NFPA®

68

Standard on Explosion Protection by Deflagration Venting

2018

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NFPA® 68

Standard on

Explosion Protection by Deflagration Venting

2018 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 10, 2017, with an effective date of November 30, 2017, 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 November 30, 2017.

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 has been added to adjust the K_{St} values for certain metal dusts if the K_{St} value was obtained in a vessel smaller than 1 m^3, and an equation has been 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, and 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 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* has been added. Requirements for the use of plastic buckets in bucket elevators have been moved from the annex to the body of the standard.

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Standard on

Explosion Protection by Deflagration Venting

2018 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex L. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

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 autoignition 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.

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

Δ 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)
Energy	1 J	1.00 W-s
	1 Btu	1055 J
	1 J	0.738 ft-lb
K_{St} conversion	1 bar-m/s	47.6 psi-ft/s
	1 psi-ft/s	0.021 bar-m/s
Concentration	1 oz avoirdupois/ft^3	1000 g/m^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)

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

A = area (m^2, ft^2, or $in.^2$)
A_S = internal surface area of enclosure (m^2 or ft^2)
A_v = vent area (m^2 or ft^2)
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/m^3 or oz/ft^3)
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 (m^3 or ft^3)

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,* 2014 edition.

NFPA 70®, National Electrical Code®, 2017 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2017 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2017 edition.

2.3 Other Publications.

Δ **2.3.1 API Publications.** American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API STD 650, *Welded Tanks for Oil Storage*, 2013, Errata, 2014.

2.3.2 ASME Publications. ASME International, Two Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, 2015.

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,* 2012A.

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,* 2016 edition.
NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2016 edition.
NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2017 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 phrase "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 that presents a flash fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. [**654,** 2017]

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.

Δ **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 ignitible mixture with air near the surface of the liquid or the solid.

N **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.

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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,** 2016]

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.

Δ **3.3.30 Replacement-in-Kind.** A replacement that satisfies the design specifications. [**652,** 2016]

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.