highest $P_{\max}$ of all components.

6.2.3* Hybrid Mixtures.

6.2.3.1 For hybrid mixtures, the vent size shall be based on the equivalent mixture K_{St} as determined by test.

6.2.3.2 Where test data are not available for hybrid mixtures with gases that have combustion characteristics similar to those

of propane (fundamental burning velocity ≤ 1.3 times that of propane) and St-1 and St-2 dusts, the design shall be permitted to be based upon $P_{\max} = 10$ bar-g and $K_{St} = 500$ bar-m/s.

6.2.4* Foams of Combustible Liquids. Design of deflagration venting for foams of combustible liquids shall be based on tests performed on the specific foam.

6.3 Enclosure Design and Support.

6.3.1 Enclosure Design Pressure Selection Criteria.

6.3.1.1* P_{rd} shall not exceed two-thirds of the ultimate strength for the vented enclosure, provided deformation of the equipment can be tolerated.

6.3.1.2* Where deformation cannot be tolerated, P_{rd} shall not exceed two-thirds of the yield strength for the vented enclosure.

6.3.1.3* For enclosures designed using the ASME *Boiler and Pressure Vessel Code* or similar codes, the maximum allowable working pressure, herein designated as P_{maxwp} , shall be determined by calculation.

6.3.1.3.1 Such determinations shall include an allowable stress for the enclosure material of construction, which is less than the measured yield stress and the measured ultimate stress for the material of construction.

6.3.1.3.2 Given a P_{maxwp} , P_{rd} shall be selected based on the following conditions as defined by Equation 6.3.1.3.2a or Equation 6.3.1.3.2b:

- (1) Permanent deformation, but not rupture, of the enclosure can be accepted:

[6.3.1.3.2a]

$$P_{rd} \leq \left(\frac{2}{3} \right) \cdot F_u \cdot P_{maxwp}$$

- (2) Permanent deformation of the enclosure cannot be accepted:

[6.3.1.3.2b]

$$P_{rd} \leq \left(\frac{2}{3} \right) \cdot F_y \cdot P_{maxwp}$$

where:

P_{rd} = maximum pressure developed in a vented enclosure [bar-g (psig)]

F_u = ratio of ultimate stress of the enclosure to the allowable stress of the enclosure per the ASME *Boiler and Pressure Vessel Code*

P_{maxwp} = enclosure design pressure [bar-g (psig)] according to ASME *Boiler and Pressure Vessel Code*

F_y = ratio of the yield stress of the enclosure to the allowable stress of the materials of construction of the enclosure per the ASME *Boiler and Pressure Vessel Code*

6.3.1.4 Ductile design considerations shall be used for materials subject to brittle failure, such as cast iron.

6.3.1.4.1 Special reinforcing shall be considered.

6.3.1.4.2 If such reinforcing is not used, the maximum allowable design stress shall not exceed 25 percent of the ultimate strength.

6.3.2* Venting shall be sufficient to prevent the maximum pressure that develops within the enclosure, P_{red} , from exceeding the enclosure strength, P_{es} , including the dynamic effect of the rate of pressure rise, as expressed by a dynamic load factor (DLF):

$$P_{red} \leq \frac{P_{es}}{DLF} \quad [6.3.2]$$

where:

P_{red} = maximum pressure developed during venting [bar-g (psig)]
 P_{es} = enclosure strength evaluated based on static pressure calculations for either deformation or burst [bar-g (psig)]
 $DLF = X_m/X_s$
 X_m = maximum dynamic deflection
 X_s = static deflection or, in other words, the displacement produced in the system when the peak load is applied statically

6.3.2.1 In the absence of detailed structural response analysis, it shall be permitted to assume a worst-case value of $DLF = 1.5$ and design based on the weakest structural element of the enclosure.

6.3.2.2* It shall be permitted to modify the value of DLF based on a documented analysis of the vented explosion pressure profile and enclosure structural response.

6.3.3 All structural elements and supports shall be included in the design calculations.

6.3.3.1* The weakest structural element, as well as any equipment or other devices that can be supported by structural elements, shall be identified.

6.3.3.2 Where designing an enclosure to prevent catastrophic failure while still allowing permanent deformation, the normal dead and live loads shall not be relied on to provide restraint.

6.3.3.3 Structural members shall be designed to support the total load.

6.3.3.4 Doors, windows, ducts, or other openings in walls that are intended to be pressure resistant shall also be designed to withstand P_{red} .

6.3.4 Relieving Walls or Roof.

6.3.4.1 Nothing in this standard shall prohibit the use of an enclosure with relieving walls, or a roof, provided the potential for damage and injury is addressed.

6.3.4.2 A lightweight roof shall be permitted to be used as a vent, provided its movement can be tolerated and provided its movement is not hindered by ice or snow.

6.3.5 Enclosure Support Criteria.

6.3.5.1* The supporting structure for the enclosure shall be strong enough to withstand any reaction forces that develop as a result of operation of the vent, including the dynamic effect of the rate of force application, as expressed by a DLF .

6.3.5.2* The following equation shall be used to determine the reaction force applicable to enclosures without vent ducts:

$$F_r = a \cdot DLF \cdot A_v \cdot P_{red} \quad [6.3.5.2]$$

where:

F_r = maximum reaction force resulting from combustion venting [kN (lbf)]
 a = units conversion [100 (1)]
 $DLF = 1.2$
 A_v = vent area [m² (in.²)]
 P_{red} = maximum pressure developed during venting [bar-g (psig)]

6.3.5.3* Modification of the value of DLF based on a documented analysis of the vented explosion pressure profile and the supporting structure's response shall be permitted.

6.3.5.4* The total reaction force shall be applied at the geometric center of the vent.

6.3.5.4.1 The calculation of reaction forces on the enclosure shall be permitted to be eliminated when all of the following conditions are satisfied:

- (1) Vent panels are of the rupture diaphragm type.
- (2) Vent panels are located at opposing positions on the enclosure.
- (3) The P_{stat} of each vent panel is equal and less than or equal to 0.1 bar-g.
- (4) Vent panels are of equal area.

6.3.5.5* The duration of the reaction force shall be calculated according to Equation 6.3.5.5, which is shown to represent the available duration data within a minus 37 percent and a plus 118 percent:

$$t_f = b \cdot \left(\frac{P_{max}}{P_{red}} \right)^{0.5} \cdot \left(\frac{V}{A_v} \right) \quad [6.3.5.5]$$

where:

t_f = duration of pressure pulse after vent opening (s)
 $b = 4.3 \cdot 10^{-3} (1.3 \cdot 10^{-3})$
 P_{max} = maximum pressure developed in an unvented explosion [bar-g (psig)]
 P_{red} = maximum pressure developed during venting [bar-g (psig)]
 V = enclosure volume [m³ (ft³)]
 A_v = area of vent (without vent duct) [m² (ft²)]

6.3.5.6* The total impulse that a structure supporting a vented enclosure experiences during deflagration venting shall be expressed by the following equation:

$$I = 0.52 \cdot F_r \cdot t_f \quad [6.3.5.6]$$

where:

I = total impulse experienced by supporting structure [kN-s (lbf-s)]
 F_r = maximum reaction force resulting from combustion venting [kN (lbf)]
 t_f = duration of pressure pulse after vent opening (s)

6.4* Enclosure Length-to-Diameter Ratio and Vent Variables.

[6.4.3.6]

6.4.1 For silos and other enclosures that can be vented at only one end, the maximum effective vent area to use to determine the expected P_{rel} shall be the enclosure cross section.

6.4.2 For enclosures that can be vented at more than one point along the major axis, the vents shall be permitted to be distributed along the major axis and sized based on the length to diameter (L/D) between vents.

6.4.2.1 The maximum effective vent area at any point along the major axis shall be the enclosure cross section.

6.4.3* L/D of Elongated Enclosures.

6.4.3.1 The L/D of an elongated enclosure shall be determined based upon the general shape of the enclosure, the location of the vent, the shape of any hopper extensions, and the farthest distance from the vent at which the deflagration could be initiated.

6.4.3.2 The maximum flame length along which the flame can travel, H , shall be determined based on the maximum distance, taken along the central axis, from the farthest end of the enclosure to the opposite end of the vent.

6.4.3.2.1 When multiple vents are provided, a single value of H , and L/D , shall be permitted to be determined for the enclosure based on the farthest vent.

6.4.3.2.2 When multiple vents are located along the central axis, the value of H , and L/D , shall be permitted to be determined for each section using the maximum distance from the closest end of one vent to the opposite end of the next vent.

6.4.3.3 The effective volume of the enclosure, V_{eff} , shall be determined based on the volume of that part of the enclosure through which the flame can pass as it travels along the maximum flame length, H .

6.4.3.3.1 Partial volume (see Section 8.4) shall not be considered in the determination of effective volume per this section.

6.4.3.3.2 When multiple vents are provided, a single value of V_{eff} shall be permitted to be determined for the enclosure based upon the farthest vent.

6.4.3.3.3 When multiple vents are located along the central axis, V_{eff} shall be permitted to be determined for each section using the maximum distance from the closest end of one vent to the opposite end of the next vent.

6.4.3.3.4 When V_{eff} is less than the total volume of the enclosure, only those vents located within the effective volume shall be considered as providing venting for the event.

6.4.3.4 It shall be permitted to conservatively determine both H and V_{eff} , or H alone, but not V_{eff} alone, based on the total enclosure, irrespective of vent location.

6.4.3.5 The effective area, A_{eff} , shall be determined by dividing V_{eff} by H .

6.4.3.6 The effective hydraulic diameter, D_{he} , for the enclosure shall be determined based on the general shape of the enclosure taken normal to the central axis:

$$D_{he} = 4 \cdot \left(\frac{A_{eff}}{p} \right)$$

where:

p = perimeter of the general shape.

6.4.3.6.1 Where the enclosure and any hopper extension are generally cylindrical, the perimeter, p , shall be permitted to be determined based on a circular cross section, given the following:

[6.4.3.6.1]

$$D_{he} = \left(\frac{4 \cdot A_{eff}}{\pi} \right)^{0.5}$$

6.4.3.6.2 Where the enclosure and any hopper extension are generally rectangular or square, and the aspect ratio of the largest cross section is between 1 and 1.2, the perimeter shall be permitted to be determined based on a square cross section, given the following:

[6.4.3.6.2]

$$D_{he} = (A_{eff})^{0.5}$$

6.4.3.6.3 Where the enclosure and any hopper extension are generally rectangular, and the aspect ratio, R , of the largest cross section is greater than or equal to 1.2, the perimeter shall be permitted to be determined based on the aspect ratio of the largest cross section, given the following:

[6.4.3.6.3]

$$\begin{aligned} D_1 &= \left(\frac{A_{eff}}{R} \right)^{0.5} \\ p &= 2 \cdot (R + 1) \cdot D_1 \\ D_{he} &= 4 \cdot \frac{A_{eff}}{p} \end{aligned}$$

6.4.3.7 L/D for use in this standard shall be set equal to H/D_{he} .

6.4.4* The vent areas shall be permitted to be reduced from those specified in Chapters 7 and 8 if large-scale tests show that the resulting damage is acceptable to the user and the authority having jurisdiction.

6.4.5* The owner/user shall be permitted to install vents that are larger in area, are lower in density, or relieve at lower pressure than the minimum requirements determined from application of Chapter 7 or Chapter 8, as appropriate.

6.5 Vent Closure Operation.

6.5.1* The vent opening shall be free and clear.

6.5.2 Vent closure operation shall not be hindered by deposits of snow, ice, paint, corrosion, or debris, or by the buildup of deposits on their inside surfaces.

6.5.2.1* The materials that are used shall be chosen to minimize corrosion from process conditions within the enclosure and from ambient conditions on the nonprocess side.

6.5.2.2 Clear space shall be maintained on both sides of a vent to enable operation without restriction and without impeding a free flow through the vent.

6.5.2.3 To prevent snow and ice accumulation, where the potential exists, and to prevent entry of rainwater and debris, the vent or vent duct exit shall not be installed in the horizontal position, unless any of the alternative methods in 6.5.2.3.1 are followed.

6.5.2.3.1 Any of the following alternative methods of protection for horizontal vent or vent duct exits shall be permitted:

- (1) Fixed rain hats where P_{rd} effects on vent area are included in accordance with Section 8.5 and restraint design includes maximum force from P_{rd} applied over the area
- (2) Weather covers mounted at an angle sufficient to shed snow, with restraints designed and tested to prevent the cover from becoming a free projectile, where inertia effects of the additional weather cover mass and P_{stat} of the cover are included
- (3) Deicing provisions such as a heated vent closure

6.5.3 Restraining devices shall not impede the operation of the vent or vent closure device. (See Chapter 10.)

6.5.4 A vent closure shall release at its P_{stat} or within a pressure range specified by the vent closure manufacturer.

6.5.5 A vent closure shall reliably withstand pressure fluctuations that are below P_{stat} .

6.5.6 A vent closure shall withstand vibration or other mechanical forces to which it can be subjected.

6.5.7* P_{stat} including the manufacturer's negative tolerance, shall be greater than the anticipated loading equivalent to the local design wind speed such that wind load will not cause the vent to open.

6.5.7.1 The area calculation shall be performed using the nominal value of P_{stat} .

6.5.8* P_{stat} including the manufacturer's positive tolerance, shall be less than the intended P_{rd} .

6.5.8.1 The area calculation shall be performed using the nominal value of P_{stat} .

6.5.9* Vent closures shall be maintained in accordance with Chapter 11.

6.6* Consequences of a Deflagration.

6.6.1 The material discharged from an enclosure during the venting of a deflagration shall be directed outside to a safe location.

Δ 6.6.2 Property damage and injury to personnel due to material ejection during venting shall be minimized or avoided by locating vented equipment outside of buildings and away from normally occupied areas. (See 6.8.2 and 6.8.3 for gases and dusts, respectively.)

Δ 6.6.2.1 Deflagration vents shall not be located in positions closer to air intakes than the distances prescribed by the fire-ball length (see 6.8.2 and 6.8.3).

Δ 6.6.2.2 Deflagration vents shall be permitted to be located closer to buildings and normally occupied areas than the distances determined by 6.8.2 or 6.8.3, provided a documented risk assessment acceptable to the authority having jurisdiction has been performed.

6.6.2.3* Where a deflector is provided in accordance with 6.6.2.4 and 6.6.2.5, it shall be permitted to reduce the axial (front-centerline) hazard distance to 50 percent of the value calculated in 6.8.2 or 6.8.3. This method shall not be used to reduce the radial hazard distance as defined in 6.8.2 and 6.8.3 [115].

6.6.2.4* A deflector design shall meet all of the following criteria:

- (1) The deflector for a rectangular vent shall be geometrically similar to the vent and sized with a linear scale factor of at least 1.75. For a round vent, the deflector shall be square shaped and at least 1.75 times the vent's hydraulic diameter.
- (2) The deflector shall be inclined 45 degrees to 60 degrees from the vent axis, as shown in Figure 6.6.2.4.
- (3) The centerline of the deflector shall be coincident with the vent axis.
- (4) The distance from the vent opening to the deflector on the vent axis shall be $1.5D_{hv}$, where D_{hv} is the vent's hydraulic diameter.
- (5) The deflector plate shall be mounted so as to withstand the force exerted by the vented explosion, calculated as P_{rd} times the deflector area.
- (6) The deflector location shall not interfere with the operation of hinged vent closures.

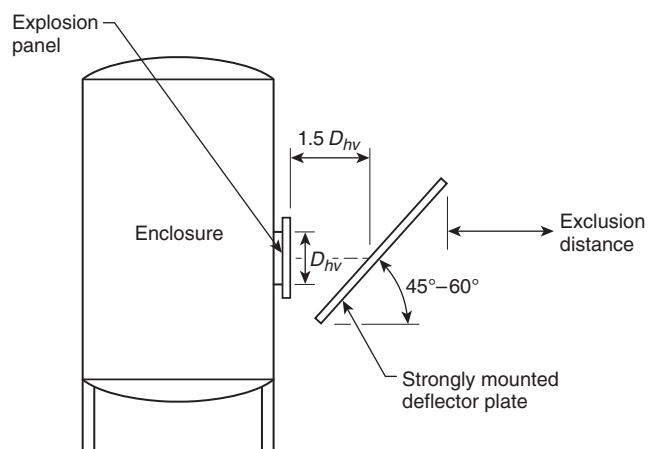
6.6.2.5* A deflector to limit flame length shall not be used as follows:

- (1) For enclosure volume greater than 20 m³ (706 ft³)
- (2) With a tethered or translating vent closure

6.6.3 Warning signs shall be posted to indicate the location of a vent.

6.7 Effects of Vent Inertia.

6.7.1* Counterweights and insulation added to panels shall be included in the total mass.



Δ FIGURE 6.6.2.4 Design for an Installation of a Blast Deflector Plate.

6.7.2* A vent closure shall have low mass to minimize inertia, thereby reducing opening time.

6.7.3 If the total mass of a closure divided by the area of the vent opening does not exceed the panel densities calculated by Equation 7.4.2 and Equation 8.3.2 (for gas and dust, respectively), all vent area correlations presented in this standard shall be permitted to be used without correction [111].

6.7.4* Hinged closures shall be permitted to be used, provided the following conditions are met:

- (1) There are no obstructions in the path of the closure that prevent it from opening.
- (2) Operation of the closure is not restrained by corrosion, sticky process materials, or paint.

N 6.8* Fireball Dimensions. Measures shall be taken to reduce the risk to personnel and equipment from the effects of fireball temperature and pressure.

N 6.8.1 A documented risk assessment shall be permitted to be used to reduce the hazard distances calculated in 6.8.2, 6.8.3, and 6.8.7.

N 6.8.2* Gas Deflagration Fireball Dimensions. In the case of gas deflagration venting, L_F , the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of each vent discharge (see Figure 6.8.2) shall be expressed by Equation 6.8.2:

Δ [6.8.2]

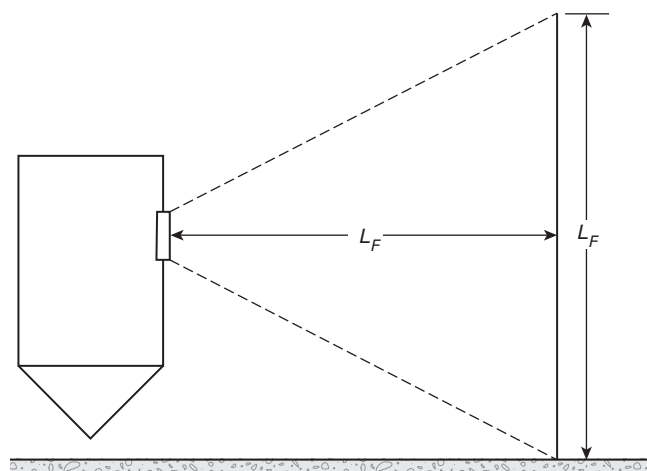
$$L_F = 3.1 \cdot \left(\frac{V}{n} \right)^{0.402}$$

where:

L_F = axial length, width, and height of fireball hazard zone distributed around the centerline of the vent (m)

V = volume of vented enclosure (m^3)

n = number of independent vents, with vent centers spaced at least 4 times the hydraulic diameter of the largest vent (see 6.8.4)



N FIGURE 6.8.2 Fireball Dimensions

N 6.8.3* Dust Deflagration Fireball Dimensions. In the case of dust deflagration venting, L_F , the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of each vent discharge (see Figure 6.8.2) shall be expressed by Equation 6.8.3:

Δ [6.8.3]

$$L_F = K \cdot \left(\frac{V}{n} \right)^{1/3}$$

where:

L_F = axial length, width, and height of fireball hazard zone distributed around the centerline of the vent (m)

K = flame length factor: 10 for metal dusts, 8 for chemical and agricultural dusts

V = volume of vented enclosure (m^3)

n = number of independent vents, with vent centers spaced at least 4 times the hydraulic diameter of the largest vent (see 6.8.4)

N 6.8.4* Definition of Independent Vents. Independent vents shall meet the requirements in 6.8.4.

N 6.8.4.1* For vents located at a single elevation and spaced around the circumference of a cylindrical vessel, the normal to the adjacent vents shall be separated by at least 60 degrees or 4 hydraulic diameters of the largest vent.

N 6.8.4.2 Vents located on different sides of a rectangular enclosure shall be considered independent.

N 6.8.4.3* For vents located along the axis of a cylindrical vessel or on the same side of a rectangular enclosure, the center of the vents shall be separated by at least four times the hydraulic diameter of the largest vent.

N 6.8.4.4 Vents that do not meet the requirements of 6.8.4 are allowed but shall not be counted separately to calculate n in 6.8.2 or 6.8.3.

N 6.8.5 Axial distance, calculated by Equation 6.8.3, shall be limited to 60 m [104].

N 6.8.6* Axial distance calculated by Equation 6.8.2 shall not be limited for gases.

N 6.8.7* Where venting is from a cubic vessel, the $P_{max,a}$ value shall be indicated approximately by Equation 6.8.7 [108]:

Δ [6.8.7]

$$P_{max,a} = 0.2 \cdot P_{red} \cdot A_v^{0.1} \cdot V^{0.18}$$

where:

$P_{max,a}$ = external pressure (bar-g)

P_{red} = reduced pressure (bar-g)

A_v = vent area (m^2)

V = enclosure volume (m^3)

N 6.8.8 For distances longer than $\alpha \cdot L_F$, the maximum external pressure, $P_{max,r}$, shall be indicated approximately by Equation 6.8.8:

Δ [6.8.8]

$$P_{max,r} = P_{max,a} (\alpha \cdot L_F / r)$$

where:

$P_{max,r}$ = maximum external pressure

$P_{max,a}$ = external pressure (bar-g)

α = 0.20 for horizontal vents and 0.25 for vertical (upward directed) vents

L_f = maximum length of fireball (m)

r = distance from vent (m)

N 6.8.9 Equation 6.8.3, Equation 6.8.7, and Equation 6.8.8 shall be valid for the following conditions:

- (1) Enclosure volume: $0.3 \text{ m}^3 \leq V \leq 10,000 \text{ m}^3$
- (2) Reduced pressure: $P_{rd} \leq 1 \text{ bar-g}$
- (3) Static activation pressure: $P_{stat} \leq 0.1 \text{ bar-g}$
- (4) Deflagration index: $K_{St} \leq 300 \text{ bar-m/s}$ for Equation 6.8.3, $K_{St} \leq 200 \text{ bar-m/s}$ for Equation 6.8.7 and Equation 6.8.8
- (5) $P_{max} \leq 9 \text{ bar-g}$

6.9 Effects of Vent Discharge Ducts.

6.9.1 If it is necessary to locate enclosures with deflagration vents inside of buildings, vent ducts shall be used to direct vented material from the enclosure to the outdoors.

6.9.2 A vent duct shall have a cross-sectional area at least as great as that of the vent itself but shall be limited to no more than 150 percent of the vent itself at any point in the vent duct.

6.9.3 When either a single enclosure or multiple close-coupled modular enclosures with a common inlet duct are protected by multiple deflagration vents, it shall be permitted to manifold multiple vent discharges within a single vent discharge duct under the following conditions:

- (1) Each vent closure has the same nominal shape, area, inertia, and P_{stat} .
- (2) Each vent discharge duct connects individually to a safe discharge location.
- (3) The vent discharge duct has a single continuous inlet perimeter without branch connections.
- (4) The vent discharge duct cross-sectional area is everywhere less than or equal to 1.5 times the total manifolded vent area (see Figure 6.9.3).

6.9.4 When either a single enclosure or multiple close-coupled modular enclosures with a common inlet duct are protected by multiple deflagration vents, it shall be permitted to provide individual vent discharge ducts for each vent under the following conditions:

- (1) Each vent closure has the same shape, area, inertia, and P_{stat} .

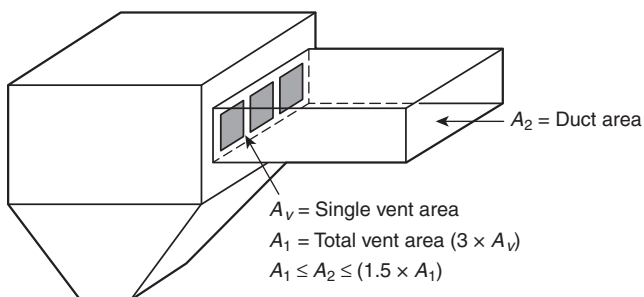


FIGURE 6.9.3 Example Range of Vent Duct Area for Manifolded Vent Duct.

- (2) Each vent discharge duct connects individually to a safe discharge location.
- (3) Each vent discharge duct cross-sectional area is everywhere less than or equal to 1.5 times the vent area.
- (4) Each vent discharge duct has the same nominal cross-sectional area and configuration.
- (5) Corrections for vent discharge duct effects use the longest duct length for all ducts.

6.9.5* Vent area calculations shall include the effects of vent ducts. (See Sections 7.5 and 8.5 for gases and dusts, respectively.)

6.9.6 Vent ducts and nozzles with total lengths of less than one hydraulic diameter, relative to the calculated installed vent area, irrespective of the duct area, shall not require a correction to increase the vent area.

6.9.7 Ducts that are used to direct vented gases from the vent to the outside of a building shall be of noncombustible construction and shall be strong enough to withstand the expected P_{rd} .

6.9.7.1 When vent ducts include bends, the support calculations shall include reaction forces based on the expected P_{rd} .

6.9.7.2* Where vent ducts include bends, they shall be long radius.

6.10* Venting with Flame Arresting and Particulate Retention.

6.10.1* Where external venting is not feasible or desirable, such as where the location of equipment outdoors or adjacent to exterior walls is impractical, or where ducting is too long to be effective, a device that operates on the principles of flame arresting and particulate retention shall be permitted to be used.

6.10.2 These devices shall be listed or approved and shall be considered only for use within the tested range of K_{St} , dust loading, dust type, enclosure volume, and P_{rd} .

N 6.10.3 When these devices are being used with metal dusts, in addition to the requirements of 6.10.2, the listing or approval shall specify the maximum metal adiabatic flame temperature.

6.10.4* The deflagration venting area provided for the protected enclosure shall be increased to compensate for the reduction in venting efficiency due to the presence of the device.

6.10.5* Limitations. The following limitations shall apply:

- (1) Where a flame-arresting vent system and a particulate retention vent system are used inside a building, a documented risk analysis shall be performed to ensure safe installation. Considerations shall include, but are not limited to, the following:
 - (a) Proximity of personnel
 - (b) Volume of room
 - (c) Possibility of combustible mixtures exterior to the equipment
 - (d) Possible toxic gaseous and particulate emissions
- (2) A flame-arresting vent system and a particulate retention vent system shall be sized to ensure that P_{rd} remains within the enclosure design limits.

6.10.6* The areas adjacent to the discharge point shall be clear of combustible dusts.

6.10.7* All devices shall be equipped with an indicating sensor that shall notify the user upon activation of the device.

6.10.8* Flame-arresting vent devices without particulate retention shall be used only where a restricted area around the device has been identified and access during operation of the protected equipment is prohibited.

6.10.8.1 The restricted area shall be based on the external volume that can be filled with an explosible dust-air cloud during the venting process.

6.10.8.2 The restricted area shall be identified as an electrically classified (hazardous) area in accordance with *NFPA 70*.

6.10.8.3 There shall be no normally present ignition sources in the restricted area, including, but not limited to, hot surfaces exceeding the auto-ignition temperature and open flames.

6.10.9* Devices without particulate retention elements that reset after relieving pressure shall be inspected after a deflagration to ensure that the design performance has not been affected.

Chapter 7 Venting Deflagrations of Gas Mixtures and Mists

7.1 Introduction.

7.1.1* This chapter shall apply to the design of deflagration vents for enclosures that contain a flammable gas or combustible mist and that have an L/D of ≤ 5 .

7.1.1.1 This chapter shall be used in conjunction with the information contained in the rest of this standard.

7.1.1.2 Chapter 6 and 3.3.32.1 shall be reviewed before using this chapter.

7.2 Venting by Means of Low Inertia Vent Closures.

7.2.1 Low Inertia Vent Closure Equations for Low P_{red} . When $P_{red} \leq 0.5$ bar-g, the minimum required vent area, A_{v0} , shall be determined by Equation 7.2.1a and Equation 7.2.1b:

[7.2.1a]

$$A_{v0} = \frac{A_s C}{\sqrt{P_{red}}}$$

[7.2.1b]

$$C = \frac{S_u \rho_u \lambda}{2G_u C_d} \left[\left(\frac{P_{max} + 1}{P_0 + 1} \right)^{1/\gamma_b} - 1 \right] (P_0 + 1)^{1/2}$$

where:

A_{v0} = the vent area calculated from Equation 7.2.1a (m^2)

A_s = the enclosure internal surface area determined according to 7.2.5 (m^2)

P_{red} = the maximum pressure developed in a vented enclosure during a vented deflagration (bar-g)

S_u = fundamental burning velocity of gas-air mixture (m/s)

ρ_u = mass density of unburned gas-air mixture (kg/m^3)

λ = ratio of gas-air mixture burning velocity accounting for turbulence and flame instabilities in vented deflagration to the fundamental (laminar) burning velocity, determined according to 7.2.6

G_u = unburned gas-air mixture sonic flow mass flux (kg/m^2-s)

C_d = vent flow discharge coefficient, determined according to 7.2.4

P_{max} = the maximum pressure developed in a contained deflagration by ignition of the same gas-air mixture (bar-g)

P_0 = the enclosure pressure prior to ignition (bar-g)

γ_b = ratio of specific heats for burned gas-air mixture

7.2.1.1 The C value for flammable gases and vapors with a P_{max} value less than 9 bar-g and a stoichiometric (near worst case) fuel concentration no greater than about 10 percent shall be permitted to be calculated using Equation 7.2.1.1 for use in Equation 7.2.1a:

[7.2.1.1]

$$C = 0.0223 \lambda S_u \text{ bar}^{1/2} \text{ for } S_u \text{ in m/s}$$

7.2.1.2 When applying Equation 7.2.1a, the value of P_{stat} shall be less than P_{red} as specified for the following conditions:

- (1) For $P_{red} \leq 0.1$ bar-g (1.5 psig), $P_{stat} \leq P_{red} - 0.024$ bar-g (0.34 psf).
- (2) For $P_{red} > 0.1$ bar-g (1.5 psig), $P_{stat} < 0.75 P_{red}$.

7.2.2 Low Inertia Vent Closure Equations for High P_{red} . When $P_{red} > 0.5$ bar-g, the minimum required vent area, A_{v0} , shall be determined from Equation 7.2.2a and Equation 7.2.2b:

[7.2.2a]

$$A_{v0} = A_s \frac{\left[1 - \left(\frac{P_{red} + 1}{P_{max} + 1} \right)^{1/\gamma_b} \right]}{\left[\left(\frac{P_{red} + 1}{P_{max} + 1} \right)^{1/\gamma_b} - \delta \right]} \frac{S_u \rho_u \lambda}{G_u C_d}$$

[7.2.2b]

$$\delta = \frac{\left(\frac{P_{stat} + 1}{P_0 + 1} \right)^{1/\gamma_b} - 1}{\left(\frac{P_{max} + 1}{P_0 + 1} \right)^{1/\gamma_b} - 1}$$

where:

A_{v0} = the vent area calculated from Equation 7.2.2a (m^2)

A_s = the enclosure internal surface area determined according to 7.2.5 (m^2)

P_{red} = the maximum pressure developed in a vented enclosure during a vented deflagration (bar-g)

S_u = fundamental burning velocity of gas-air mixture (m/s)

ρ_u = mass density of unburned gas-air mixture (kg/m^3)

λ = ratio of gas-air mixture burning velocity accounting for turbulence and flame instabilities in vented deflagration to the fundamental (laminar) burning velocity, determined according to 7.2.6

G_u = unburned gas-air mixture sonic flow mass flux (kg/m^2-s)

C_d = vent flow discharge coefficient, determined according to 7.2.4

P_{max} = the maximum pressure developed in a contained deflagration by ignition of the same gas-air mixture (bar-g)

P_0 = the enclosure pressure prior to ignition (bar-g)

γ_b = ratio of specific heats for burned gas-air mixture

P_{stat} = nominal vent deployment or burst pressure (bar-g)

7.2.3* Gas-Air Mixture Parameters.

7.2.3.1* The design of a deflagration vent for an enclosure containing a combustible mist shall be based on a value of S_u equal to 0.46 m/s unless a value of S_u applicable to the mist of a particular substance is determined by test.

7.2.3.2* The burning velocity, S_u , shall be the maximum value for any gas concentration unless a documented hazard analysis shows that there is not a sufficient amount of gas to develop such a concentration.

7.2.3.3 It shall be permitted to assume a mass density of unburned gas-air mixture, ρ_u , equal to 1.2 kg/m³ for flammable gases with stoichiometric concentrations less than 5 vol % and initially at ambient temperature.

7.2.3.4 It shall be permitted to assume an unburned gas-air mixture sonic flow mass flux, G_w , equal to 230.1 kg/m²-s for an enclosure initially at ambient temperatures.

7.2.3.5 It shall be permitted to assume the ratio of specific heats for burned gas-air mixture, γ_b , equal to 1.15 for flammable gases with stoichiometric concentrations less than 5 vol % and initially at ambient temperatures.

7.2.3.6 It shall be permitted to assume the unburned gas-air mixture dynamic viscosity, μ_u , equal to 1.8×10^{-5} kg/m-s for flammable gases with stoichiometric concentrations less than 5 vol % and initially at ambient temperatures.

7.2.3.7 It shall be permitted to assume the unburned gas-air mixture sound speed, a_u , equal to 343 m/s for flammable gases with stoichiometric concentrations less than 5 vol % and initially at ambient temperatures.

7.2.4 Enclosure Parameters.

7.2.4.1 The value of C_d shall be 0.70 unless the vent occupies an entire wall of the enclosure, in which case a value of 0.80 shall be permitted to be used.

7.2.4.2* The value of P_0 shall be greater than or equal to the normal operating pressure and chosen to represent the likely maximum pressure at which a flammable gas mixture can exist at the time of ignition.

7.2.4.3* For initially elevated pressures, the enclosure shall be located to accommodate the blast wave.

7.2.5* Calculation of Internal Surface Area.

7.2.5.1* The internal surface area, A_s , shall include the total area that constitutes the perimeter surfaces of the enclosure that is being protected.

7.2.5.1.1 Nonstructural internal partitions that cannot withstand the expected pressure shall not be considered to be part of the enclosure surface area.

7.2.5.1.2 The enclosure internal surface area, A_s , in Equation 7.2.2 includes the roof or ceiling, walls, floor, and vent area and shall be based on simple geometric figures.

7.2.5.1.3 Surface corrugations and minor deviations from the simplest shapes shall not be taken into account.

7.2.5.1.4 Regular geometric deviations, such as saw-toothed roofs, shall be permitted to be "averaged" by adding the contributed volume to that of the major structure and calculating A_s for the basic geometry of the major structure.

7.2.5.1.5* The internal surface of any adjoining rooms shall be included.

7.2.5.2 The surface area of equipment and contained structures shall be neglected.

7.2.6* Determination of Turbulent Flame Enhancement Factor, λ .

7.2.6.1* The baseline value, λ_0 , of λ shall be calculated from Equations 7.2.6.1a through 7.2.6.1f:

[7.2.6.1a]

$$\Phi_1 = \begin{cases} 1, & \text{if } Re_f < 4000 \\ \left(\frac{Re_f}{4000} \right)^0, & \text{if } Re_f \geq 4000 \end{cases}$$

[7.2.6.1b]

$$Re_f = \frac{\rho_u S_u (D_{he}/2)}{\mu_u}$$

[7.2.6.1c]

$$\Phi_2 = \max \left\{ 1, \beta_1 \left(\frac{Re_v}{10^6} \right)^{\left(\frac{\beta_2}{S_u} \right)^{0.5}} \right\}$$

[7.2.6.1d]

$$Re_v = \frac{\rho_u u_v (D_v/2)}{\mu_u}$$

[7.2.6.1e]

$$u_v = \min \left\{ \sqrt{\frac{2 \times 10^5 P_{md}}{\rho_u}}, a_u \right\}$$

[7.2.6.1f]

$$\lambda_0 = \phi_1 \phi_2$$

where:

- ρ_u = mass density of unburned gas-air mixture (kg/m³)
- S_u = fundamental burning velocity of gas-air mixture (m/s)
- D_{he} = the enclosure hydraulic equivalent diameter as determined in Chapter 6 (m)
- μ_u = the unburned gas-air mixture dynamic viscosity (kg/m-s)
- $\beta_1 = 1.23$
- $\beta_2 = 2.37 \times 10^{-3}$ m/s
- D_v = the vent diameter as determined through iterative calculation (m)
- u_v = maximum velocity through vent (m/s)
- P_{red} = the maximum pressure developed in a vented enclosure during a vented deflagration (bar-g)
- a_u = the unburned gas-air mixture sound speed (m/s)
- $\theta = 0.39$

7.2.6.2 The total external surface area, A_{obs} , of the following equipment and internal structures that can be in the enclosure shall be estimated:

- (1) Piping, tubing, and conduit with diameters greater than 1/2 in.
- (2) Structural columns, beams, and joists
- (3) Stairways and railings
- (4) Equipment with a characteristic dimension in the range of 2 in. to 20 in. (5.1 cm to 51 cm)

7.2.6.3 When $A_{obs} < 0.2A_s$, λ_1 shall be equal to λ_0 as determined in 7.2.6.1.

7.2.6.4 When $A_{obs} > 0.2A_s$, λ_1 shall be determined as follows:

[7.2.6.4]

$$\lambda_1 = \lambda_0 \exp \left(\sqrt{\frac{A_{obs}}{A_s}} - 0.2 \right)$$

7.2.6.5 The L/D of the enclosure shall be determined according to Section 6.4.

7.2.6.6 For L/D values less than 2.5, λ shall be set equal to λ_1 .

7.2.6.7 For L/D values from 2.5 to 5 and for P_{red} no higher than 2 bar-g, λ shall be calculated as follows:

[7.2.6.7]

$$\lambda = \lambda_1 \left[1 + \left(\frac{L/D}{2.5} - 1 \right)^2 \right]$$

7.2.6.8 Equations for determining λ shall be subject to the following limitations:

- (1) $S_u < 3$ m/s (300 cm/s).
- (2) $P_{max} < 10$ bar-g.
- (3) The maximum air velocity in the enclosure prior to ignition is no greater than 5 m/s.

- (4) The enclosure is isolated from possible flame jet ignition and pressures caused by a deflagration in an interconnected enclosure.

7.2.6.9 For long pipes or process ducts where L/D is greater than 5, the requirements of Chapter 9 shall be used.

7.2.6.10 Methods to Reduce Flame Enhancement.

7.2.6.10.1 The value of λ shall be permitted to be reduced for gas deflagrations in relatively unobstructed enclosures by the installation of noncombustible, acoustically absorbing wall linings, provided that large-scale test data confirm the reduction.

7.2.6.10.2 The tests shall be conducted with the highest anticipated turbulence levels and with the proposed wall lining material and thickness.

7.3 Partial Volume Effects.

7.3.1 When a documented hazard analysis demonstrates that there is insufficient gas in the enclosure to form a stoichiometric gas-air mixture occupying the entire enclosure volume, the vent area, A_{v0} , calculated from Equation 7.2.1a or Equation 7.2.2a, as appropriate, shall be permitted to be reduced as described in 7.3.3.

7.3.2* A partial volume fill fraction, X_r , shall be calculated as shown in Equation 7.3.2:

[7.3.2]

$$X_r = \frac{V_{gas} / (V_{enc} - V_{solid})}{x_{st}}$$

where:

- V_{gas} = maximum volume of gas that can be mixed with air in the enclosure
- V_{enc} = enclosure volume
- V_{solid} = volume of solid objects
- x_{st} = stoichiometric volume concentration of gas

7.3.3 If $X_r < 1$, the minimum required vent area, A_{v1} , shall be calculated from the following equation:

[7.3.3]

$$A_{v1} = A_{v0} X_r^{-1/3} \cdot \sqrt{\frac{X_r - \Pi}{1 - \Pi}}$$

where:

- A_{v1} = vent area for partial volume deflagration
- A_{v0} = vent area for full volume deflagration as determined from Equation 7.2.1a or 7.2.2a
- X_r = fill fraction $> \Pi$
- $\Pi = P_{red}/P_{max}$

7.3.4 If $X_r > 1$, A_{v1} shall be set equal to A_{v0} .

7.4 Effects of Panel Inertia.

7.4.1* When the mass of the vent panel ≤ 40 kg/m², Equation 7.4.2 shall be used to determine whether an incremental increase in vent area is needed, and Equation 7.4.3 shall be used to determine the value of that increase.

7.4.2 The vent area determined in Section 7.3 shall be adjusted for vent mass when the vent mass exceeds M_T as calculated in Equation 7.4.2:

$$M_T = \left[\frac{P_{red}^{0.2} \cdot n^{0.3} \cdot V}{(S_u \cdot \lambda)^{0.5}} \right]^{1.67} \quad [7.4.2]$$

where:

M_T = threshold mass (kg/m²)

P_{red} = the maximum pressure developed in a vented enclosure during a vented deflagration (bar-g)

n = number of panels

V = enclosure volume (>1 m³)

7.4.3 For $M > M_T$, the required vent area, A_{v2} , shall be calculated as follows:

$$A_{v2} = A_{v1} \cdot F_{SH} \left[1 + \frac{(0.05) \cdot M^{0.6} \cdot (S_u \cdot \lambda)^{0.5}}{n^{0.3} \cdot V \cdot P_{red}^{0.2}} \right] \quad [7.4.3]$$

where:

A_{v2} = vent area for panel inertia (m²)

M = mass of vent panel (kg/m²)

A_{v1} = vent area determined in Section 7.3 (m²)

F_{SH} = 1 for translating panels or 1.1 for hinged panels

7.4.4 If $M < M_T$, A_{v2} shall be set equal to A_{v1} .

7.5* Effects of Vent Ducts.

7.5.1* Where vent ducting is used, a lower value, P'_{red} , shall be used in place of the actual P_{red} in all equations in this chapter.

7.5.2 Duct lengths shorter than 3 m (10 ft) and shorter than four duct hydraulic diameters in length shall be treated using Curve A in Figure 7.5.2. For ducts exceeding either of these limitations, Curve B shall be used.

7.5.2.1 For vent ducts with lengths less than 3 m (10 ft) and shorter than four duct hydraulic diameters, the following equation shall be permitted to be used to determine P'_{red} :

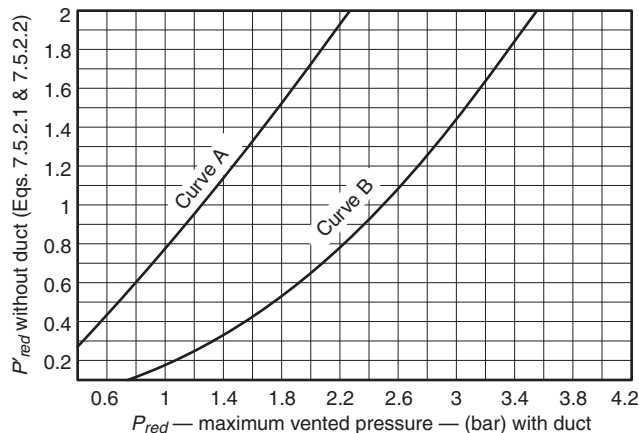
$$P'_{red} = 0.779 \cdot (P_{red})^{1.161} \quad [7.5.2.1]$$

7.5.2.2 For vent ducts with lengths of 3 m to 6 m (10 ft to 20 ft) or shorter vent ducts longer than four duct hydraulic diameters, the following equation shall be permitted to be used to determine P'_{red} :

$$P'_{red} = 0.172 \cdot (P_{red})^{1.936} \quad [7.5.2.2]$$

7.5.3* Duct lengths shorter than 3 m (10 ft) shall be treated as 3 m (10 ft) in length for calculation purposes.

7.5.3.1 If longer ducts are needed, P'_{red} shall be determined by appropriate tests.



Notes:

1. Curve A to be used for duct length < 3 m (10 ft) and less than four duct hydraulic diameters.
2. Curve B to be used for duct length of 3 m to 6 m (10 ft to 20 ft) or of four or more duct hydraulic diameters. Curve B is not valid for duct lengths > 6 m (20 ft).
3. For both Curve A and Curve B: Unlike a piping system described in Chapter 9 where flammable vapor is presumed present, in this situation flammable vapor is not initially present in the vent duct.

FIGURE 7.5.2 Maximum Pressure Developed During Venting of Gas, with and Without Vent Ducts.

7.5.3.2 Vent ducts and nozzles with total lengths of less than one hydraulic diameter shall not require a correction.

7.6 Deflagration Venting of Enclosures Interconnected with Pipelines. For interconnected enclosures, explosion isolation or suppression shall be provided in accordance with NFPA 69, unless a documented risk assessment acceptable to the authority having jurisdiction demonstrates that increased vent area prevents enclosure failure. (See A.8.11.2.)

Chapter 8 Venting of Deflagrations of Dusts and Hybrid Mixtures

8.1 Introduction.

8.1.1 This chapter shall apply to all enclosures with $L/D \leq 6$ handling combustible dusts or hybrid mixtures.

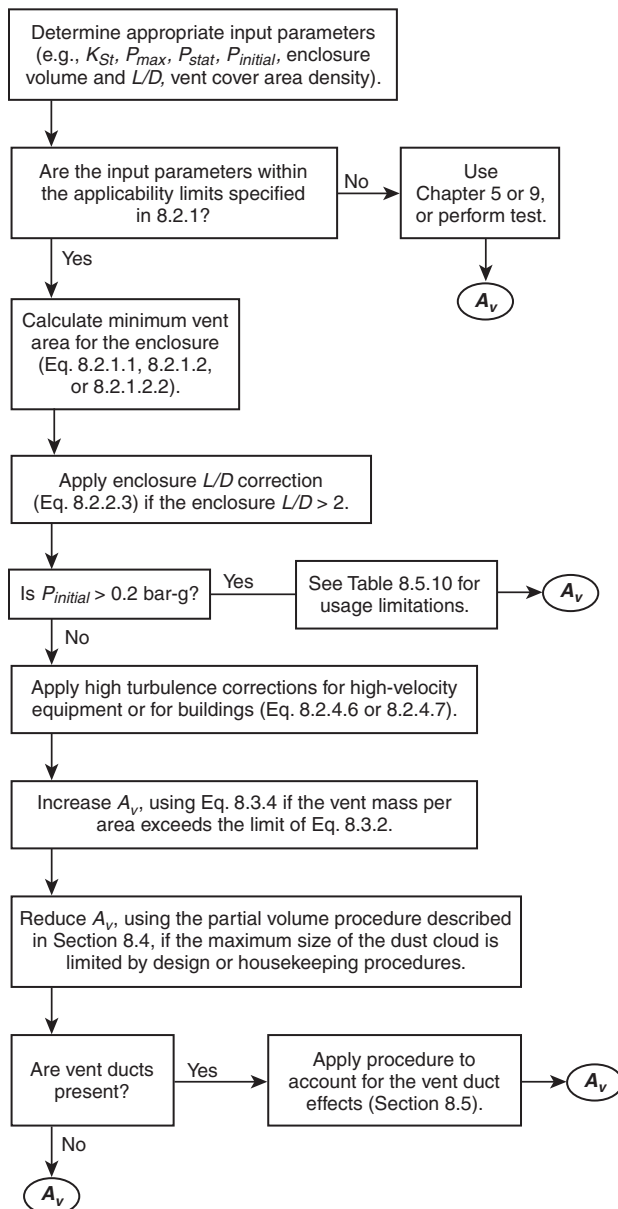
8.1.1.1 This chapter shall be used with the information contained in the rest of this standard.

8.1.1.2 In particular, Chapters 6, 7, 10, and 11 shall be reviewed before the information in this chapter is applied.

8.1.1.3 This chapter provides a number of equations and calculation procedures that shall be used to treat a variety of vent sizing applications.

8.1.1.4 The general flowchart given in Figure 8.1.1.4 shall be permitted to be used to select applicable vent sizing methods.

8.1.2* Where actual material is not available for test, vent sizing shall be permitted to be based on K_{St} values for similar composition materials of particle size no greater than the specified particle size range per the chosen standard: ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or ISO



▲ FIGURE 8.1.1.4 Dust Explosion Vent Sizing Calculation Flowchart.

6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dust in air*.

8.1.2.1 Where the actual material intended to be produced is smaller than the size determined by 8.1.2, tests shall be performed near the intended particle size.

8.1.2.2 When the actual material is available, the K_{St} shall be verified by test.

8.2 Venting by Means of Low-Inertia Vent Closures.

8.2.1 Minimum Vent Area Requirement. Minimum vent area shall be determined per 8.2.1 based on the initial pressure in the enclosure prior to ignition.

8.2.1.1 Minimum Vent Area Requirement for Near Atmospheric Initial Pressure. When enclosure pressure is initially between -0.2 bar-g (-20 kPa) and 0.2 bar-g (20 kPa), A_{v0} shall be determined from Equation 8.2.1.1:

$$A_{v0} = 1 \cdot 10^{-4} \cdot (1 + 1.54 \cdot P_{stat}^{4/3}) \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max} - 1}{P_{red}}} \quad [8.2.1.1]$$

where:

A_{v0} = vent area (m^2)

P_{stat} = nominal static burst pressure of the vent (bar-g)

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

V = enclosure volume (m^3)

P_{max} = maximum pressure of an unvented deflagration initially at atmospheric pressure (bar-g)

P_{red} = reduced pressure after deflagration venting (bar-g) [115]

8.2.1.2* Minimum Vent Area Requirement for Elevated or Subatmospheric Initial Pressure. When enclosure pressure is initially >0.2 bar-g (20 kPa) or <-0.2 bar-g (-20 kPa), A_{v0} shall be determined from Equation 8.2.1.2:

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left[1 + 1.54 \cdot \left(\frac{P_{stat} - P_{initial}}{1 + P_{effective}} \right)^{4/3} \right] \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{1}{\Pi_{effective}} - 1} \quad [8.2.1.2]$$

where:

A_{v0} = vent area (m^2)

P_{stat} = static burst pressure of the vent (bar-g)

$P_{initial}$ = enclosure pressure at moment of ignition (bar-g)

$P_{effective} = 1/3 P_{initial}$ (bar-g)

$\Pi_{effective} = (P_{red} - P_{effective}) / (P_{max}^E - P_{effective})$

P_{red} = reduced pressure (bar-g)

$P_{max}^E = [(P_{max} + 1) \cdot (P_{initial} + 1) / (1 \text{ bar-abs}) - 1]$ maximum pressure of the unvented deflagration at pressure (bar-g)

P_{max} = maximum pressure of an unvented deflagration initially at atmospheric pressure (bar-g)

8.2.1.2.1* When enclosure pressure is initially <-0.2 bar-g (-20 kPa), the vent area in Equation 8.2.1.2 shall be evaluated over the range between operating pressure and atmospheric pressure and the largest vent area correction applied.

8.2.1.2.2 When enclosure pressure is initially <-0.2 bar-g (-20 kPa), it shall be permitted to determine minimum vent area per Equation 8.2.1.2.2.

$$A_{v0} = 1.1 \cdot 10^{-4} \cdot [1 + 1.54 \cdot P_{stat}^{4/3}] \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max} - 1}{P_{red}}} \quad [8.2.1.2.2]$$

8.2.1.2.3 When enclosure pressure is initially >0.2 bar-g (20 kPa), deflagration vents shall be permitted only when the following conditions are met:

- (1) Vent duct length $L/D \leq 1$
- (2) Panel density $M \leq M_T$ and $\leq 40 \text{ kg/m}^2$

- (3) v_{axial} and $v_{tan} < 20$ m/s
 (4) No allowance for partial volume

8.2.1.3 The following limitations shall be applicable to 8.2.1:

- (1) $5 \text{ bar-g} \leq P_{max} \leq 12 \text{ bar-g}$
 (2) $10 \text{ bar-m/s} \leq K_{St} \leq 800 \text{ bar-m/s}$
 (3) $0.1 \text{ m}^3 \leq V \leq 10,000 \text{ m}^3$
 (4) $P_{stat} \leq P_{initial} + 0.75(1 + P_{effective}) \text{ bar-g}$ when $P_{initial}$ is $>0.2 \text{ bar-g}$
 (5) $P_{stat} < 0.75 \text{ bar-g}$ when $P_{initial}$ is $<0.2 \text{ bar-g}$

8.2.2 Effects of Elevated L/D .

8.2.2.1 The L/D of the enclosure shall be determined according to Section 6.4.

8.2.2.2 When $L/D \leq 2$, A_{v1} shall be set equal to A_{v0} .

8.2.2.3 For $2 < L/D \leq 6$, the required vent area, A_{v1} , shall be calculated as follows (where $\exp(A) = e^A$, e is the base of the natural logarithm [114]):

$$A_{v1} = A_{v0} \cdot \left[1 + 0.6 \cdot \left(\frac{L}{D} - 2 \right)^{0.75} \cdot \exp \left(-0.95 \cdot \left(\frac{P_{red}}{1 + P_{initial}} \right)^2 \right) \right] \quad [8.2.2.3]$$

where:

- A_{v0} = vent area as calculated by 8.2.1
 L/D = length-to-diameter ratio
 P_{red} = reduced pressure after deflagration venting (bar-g)
 $P_{initial}$ = enclosure pressure at moment of ignition (bar-g)

8.2.2.4 When initial pressure in the enclosure is less than 0.2 bar-g (20 kPa), $P_{initial}$ in Equation 8.2.2.3 shall be set to zero.

8.2.2.5* It shall be permitted to extend Equation 8.2.2.3 to values of L/D of 8 for top-fed bins, hoppers, and silos, provided the calculated required vent area, after application of all correction factors, does not exceed the enclosure cross-sectional area.

8.2.2.6 For situations where vents can be distributed along the major axis of the enclosure, Equation 8.2.1.1 and Equation 8.2.2.3 shall be permitted to be applied where L is the spacing between vents along the major axis.

8.2.3 Reserved.

8.2.4 Effects of Additional Turbulence.

8.2.4.1* For this application, average air axial velocity shall be calculated according to the following equation:

$$v = \frac{Q}{A} \quad [8.2.4.1]$$

where:

- v = average axial gas velocity (m/s)
 Q = volumetric air flow rate (m^3/s)
 A = average cross-sectional area of the flow path (m^2) [118, 119]

8.2.4.2* If a circumferential (i.e., tangential) air velocity is in the equipment, v_{tan} shall be given by $0.5 v_{tan_max}$ where v_{tan_max} is the maximum tangential air velocity in the equipment.

8.2.4.3 Values of Q , v_{axial} , v_{tan_max} and v_{tan} shall be measured or calculated by engineers familiar with the equipment design and operation.

8.2.4.4 The measurements or calculations shall be documented and made available to vent designers and the authority having jurisdiction.

8.2.4.5 When the maximum values derived for v_{axial} and v_{tan} are less than 20 m/s, A_{v2} shall be set equal to A_{v1} .

8.2.4.6* When either v_{axial} or v_{tan} is larger than 20 m/s, A_{v2} shall be determined from the following equation where $\max(A, B)$ = maximum value of either A or B [118, 119]:

$$A_{v2} = \left[1 + \frac{\max(v_{axial}, v_{tan}) - 20}{36} \cdot 0.7 \right] \cdot A_{v1} \quad [8.2.4.6]$$

where:

- v_{axial} = axial air velocity (m/s)
 v_{tan} = tangential air velocity (m/s)
 A_{v1} = vent area calculated by 8.2.2

8.2.4.7* Vent areas for buildings in which there is a dust explosion hazard shall be determined from Equation 8.2.4.7 [118, 119]:

$$A_{v2} = 1.7 \cdot A_{v1} \quad [8.2.4.7]$$

where:

- A_{v1} = vent area calculated by 8.2.2

8.2.4.8 The required vent areas for these buildings shall be permitted to be reduced through use of the partial volume Equation 8.4.3.

8.3* Effects of Panel Inertia.

8.3.1 When the mass of the vent panel $\leq 40 \text{ kg/m}^2$, Equation 8.3.2 shall be used to determine whether an incremental increase in vent area is needed and the requirements of 8.3.4 shall be used to determine the value of that increase.

8.3.2 The vent area shall be adjusted for vent mass where the vent mass exceeds M_T as calculated in Equation 8.3.2:

$$M_T = \left[6.67 \cdot (P_{red}^{0.2}) \cdot (n^{0.3}) \cdot \left(\frac{V}{K_{St}^{0.5}} \right) \right]^{1.67} \quad [8.3.2]$$

where:

- M_T = threshold mass (kg/m^2)
 P_{red} = reduced pressure after deflagration venting (bar-g)
 n = number of panels
 V = volume (m^3)
 K_{St} = deflagration index (bar-m/s)

8.3.3 Where $M > 40 \text{ kg/m}^2$, it shall be permitted to use the procedure provided in Annex G.

8.3.4 For $M > M_T$, the required vent area A_{v3} , shall be calculated as follows:

$$A_{v3} = F_{SH} \left[1 + (0.0075) \cdot M^{0.6} \cdot \left(\frac{K_{St}^{0.5}}{n^{0.3} V P_{red}^{0.2}} \right) \right] \cdot A_{v2} \quad [8.3.4]$$

where:

F_{SH} = 1 for translating panels or 1.1 for hinged panels

M = mass of vent panel (kg/m^2)

K_{St} = deflagration index ($\text{bar}\cdot\text{m}/\text{s}$)

n = number of panels

V = volume (m^3)

P_{red} = reduced pressure after deflagration venting ($\text{bar}\cdot\text{g}$)

A_{v2} = vent area calculated by 8.2.4.5, Equation 8.2.4.6, or Equation 8.2.4.7, as applicable

8.3.5 If $K_{St} < 75 \text{ bar}\cdot\text{m}/\text{s}$, $K_{St} = 75$ shall be used in Equation 8.3.4.

8.3.6 Where $M \leq M_T$, A_{v3} shall be set equal to A_{v2} .

8.4* Effects of Partial Volume.

8.4.1* It shall be permitted to calculate the partial volume fill fraction X_r as follows:

$$X_r = \frac{M_e / (V_{enc} - V_{solid})}{c_r} \quad [8.4.1]$$

where:

M_e = total mass of combustible dust that could be suspended inside the enclosure (g)

V_{enc} = enclosure volume (m^3)

V_{solid} = volume of solid objects (m^3)

$c_r = 0.5 \cdot c_w$

c_w = worst case dust concentration (g/m^3)

8.4.2 The value of c_w shall be based upon $(dP/dt)_{max}$ versus concentration test data using ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

8.4.2.1 If a measured value of c_w is available, the lowest value of c_w for the various samples shall be used to determine c_r .

8.4.2.2 If a measured value of c_w is not available, a value of $200 \text{ g}/\text{m}^3$ shall be permitted to be used to determine c_r .

8.4.3 When the volume fill fraction, X_r , can be determined for a worst-case explosion scenario, the minimum required vent area shall be permitted to be calculated from the following equation:

$$A_{v4} = A_{v3} \cdot X_r^{-1/3} \cdot \sqrt{\frac{X_r - \Pi}{1 - \Pi}} \quad [8.4.3]$$

where:

A_{v4} = vent area for partial volume deflagration

A_{v3} = vent area for full volume deflagration as determined from Equation 8.3.4 or from 8.3.6

X_r = fill fraction $> \Pi$

$\Pi = P_{red} / P_{max}$

8.4.3.1* If $X_r \leq \Pi$, deflagration venting shall not be required.

8.4.3.2 Where partial volume is not applied, A_{v4} shall be set equal to A_{v3} .

8.4.4* Process Equipment Partial Volumes. Process equipment involving nonsolvent drying shall be permitted to use partial volume venting in accordance with Equation 8.4.3.

8.4.4.1 In applications involving dryers with recirculation of dry product, the fill fraction shall be taken as 1.0.

8.4.4.2 If the solvent is flammable, hybrid deflagration K_{St} values shall be determined.

8.4.4.3 In applications such as a spray dryer or fluidized bed dryer, the specific fill fraction to be used for vent design shall be based on measurements with representative equipment and process materials.

8.4.4.4 In applications involving spray dryers where a partial volume venting is calculated in accordance with Equation 8.4.3, the vent shall be mounted within the chosen partial volume zone of the dryer that contains the driest fraction of material.

8.4.4.5 In these applications, the determination of X_r shall be documented and submitted to the authority having jurisdiction for review and concurrence.

8.4.5 Building Partial Volumes. (See Annex J.)

8.4.5.1 This subsection shall apply to large process buildings in which a dust explosion hazard is associated with combustible material deposits on the floor and other surfaces, and with the material contained in process equipment.

8.4.5.2 The minimum required deflagration vent area for the building dust explosion hazard shall be based either on the full building volume or on a partial volume determined as follows:

- (1) Collect at least three representative samples of the floor dust from either the actual building or a facility with similar process equipment and materials. The samples shall be obtained from measured floor areas, A_f , that are each 0.37 m^2 (4 ft^2) or larger.
- (2) Weigh each sample and calculate the average mass, $\bar{M}_f$ (grams), of the floor samples.
- (3) Collect at least two representative samples from measured sample areas, A_{ss} , on other surfaces with dust deposits. These surfaces on any plane could include beams, shelves, and external surfaces of process equipment and structures. Calculate the total area, A_{sur} , of these surfaces with dust deposits.
- (4) Weigh each sample and calculate the average mass, $\bar{M}_f$ (grams), of the surface samples.
- (5) Determine the total mass, M_o , of combustible dust that could be released from the process equipment in the building.
- (6) Test the dust samples per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, to determine P_{max} , K_{St} , and the worst-case concentration, c_w , corresponding to the largest value of K_{St} .
- (7) Using the highest values of P_{max} and K_{St} , the building volume, V , and $\Pi = P_{red}/P_{max}$, use Equation 8.3.4 or 8.3.6 to calculate the vent area, A_{v3} , needed if the full building volume were filled with combustible dust.

- (8) Calculate the worst-case building partial volume fraction, X_r , in accordance with 8.4.5.3.1.
- (9) If the calculated $X_r > 1$, the minimum required vent area is equal to A_{v3} .
- (a) If $X_r \leq \Pi$, no deflagration venting is needed.
- (b) If $1 > X_r > \Pi$, the minimum required vent area, A_{v4} , is calculated from Equation 8.4.5.3 as follows:

[8.4.5.2]

$$A_{v4} = A_{v3} \cdot X_r^{-1/3} \cdot \sqrt{\frac{X_r - \Pi}{1 - \Pi}}$$

where:

A_{v4} = vent area for partial volume deflagration

A_{v3} = vent area for full volume deflagration as determined from Equation 8.3.4 or from 8.3.6

X_r = fill fraction $> \Pi$

$\Pi = P_{rel}/P_{max}$

8.4.5.3 The worst-case building partial volume fraction, X_r , shall be calculated from the following equation:

▲

[8.4.5.3]

$$X_r = \frac{\bar{M}_f \cdot A_{f-dusty} \cdot \eta_{Dfloor}}{A_{fs} \cdot (V - V_{solid}) \cdot c_r} + \frac{\bar{M}_s \cdot A_{sur} \cdot \eta_{Dsur}}{A_{ss} \cdot (V - V_{solid}) \cdot c_r} + \frac{M_e}{(V - V_{solid}) \cdot c_r}$$

where:

X_r = worst-case building partial fraction

$\bar{M}_f$ = average mass of floor samples (g)

$A_{f-dusty}$ = total area of floor with dust deposits (m²)

η_{Dfloor} = entrainment factor for floor accumulations

A_{fs} = measured floor areas (m²)

V = building volume (m³)

V_{solid} = volume of solid objects (m³)

c_w = worst-case dust concentration (g/m³)

$c_r = 0.5 \cdot c_w$

$\bar{M}_s$ = average mass of surface samples (g)

A_{sur} = total area of surfaces with dust deposits (m²)

η_{Dsur} = entrainment factor for surface accumulations

A_{ss} = measured sample areas of surfaces with dust deposits (m²)

M_e = total mass of combustible dust that could be released from the process equipment in the building (g)

8.4.5.3.1 If a measured value of c_w is available, the lowest value of c_w for the various samples shall be used to determine c_r in Equation 8.4.5.3.

8.4.5.3.2 If a measured value of c_w is not available, a value of 200 g/m³ shall be permitted to be used to determine c_r in Equation 8.4.5.3.

8.4.5.3.3* If measured values of $\bar{M}_f/A_f$ and $\bar{M}_s/A_s$ are not available, and if the facility is to be maintained with dust layer thickness in accordance with NFPA 654, an approximate value for these ratios shall be permitted to be used, based on a dust layer bulk density of 1200 kg/m³ and a layer thickness of 0.8 mm (1/32 in.) over the entire floor area and other surfaces defined in 8.4.5.3.4.

8.4.5.3.4 The total mass of dust that could be released from process equipment in the building/room M_e shall be determined as follows:

- (1) Evaluate equipment with exposed dust accumulations, such as but not limited to screeners, open-top conveyors or conveyor belts, open packaging or shipping containers, and enclosureless dust collectors
- (2) Evaluate anticipated episodic spills from equipment in light of current housekeeping procedures and practices
- (3) Do not include material in closed packaging or shipping containers, material in enclosed silos or storage bins, or in otherwise explosion-protected equipment

8.4.5.3.5 The entrainment factor, η_{Dh} for each representative area shall be determined by one of the following methods:

- (1) Assume an entrainment factor of 1
- (2) Calculate the entrainment factor as follows:
 - (a) Determine the average particle density, ρ_p for each sampled dust layer
 - (b) Determine the entrainment threshold velocity using the following equation:

[8.4.5.3.5a]

$$U_t = 0.46 \cdot \rho_p^{1/3}$$

where:

U_t = threshold velocity (m/s)

ρ_p = particle density (kg/m³)

- (c) Assume a maximum free-stream velocity, U , of 50 m/s or establish a different free-stream velocity calculated from a maximum credible initiating event
- (d) Determine a maximum entrainment rate using the following equation:

[8.4.5.3.5b]

$$m'' = 0.002 \cdot \rho \cdot U \cdot (U^{1/2} - U_t^2/U^{3/2})$$

where:

m'' = entrained mass flux (kg/m²-s)

ρ = gas density (kg/m³)

U = free-stream velocity (m/s) $> U_t$

U_t = threshold velocity (m/s)

- (e) Determine initiating event time, t , by dividing the building's or enclosure's longest dimension by 1/2 the maximum free-stream velocity
- (f) Using the appropriate surface area, A , determine the maximum mass, M_{max} , from the presumed initiating event using the following equation:

[8.4.5.3.5c]

$$M_{max} = m'' \cdot A \cdot t$$

where:

m'' = entrained mass flux (kg/m²-s)

A = surface area (m²)

t = initiating event time(s)

- (g) Determine the entrainment factor using the following equation:

[8.4.5.3.5d]

$$\eta_D = \begin{cases} \frac{M_{max}}{M}, & \text{if } \frac{M_{max}}{M} < 1 \\ 1, & \text{if } \frac{M_{max}}{M} \geq 1 \end{cases}$$

where:

 M = average accumulation mass (kg) M_{max} = maximum entrained mass (kg)**8.5* Effects of Vent Ducts.**

▲ **8.5.1*** If there is no vent duct, $A_{vf} = A_{v4}$; otherwise, the effect of vent ducts shall be calculated from the following equations:

[8.5.1a]

$$A_{vf} = A_{v4} \cdot (1 + 1.18 \cdot E_1^{0.8} \cdot E_2^{0.4}) \cdot \sqrt{\frac{K}{K_0}}$$

[8.5.1b]

$$E_1 = \frac{A_{vf} \cdot L_{duct}}{V}$$

[8.5.1c]

$$E_2 = \frac{10^4 \cdot A_{vf}}{(1 + 1.54 \cdot P_{stat}^{4/3}) \cdot K_{St} \cdot V^{3/4}}$$

[8.5.1d]

$$K \equiv \frac{\Delta P}{\frac{1}{2} \cdot \rho \cdot U^2} = K_{inlet} + \frac{f_D \cdot L_{duct}}{D_h} + K_{elbows} + K_{outlet} + \dots$$

where:

 A_{vf} = vent area required when a duct is attached to the vent opening (m²) A_{v4} = vent area after adjustment for partial volume (m²), per Equation 8.4.3 K = overall resistance coefficient of the vent duct application K_0 = 1.5, the resistance coefficient value assumed for the test configurations that generated the data used to validate 8.2.1 and 8.2.2 L_{duct} = vent duct overall length, including centerline length through elbows and fittings (m) V = enclosure volume (m³) P_{stat} = nominal static opening pressure of the vent cover (bar-g) ΔP = static pressure drop from the enclosure to the duct exit at average duct slow velocity, U (bar) ρ = gas density (kg/m³) U = fluid velocity (m/s) K_{inlet} K_{elbows} = resistance coefficients for fittings K_{outlet} f_D = D'Arcy friction factor for fully turbulent flow; see Equation A.8.5c for typical formula [114] D_h = vent duct hydraulic diameter (m)

8.5.2 Under certain circumstances, in which there are two solutions for vent area, the smaller vent area shall be used.

8.5.3 Where these equations do not produce a solution for vent area, the design shall be modified by decreasing the vent duct length, strengthening the vessel to contain a higher P_{red} , or both.

8.5.4 Equation 8.5.1a shall not be used if the vent cover is not located at the entrance of the duct.

8.5.5 Equation 8.5.1a shall not be used if the initial pressure exceeds 0.2 bar-g.

8.5.6 Equation 8.5.1a shall not be used if the vent duct cross-sectional area varies by more than 10 percent anywhere along the length.

8.5.7 It shall be permitted to use Equation 8.5.1a for vent ducts equipped with elbows, bird screens, and rain covers as long as the obstructions are properly accounted for through the duct resistance coefficient K .

8.5.8 It shall be permitted to use vent ducts outside the limitations of Equation 8.5.1a if designed in accordance with full-scale test data.

8.5.9 The maximum length of the duct shall be limited to obey the following inequality, where $\min(A, B)$ = the minimum value of either A or B :

[8.5.9]

$$L_{eff} \leq \min \left[\frac{10,000 \cdot D}{K_{St}}, \frac{11,000}{K_{St}} \right]$$

where:

$$L_{eff} = \min(L_{duct}, L_{dusty})$$

$$L_{dusty} = (P_{max} - P_{red}) \cdot V / A_v$$

8.5.10 Table 8.5.10 shall be reviewed to determine the combination rules and limitations for application of various dust models in this chapter.

8.6 Bins, Hoppers, and Silos.

8.6.1 Deflagration venting for bins, hoppers, and silos shall be from the top or the upper side, above the maximum level of the material contained, and shall be directed to a safe outside location (see Section 6.8).

8.6.1.1* Deflagration venting shall be permitted to be through vent closures located in the roof or sidewall or by making the entire enclosure top a vent.

8.6.1.2 In all cases, the total volume of the enclosure shall be assumed to contain a suspension of the combustible dust in question.

8.6.1.3 No credit shall be taken for the enclosure being partly full of settled material.

8.6.1.4 For a multiple application, the closures shall be placed symmetrically to minimize the effects of potential reaction forces (see 6.3.5).

8.6.1.5 Care shall be taken not to fill the enclosure above the bottoms of the vent panels, because large amounts of dust can blow out into the atmosphere, ignite, and form a large fireball.

Table 8.5.10 Combination Rules and Limitations for NFPA 68 Dust Models

Vent ducts	$P_{initial} \leq 1.2$ bar-abs $1 \leq L/D \leq 6$ Allow turbulence Panel density ≤ 40 kg/m ² Allow partial volume No elevated pressure (calculate vent duct effect last)
Partial volume	$P_{initial} \leq 1.2$ bar-abs $1 \leq L/D \leq 6$ Allow turbulence Panel density ≤ 40 kg/m ² Allow vent ducts No elevated pressure (calculate vent duct effect last)
Panel inertia	$P_{initial} \leq 1.2$ bar-abs $1 \leq L/D \leq 6$ Allow turbulence Allow partial volume Allow vent ducts No elevated pressure (calculate vent duct effect last)
Elevated pressure	$1.2 < P_{initial} \leq 5$ bar-abs $1 \leq L/D \leq 6$ Turbulence (v_{axial} and v_{tan}) < 20 m/s Panel density $\leq M_T$ and ≤ 40 kg/m ² Full volume, no partial volume No vent ducts (calculate elevated pressure effect last)
Subatmospheric pressure	$P_{initial} \leq 0.8$ bar-abs $1 \leq L/D \leq 6$ Allow turbulence Panel density ≤ 40 kg/m ² Allow partial volume Allow vent ducts (calculate vent duct effect last)

8.6.2 Deflagration venting shall be permitted to be accomplished by means of vent closures located in the roof of the enclosure.

8.6.2.1 The vent operation procedures outlined in Section 6.5 shall be followed.

8.6.3* The entire enclosure top shall be permitted to be used to vent deflagrations.

8.6.3.1 Roof panels shall be as lightweight as possible and shall not be attached to internal roof supports.

8.6.3.2 API STD 650, *Welded Steel Tanks for Oil Storage*, shall be referenced for guidelines for the design of a frangible, welded roof joint.

8.6.3.3 Equipment, piping, and other process connections shall not restrict the roof's operation as a vent closure.

8.6.3.3.1 Equipment, piping, and other process connections shall be included in the vent panel inertia evaluation per Section 8.3.

8.6.3.4 The entire enclosure rooftop shall be labeled as an explosion vent in accordance with 11.3.4.

8.6.3.5 Access to the rooftop shall be restricted during operation of the protected enclosure.

8.6.3.6 Initial inspection shall include the roof-wall connections.

8.6.3.7 The remaining portions of the enclosure, including anchoring, shall be designed to resist the calculated P_{red} based on the vent area provided. (See Section 6.3.)

8.7 Venting of Dust Collectors Using Bags, Filters, or Cartridges.

8.7.1* Determination of V and L/D for Dust Collectors.

8.7.1.1* Unlike the general approach of 6.4.3.2, the maximum flame length, H , shall be the longest distance, taken on the dirty side of the tube sheet, parallel to the major axis of the enclosure, either horizontal or vertical, and ignoring the location of explosion vents.

8.7.1.2* Both the enclosure volume, V , and the effective volume of the enclosure, V_{eff} , shall be determined based on the total dirty volume of the enclosure on the dirty side of the tube sheet, including the volume occupied by the filters and ignoring the location of the explosion vents.

8.7.1.3 The effective area of the enclosure, A_{eff} , shall be determined by dividing V_{eff} by H .

8.7.1.4 The effective hydraulic diameter, D_{he} , for the enclosure shall be determined based on the general shape of the enclosure taken normal to the maximum flame path. (See 6.4.3.6.)

8.7.1.5 L/D for dust collectors shall be set equal to H/D_{he} as determined above.

8.7.2* In applications involving flexible filters where vents are located totally above the free end of the filter and a free vent path inside the dust collector is not maintained with internal restraint, the otherwise required minimum vent area shall be increased by 25 percent.

8.7.3 If the clean air plenum contains dust, or if the material entering the dust collector is a hybrid mixture, one of the following protection measures shall be applied:

- (1) A separate vent shall be provided on the clean air side, calculated based on the clean air side volume using the methodology in Chapter 7 or Chapter 8, as applicable.
- (2) The clean air side gas concentration shall be evaluated for flammability and protected in accordance with NFPA 69.

8.8 Bucket Elevators.

8.8.1* Bucket elevators shall be classified as single-casing (single leg) or double-casing (twin leg) design.

8.8.2* Head and Boot Vents.

8.8.2.1 Vent areas shall be not less than the cross-sectional area of each leg and at a minimum shall be fitted both at the head and as close to the boot as practicable.

8.8.2.2 Where a vent is not installed directly on the boot, a vent shall be installed on each casing at a distance from the boot less than or equal to the smaller of 6 m or the additional vent spacing distance per Table 8.8.3.3.

8.8.3 Additional Casing Vents.

8.8.3.1 The owner/operator shall be permitted to choose a design strength based on a P_{red} of 0.2, 0.5, or 1.0 bar-g.

8.8.3.2 The casing(s), head, and boot shall all be designed for the same P_{red} chosen from 8.8.3.1.

8.8.3.3 Additional vents shall be installed in each casing at center-to-center spacing distance along the elevator axis based on the bucket elevator classification, the K_{St} of the material being handled, and the design strength based on P_{red} as given in Table 8.8.3.3.

8.8.3.4 For a P_{red} that falls between one of the P_{red} values on Table 8.8.3.3, interpolation between numerical values on the table, but not extrapolation, shall be permitted.

8.8.3.5* Where plastic buckets are used, the corresponding anticipated elevator P_{red} of 0.2, 0.5, or 1.0 bar-g shall be increased by the factors given in Table 8.8.3.5 before applying the spacing requirements in 8.8.3.3.

8.8.3.6* At each vent location, the total vent area shall be not less than the cross-sectional area of each leg.

8.8.3.7 For K_{St} values less than 100 bar-m/s where a P_{red} of 0.2 bar-g is selected, vents shall be placed at an interval not exceeding 6 m on the leg(s).

8.8.4* Vent closures shall have P_{stat} less than or equal to 0.1 bar-g.

Table 8.8.3.3 Additional Vent Spacing

Bucket Elevator Classification	K_{St} (bar-m/s)	Spacing (m)		
		P_{red} 0.2 bar-g	P_{red} 0.5 bar-g	P_{red} 1.0 bar-g
Double-casing (twin leg)	<100	6	None required	None required
	100–150	3	10	19
	151–175	N/A	4	8
	176–200	N/A	3	4
	>200	N/A	N/A	3
Single-casing (single leg)	<100	N/A*	None required	None required
	100–150	N/A	7	14
	151–175	N/A	4	5
	176–200	N/A	3	4
	>200	N/A	N/A	3

N/A: Not allowed.

*For P_{red} = 0.3 bar-g, vent spacing of 6 m is appropriate.

Source: [120]

Table 8.8.3.5 P_{red} Increase for Plastic Buckets

K_{St} (bar-m/s)	Percent Increase in P_{red}
<100	20
100–150	35
151–200	50

Source: [120, 124].

8.9* Venting Internal to a Building with Flame-Arresting and Particulate Retention Device.

8.9.1 Expected overpressure shall be compared to the building design, and building venting shall be considered to limit overpressures.

8.9.1.1 The resulting pressure increase in an unvented building shall be permitted to be estimated from the following:

- (1) $\Delta P = 1.74 P_0 (V_1/V_0)$
- (2) V_0 = free volume of building
- (3) V_1 = volume of protected equipment
- (4) P_0 = ambient pressure [14.7 psia (1.013 bar-abs)]
- (5) ΔP = pressure rise in the building (in same units as P_0)

8.9.1.2 It shall be permitted to use a lower value of the coefficient than that shown in 8.9.1.1(1) where experimental data are available to substantiate the lower value.

8.9.2 The deflagration venting area provided for the protected enclosure shall be adjusted to compensate for the venting efficiency as determined by test for the device.

8.10* Venting Silos or Other Storage Vessel Provided with Integral Bin Vents.

8.10.1 Where bin vents (air material separators) are installed in common with a silo or any other storage vessel, they shall be protected as follows:

- (1) The protected volume shall be calculated as the sum of the volume of the silo and the volume of the collector in accordance with Section 8.7.
- (2) The L/D of the combination shall be calculated based on the dimensions of the silo alone in accordance with Section 6.4.
- (3) Vent panels shall be located on the silo top surface or on the side walls above the maximum level of the contents of the silo.
- (4) It shall be permitted to locate a portion of the venting on the bin vent surface in accordance with the following proportions:

[8.10.1a]

$$A_{v,bin\ vent} = A_{v,total} - A_{v,silo\ min}$$

[8.10.1b]

$$A_{v,silo\ min} = \left(\frac{V_{silo}}{V_{total}} \right)^{2/3} A_{v,total}$$

where:

$A_{v,bin\ vent}$ = vent area of the bin vent/collector

$A_{v,total}$ = total vent area calculated for the bin vent–silo combination

$A_{v,silo\ min}$ = minimum explosion venting area required to be on the silo

$A_{v,silo}$ = actual explosion venting area installed on the silo

8.10.2 Where the open area of the connection between the bin vent and the silo is greater than or equal to the vent area required for the combined volume, it shall be permitted to locate all or any portion of the venting on the bin vent surface.

8.10.2.1 When 8.10.2 is applied, the clear path requirements of Section 8.7 shall apply.

8.11* Deflagration Venting of Enclosures Interconnected with Pipelines.

▲ 8.11.1* For interconnecting pipelines with inside diameters no greater than 0.3 m (1 ft) and lengths no greater than 6 m (20 ft), the following requirements shall apply [104]:

- (1) The venting device for the enclosure shall be designed for $P_{stat} < 0.2$ bar-g.
- (2) Enclosures of volumes within 10 percent of each other shall be vented as determined by 8.2.1 and 8.2.2.
- (3) If enclosures have volumes that differ by more than 10 percent, the vents for both enclosures shall be designed as if P_{rel} were equal to 1 bar-g or less. The enclosure shall be designed with P_{es} equal to a minimum of 2 bar-g.
- (4) If it is not possible to vent the enclosure with the smaller volume in accordance with this standard, the smaller enclosure shall be designed for the maximum deflagration pressure, P_{max} , and the vent area of the larger enclosure with the larger volume shall be doubled.
- (5) The larger enclosure shall be vented or otherwise protected as described in NFPA 69 in order for the deflagration venting of smaller enclosures to be effective.

8.11.2* For enclosures outside the scope of 8.11.1, explosion isolation or suppression shall be provided in accordance with NFPA 69 unless a documented risk assessment acceptable to the authority having jurisdiction demonstrates that increased vent area prevents enclosure failure.

Chapter 9 Venting of Deflagrations of Gases and Dusts in Pipes and Ducts Operating at or Near Atmospheric Pressure

9.1* Introduction.

9.1.1 This chapter applies to systems handling gases or dusts operating at pressures up to 0.2 bar-g (3 psi).

9.1.2 This chapter shall apply to pipes, ducts, and elongated vessels with length-to-diameter ratios of 5 or greater for gases and 6 or greater for dusts.

9.1.3 This chapter shall not apply to vent discharge ducts.

9.1.4 This chapter shall not apply to oxidants other than air or to mixtures at elevated initial temperatures that are greater than 57°C (134°F).

9.2* Design.

9.2.1 Each vent location along a pipe, duct, or elongated vessel shall have a vent area equal to the total cross-sectional area at each vent location.

9.2.2 The vent area needed at a vent location shall be permitted to be accomplished by using one, or more than one, vent at each location.

9.2.3 For noncircular cross sections, the diameter shall be the hydraulic diameter that is equal to $4(A/p)$, where A is the cross-sectional area and p is the perimeter of the cross section.

9.2.4* Pipes or ducts connected to a vessel in which a deflagration can occur shall have a vent located on the pipe or duct at a location no more than two pipe or duct diameters from the point of connection to the vessel.

9.2.5 For systems that handle gases, vents shall be provided on each side of turbulence-producing devices at a distance of no more than three diameters of the pipe or duct.

9.2.6 The weight of deflagration vent closures shall not exceed 12.2 kg/m² (2.5 lb/ft²) of free vent area.

9.2.7 Deflagration vents shall discharge to a location that cannot endanger personnel.

9.2.8 The static burst pressure of the vent closures shall be less than 0.3 bar-g (4.4 psi).

9.2.9 Transition to Detonation.

9.2.9.1 Vents shall be placed on pipes and ducts to prevent a deflagration from transitioning into a detonation.

9.2.9.2* If L/D ratios are greater than those shown in Figure 9.2.10.1, multiple vents shall be installed in accordance with Section 9.3.

9.2.10 Use of a Single Deflagration Vent on a Pipe or Duct.

9.2.10.1* Figure 9.2.10.1 shall be used to determine the maximum allowable length of a smooth, straight pipe, duct, or vessel that is closed on one end and vented on the other where no additional deflagration vents are required.

9.2.10.2 The maximum pressure during deflagration venting, P_{rel} , in a pipe or duct shall be no greater than 50 percent of the yield strength of the pipe or duct.

9.2.10.2.1 Flammable Gas Systems with a Flow Velocity of 2 m/s or Less.

9.2.10.2.1.1 The maximum pressure during deflagration venting, P_{rel} , in a pipe or duct that conveys propane or gases that have a fundamental burning velocity of less than 60 cm/s shall be determined from Figure 9.2.10.2.1.1.

9.2.10.2.1.2 For other pipe diameters, P_{rel} shall be determined by interpolation using Figure 9.2.10.2.1.1.

9.2.10.2.2 Dust Systems with a Flow Velocity of 2 m/s or Less.

9.2.10.2.2.1* The maximum pressure during deflagration venting, P_{rel} , in a pipe or duct that conveys dusts shall be estimated from Figure 9.2.10.2.2.1.

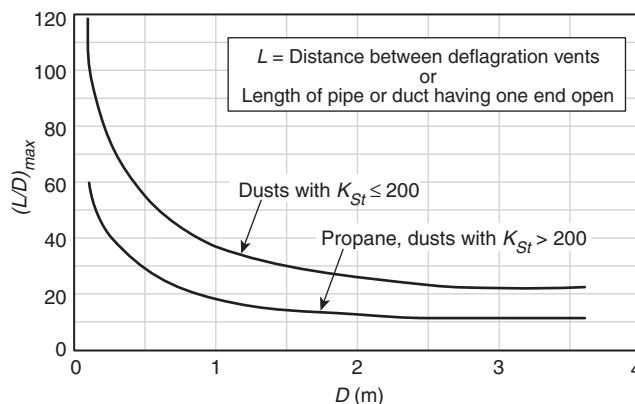


FIGURE 9.2.10.1 Maximum Allowable Distance, Expressed as Length-to-Diameter Ratio, for a Smooth, Straight Pipe or Duct.