First Revision No. 28-NFPA 68-2021 [Global Input]

Add to E.1:

The value of Su can be estimated using the method given here if an experimental value of Su is not available. Other methods can be used to estimate Su, such as the maximum experimental safe gap (MESG) correlation in Schampel [125].

Add to K.1:

(125) Schampel, K., Flammendurchschlagsicherungen (Bd. 170), Kontakt & Studium), Ehningen bei Boblingen; Expert-Verlag, 1988

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri Jun 04 15:00:42 EDT 2021

Committee Statement

Committee Statement: Provide users of the standard with the document intended to be referenced here.

Response Message: FR-28-NFPA 68-2021

First Revision No. 30-NFPA 68-2021 [Global Input]

In 7.2.3.6 and 7.2.6.1, change "dynamic velocity" to "dynamic viscosity".

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri Jun 04 15:04:37 EDT 2021

Committee Statement

Committee Statement: The correct term intended by the committee was viscosity, not velocity.

Response Message: FR-30-NFPA 68-2021

First Revision No. 12-NFPA 68-2021 [Detail]

Table F.1(d) Metal Dusts

Material	Mass Median Diameter (µm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar-g)	K_{St} (bar-m/s)	Dust Hazard Class
Aluminum	29	30	12.4	415	3
Bronze	18	750	4.1	31	1
Iron carbonyl	<10	125	6.1	111	1
Magnesium	28	30	17.5	508	3
~~Phenolic resin~~	~~55~~	—	~~7.9~~	~~269~~	~~2~~
Zinc	10	250	6.7	125	1
Zinc	<10	125	7.3	176	1

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue May 25 13:04:25 EDT 2021

Committee Statement

Committee Statement: Phenolic resin is not a metal even though it may be used in metal manufacturing. Additionally, this information is redundant as it appears in the plastic dust table already.

Response Message: FR-12-NFPA 68-2021

Public Input No. 15-NFPA 68-2019 [Section No. F.1]

NFPA

First Revision No. 4-NFPA 68-2021 [Chapter 2]

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~~ 2019 edition.

NFPA 70®, National Electrical Code®, ~~2017~~ 2023 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* ~~2017~~ 2020 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* ~~2017~~ 2022 edition.

2.3 Other Publications.

2.3.1 API Publications.

American Petroleum Institute, ~~1220 L Street,~~ 200 Massachusetts Avenue NW, Suite 1100, Washington, DC ~~20005-4070~~ 20001-5571 .

API STD 650, *Welded Tanks for Oil Storage*, 13th edition, ~~2013, Errata, 2014~~ 2020 .

2.3.2 ASME Publications.

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

ASME *Boiler and Pressure Vessel Code*, ~~2015~~ 2017 .

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~~ 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,* ~~2016~~ 2021 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust,* ~~2016~~ 2019 edition.

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

Supplemental Information

File Name	Description	Approved
68_FR_4_Chapter_2.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri May 21 22:21:05 EDT 2021

Committee Statement

Committee Statement: Updating reference standards to the most recent editions.

Response Message: FR-4-NFPA 68-2021

First Revision No. 3-NFPA 68-2021 [Section No. 3.3.2]

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,**~~ **652,** ~~2017~~ 2019]

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri May 21 22:15:24 EDT 2021

Committee Statement

Committee Statement: NFPA 654 now extracts this definition from NFPA 652.

Response Message: FR-3-NFPA 68-2021

First Revision No. 2-NFPA 68-2021 [Section No. 3.3.30]

3.3.30 Replacement-in-Kind.

A replacement that satisfies the design specifications of the replaced item . [**652,**~~2016~~ 2019]

Submitter Information Verification

Committee: EXL-AAA
Submittal Date: Fri May 21 22:13:46 EDT 2021

Committee Statement

Committee Statement: Updating the extract to the most recent edition of the standard.
Response Message: FR-2-NFPA 68-2021

First Revision No. 11-NFPA 68-2021 [Section No. 6.7.3]

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 ~~7.3.2~~ 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].

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue May 25 12:56:01 EDT 2021

Committee Statement

Committee Statement: This revision fixes an incorrect cross reference.

Response Message: FR-11-NFPA 68-2021

Public Input No. 19-NFPA 68-2020 [Section No. 6.7.3]

First Revision No. 15-NFPA 68-2021 [New Section after 6.9.2]

6.9.3

When these devices are being used with metal dusts, in addition to the requirements of 6.9.2 , the listing or approval shall specify the maximum metal adiabatic flame temperature.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Wed May 26 12:14:37 EDT 2021

Committee Statement

Committee Statement: The committee recognizes the need to address adiabatic flame temperature when applying flameless venting to metal dusts.

Response Message: FR-15-NFPA 68-2021

Public Input No. 30-NFPA 68-2021 [New Section after 6.9.8]

Public Input No. 29-NFPA 68-2021 [New Section after A.7.1.1]

First Revision No. 13-NFPA 68-2021 [Section No. 7.3.2]

7.3.2*

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

$$X_r = \frac{V_{gas} / V_{enc}}{x_{st}} \quad X_r = \frac{V_{gas} / \left(V_{enc} - V_{solid}\right)}{x_{st}} \qquad [7.3.2]$$

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

A.7.3.2

The open volume of the enclosure is the total volume of the enclosure less the volume of large solid objects, not the total volume of the enclosure.

Where an object is not gastight, the solid volume of the object might be less than the total volume of the object. Typical electrical or equipment cabinets are not gastight, some are ventilated, and the volume of such cabinets is not the same as the volume of solid objects within the cabinets. There are certain applications, such as battery energy storage systems, where electrical equipment is considered a solid object and would be subtracted from the enclosure volume.

This distinction becomes relevant as the fraction of the enclosure volume filled with solid objects increases, reducing the open-air volume available for mixing. If the partial volume effects were calculated using the total volume of the enclosure, the required vent area would be underpredicted.

Supplemental Information

File Name	Description	Approved
68_FR_13_7.3.2.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Wed May 26 10:26:00 EDT 2021

Committee Statement

Committee Statement: The volume of solid objects should be subtracted from the enclosure volume to accurately calculate the volume available for mixing of gas and air and the required vent area. This clarification was prompted by the calculation of vent areas for Battery Energy Storage Systems.

Response Message: FR-13-NFPA 68-2021

Public Input No. 23-NFPA 68-2021 [New Section after A.7.2.6.1]

Public Input No. 22-NFPA 68-2021 [Section No. 7.3.2]

First Revision No. 16-NFPA 68-2021 [Section No. 7.6]

7.6* Fireball Dimensions.

Measures shall be taken to reduce the risk to personnel and equipment from the effects of fireball temperature.

A.7.6

The fireball from a vented gas or dust deflagration presents a hazard to personnel in the vicinity. People caught in the flame itself will be at obvious risk from burns, but those who are outside the flame area can be at risk from thermal radiation effects. The heat flux produced by the fireball, the exposure time, and the distance from the fireball are important variables to determine the hazard.

~~The number of vents, *n* , should be those vents whose discharge directions are separate and evenly distributed around the circumference of a vessel or along the central axis. If multiple vent panels cover a single vent opening, they should not be treated as separate for this purpose.~~

7.6.1

A documented risk assessment shall be permitted to be used to reduce the hazard distances calculated in this section.

7.6.2*

The hazard zone from a vented gas deflagration shall be calculated by the following equation: In the case of gas deflagration venting, *D* , the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of the vent discharge *(see Figure 7.6.2)* shall be expressed by Equation 7.6.2:

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

[7.6.1 7.6.2]

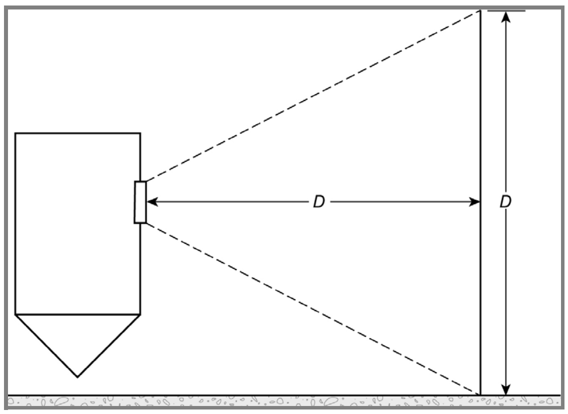
where:

D = axial distance (front-centerline) from 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 evenly distributed vents *(see 7.6.2.1 and 7.6.2.2)*

Figure 7.6.2 Fireball Dimensions



A.7.6.2

If the vented material exits from the vent horizontally, the horizontal length of the fireball is anticipated. It is extremely important to note that the fireball can, in fact, extend downward as well as upward [91, 108]. In some deflagrations, buoyancy effects can allow the fireball to rise to elevations well above the distances specified. Equation 7.6.2 calculates the fireball dimension, but that is not the only factor to consider in evaluating the hazard from an emerging vented deflagration. Other factors to consider include, but are not limited to, environmental matters such as prevailing wind speed and direction, external nearby structures, particle size, vent configuration and weight, and nearby operations. A safety factor should be considered based on an assessment of the risk elements that are present in or near the anticipated path of travel of the emerging flame and unburned gas.

7.6.2.1*

Evenly distributed vents shall meet the requirements in 7.6.2.1.1 through 7.6.2.1.3 .

A.7.6.2.1

The number of vents, *n*, should be those vents whose discharge directions are separate and evenly distributed around the circumference of a vessel or along the central axis calculated fireball hazard areas do not overlap. If the calculated fireball hazards of vents overlap, they should not be counted separately in the calculation of *n* . If multiple vent panels cover a single vent opening, they should not be treated as separate for this purpose counted separately in the calculation of *n* .

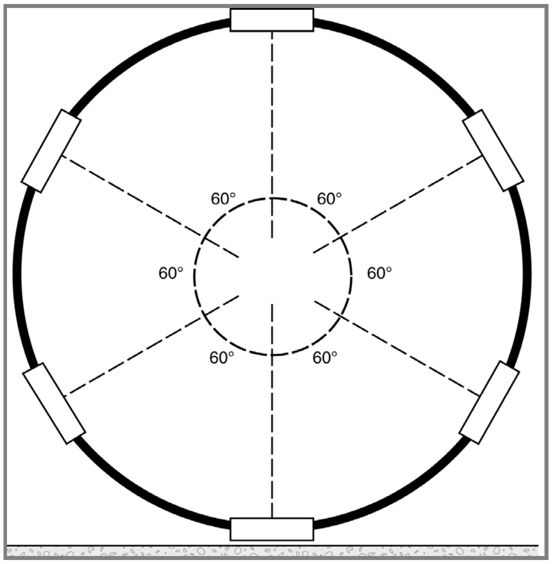
7.6.2.1.1*

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.

A.7.6.2.1.1

An example of evenly distributed vents spaced around the circumference of a vessel is shown in Figure A.7.6.2.1.1 .

Figure A.7.6.2.1.1 Vessel with Vents Around Circumference.



7.6.2.1.2

Vents located on different sides of a rectangular enclosure shall be considered evenly distributed.

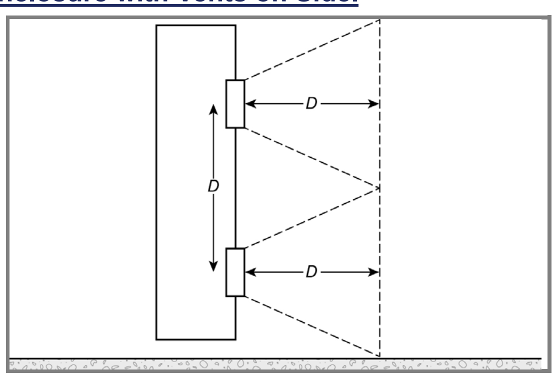
7.6.2.1.3*

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 the dimension D, determined by initially assuming that all of the vents are evenly distributed.

A.7.6.2.1.3

An example of evenly distributed vents spaced on the same side of a rectangular enclosure is shown in Figure A.7.6.2.1.3 .

Figure A.7.6.2.1.3 Enclosure with Vents on Side.



7.6.2.2

Vents that do not meet the requirements of 7.6.2.1 shall not be counted separately to calculate *n* in 7.6.2 .

7.6.2.3*

Axial distance calculated by Equation 7.6.2 shall not be limited for gases.

A.7.6.2.3

There is no maximum limit for the length of the calculated axial distance for gases in contrast to combustible dust fireballs where a maximum axial distance is listed in 8.9.2.3 .

~~**7.6.3**~~

~~The hazard zone measured radially (to the sides, measured from the centerline of the vent) shall be calculated as 0.5 *D* .~~

Supplemental Information

File Name	Description	Approved
68_FR_16_7.6.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 09:42:37 EDT 2021

Committee Statement

Committee Statement: Language was needed to explain how to evaluate the number of evenly distributed vents and the statements were realigned to mirror the order in Chapter 8 for dust fireball dimensions.

Response Message: FR-16-NFPA 68-2021

Public Input No. 3-NFPA 68-2018 [Section No. 7.6.1]

First Revision No. 29-NFPA 68-2021 [Section No. 8.3.4]

8.3.4

For $M > M_T$, the required vent area A_{V3}, shall be calculated as follows:

$$A_{v3} = F_{SH}\left[1+(0.0075)\cdot M^{0.6}\cdot\left(\frac{K_{St}^{0.5}}{n^{0.3}VP_{red}{}^{0.2}}\right)\right]\cdot A_{v2}$$ **[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 (bar-m/s)

n = number of panels

V = volume (m~~2~~ 3)

P_{red} = ~~Reduced~~ reduced pressure after deflagration venting (bar-g)

A_{V2} = vent area calculated by 8.2.4.5, Equation 8.2.4.6, or Equation 8.2.4.7, as applicable

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri Jun 04 15:03:39 EDT 2021

Committee Statement

Committee Statement: Correcting the units for volume.

Response Message: FR-29-NFPA 68-2021

First Revision No. 26-NFPA 68-2021 [New Section after 8.4.1]

8.4.1

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

$$X_r = \frac{M_e / (V_{enc} - V_{solid})}{0.5 c_w} \quad [8.4.1]$$

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

8.4.2

It shall be permitted to evaluate X_r based upon $(dP/dt)_{max}$ versus concentration test data using ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, in order to minimize the vent area correction required by 8.4.3.

Supplemental Information

File Name	Description	Approved
68_FR_26_8.4.1_8.4.2.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 12:55:08 EDT 2021

Committee Statement

Committee Statement: A method to calculate the partial volume fill fraction has been provided to address the potential for greater fill fraction and required vent area at lower dust concentrations.

Response Message: FR-26-NFPA 68-2021

First Revision No. 27-NFPA 68-2021 [Section No. 8.4.3.3.5]

8.4.5.3.5

The entrainment factor, η_D, 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:

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

[~~8.4.3.3.5a~~ 8

where:

U_t = threshold velocity (m/s)

ρ_p = particle density (kg/m^3)

(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:

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

[~~8.4.3.3.5b~~ 8

where:

m'' = entrained mass flux (kg/m^2-s)

ρ = gas density (kg/m^3)

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 ½ 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:

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

[~~8.4.3.3.5c~~ 8

where:

m'' = entrained mass flux (kg/m^2-s)

A = surface area (m^2)

t = initiating event time(s)

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

$$\eta_D = \begin{Bmatrix} \dfrac{M_{max}}{M}, \text{ if } \dfrac{M_{max}}{M} < 1 \\ 1, \text{ if } \dfrac{M_{max}}{M} \geq 1 \end{Bmatrix}$$

[~~8.4.3.3.5d~~ 8

where:

M = average accumulation mass ~~of the sample~~ (~~g~~ kg)

M_{max} = maximum entrained mass (kg)

Supplemental Information

File Name	Description	Approved
68_FR_27_8.4.3.3.5_g_.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Fri Jun 04 14:43:11 EDT 2021

Committee Statement

Committee Statement:	Mass should be in kg to match all of the previous equations in this section. Also providing additional information for the users of this equation.
Response Message:	FR-27-NFPA 68-2021

First Revision No. 23-NFPA 68-2021 [Section No. 8.7.1]

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*

~~The~~ 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.

A.8.7.1.2

Many flexible and rigid filter elements extend upstream from the tube sheet and retain dust on the outer surface. This section does not subtract the volume of such elements from the effective volume. Pocket filter elements extend downstream from the tube sheet and retain dust on their inner surface. This section includes the volume of such elements in the effective volume. Therefore, for dust collectors, the effective volume (V_{eff}) is equal to the total dirty side volume (*V*) to be used in the venting equations.

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.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 12:05:45 EDT 2021

Committee Statement

Committee Statement: This revision clarifies how to calculate the volume V that is used in the venting equations, and that it does equal Veff for dust collectors.

Response Message: FR-23-NFPA 68-2021

First Revision No. 18-NFPA 68-2021 [Sections 8.8.3.3, 8.8.3.4]

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.

Table 8.8.3.3 Additional Vent Spacing

-	-	Spacing (m)		
Bucket Elevator Classification	**K_{St} (bar-m/s)**	**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]

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 ~~design~~ P_{red} of 0.2, 0.5, or 1.0 bar-g shall be increased by the factors given in Table 8.8.3.5before applying the spacing requirements in 8.8.3.3 .

Table 8.8.3.5 ~~Design~~ P_{red}~~Adjustment~~ 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].

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 10:28:39 EDT 2021

Committee Statement

Committee Statement: Guidance has been added to clarify that interpolation is acceptable, but not extrapolation. The section for plastic buckets was revised to make it clear that plastic buckets result in a required increase in the design strength of the elevator (due to an increase in Pred) vs metal buckets. In lieu of adding a new column to 8.8.3.3 as proposed in the Public Input, clarification was added to the headings of Table 8.8.3.4.

Response Message: FR-18-NFPA 68-2021

Public Input No. 21-NFPA 68-2020 [Sections 8.8.3.3, 8.8.3.4]

First Revision No. 17-NFPA 68-2021 [Section No. 8.9.2]

8.9.2*

In the case of dust deflagration venting, ~~the distance,~~ *D*, the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of the vent discharge *(see Figure 8.9.2)* shall be expressed by Equation 8.9.2:

$$D = K \cdot \left(\frac{V}{n}\right)^{1/3} \quad [8.9.2]$$

where:

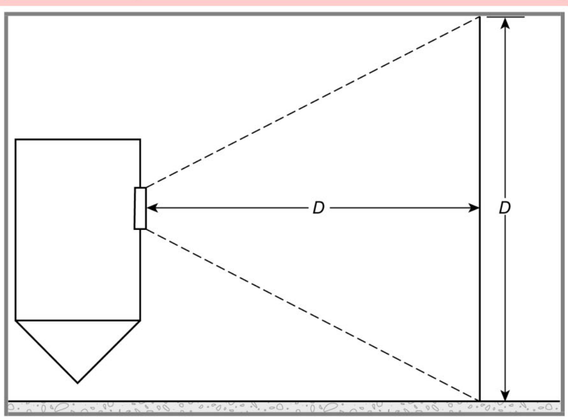
D = axial ~~distance (front) from~~ length, width, and height of fireball hazard zone distributed around the centerline of the vent (m)

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

V = volume of vented enclosure (m^3)

n = number of evenly distributed vents *(see 8.9.2.1 and 8.9.2.2)*

Figure 8.9.2 Fireball Dimensions.



A.8.9.2

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

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

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

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

8.9.2.1*

Evenly distributed vents shall meet the requirements in 8.9.2.1.1 through 8.9.2.1.3 .

A.8.9.2.1

The number of vents, *n* , should be those vents whose calculated fireball hazard areas do not overlap. If the calculated fireball hazards of vents overlap, they should not be counted separately in the calculation of *n* . If multiple vent panels cover a single vent opening, they should not be counted separately in the calculation of *n* .

8.9.2.1.1*

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.

8.9.2.1.2

Vents located on different sides of a rectangular enclosure shall be considered evenly distributed.

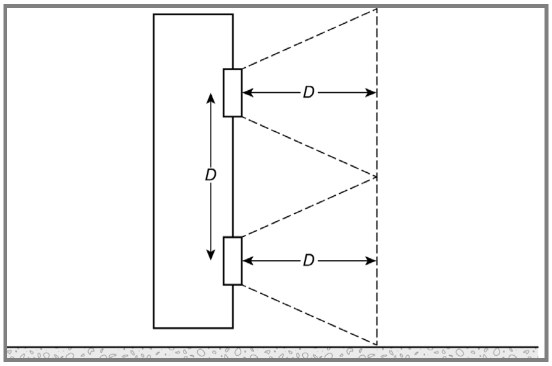
8.9.2.1.3*

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 the dimension D, determined by initially assuming that all of the vents are evenly distributed.

A.8.9.2.1.3

An example of evenly distributed vents spaced on the same side of a rectangular enclosure is shown in Figure A.8.9.2.1.3 .

Figure A.8.9.2.1.3 Enclosure with Vents on Side.



8.9.2.2

Vents that do not meet the requirements of 8.9.2.1 shall not be counted to calculate *n* in 8.9.2 .

8.9.2.3

Axial distance, calculated by Equation 8.9.2, shall be limited to 60 m [104].

8.9.2.3*

The maximum width and height of the projected flame shall be taken as *D* and shall be assumed to be equally distributed around the centerline of the vent discharge (*see Figure 8.9.2.2*).

A.8.9.2.3

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

Supplemental Information

File Name	Description	Approved
68_FR_17_8.9.2.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 09:48:47 EDT 2021

Committee Statement

Committee Statement: Language was needed to explain how to evaluate the number of evenly distributed vents and the statements were realigned to mirror the order in Chapter 7 for gas fireball dimensions. The figure for fireball dimensions was revised to show that the dimensions of D are significantly greater than the dimensions of the vessel, noting that the figure is not drawn to scale.

Response Message: FR-17-NFPA 68-2021

Public Input No. 5-NFPA 68-2018 [Section No. 8.9.2.2]

Public Input No. 4-NFPA 68-2018 [Section No. 8.9.2 [Excluding any Sub-Sections]]

First Revision No. 8-NFPA 68-2021 [New Section after 10.1.1.2]

10.1.1.3

The louvered vent shall be designed to withstand no less than 10 percent above the maximum intended P_{red} and documented via design calculations or a test report.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue May 25 12:34:43 EDT 2021

Committee Statement

Committee Statement: A design basis for the mechanical strength of louvers was required.

Response Message: FR-8-NFPA 68-2021

First Revision No. 9-NFPA 68-2021 [Section No. 10.2.1]

10.2.1 Manufactured Vent Design Documentation.

10.2.1.1

The vent closure manufacturer or designer shall be responsible for documenting the value and tolerance of the P_{stat} of a vent closure as well as the maximum P_{red}, where installed according to the manufacturer's recommendation in the intended application.

10.2.1.2*

Where non-fragmenting operation is desired, the evaluation of maximum P_{red} shall include all accessories, external release mechanisms, and insulation.

A.10.2.1.2

A test method for evaluating maximum P_{red} is presented in EN 14797, *Explosion venting devices*. Other dynamic loading test methods can be used to validate application limits including maximum K_{St}, fuel types (organic dust only, gas only, hybrid mixtures, or metal dusts), P_{red}, and *dP/dt* fragmentation limits.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue May 25 12:37:50 EDT 2021

Committee Statement

Committee Statement: Language has been added to address dynamic properties of vent closure operation, including fragmentation concerns.

Response Message: FR-9-NFPA 68-2021

First Revision No. 22-NFPA 68-2021 [Section No. A.1.3]

A.1.3

Vents act as a system in conjunction with the strength of the protected enclosure. However, some lightweight structures, such as damage-limiting buildings, can be considered to be totally self-relieving and require no specific vents.

NFPA 30, NFPA 30B, NFPA 33, NFPA 35, NFPA 52, NFPA 58 , NFPA 61, NFPA 69, NFPA 400, NFPA 484, NFPA 652 , and NFPA 654 specify under which conditions deflagration venting (explosion protection measures) is required.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 11:45:17 EDT 2021

Committee Statement

Committee Statement: Adding two other documents that refer to NFPA 68 for explosion venting requirements.

Response Message: FR-22-NFPA 68-2021

First Revision No. 21-NFPA 68-2021 [Section No. A.6.4.3]

A.6.4.3

Example 1. Cylindrical enclosure with a hopper and vented in the roof:

(1) *H* equals the vertical height of the enclosure = 6 m.

(2) V_{eff} equals the total free volume of the enclosure.

(a) The volume of the cylindrical part = $(\pi \cdot D^2 / 4) \cdot h$ = $[\pi \cdot (1.8)^2 / 4] \cdot 4 = 10.18$ m^3.

(b) The volume of the hopper, with diameters D_1 and D_2 = $\pi \cdot h \cdot [(D_1)^2 + (D_1 \cdot D_2) + (D_2)^2] / 12$ = π · 2 · [(~~2~~ 1.8)^2 + (~~2~~ 1.8 · 0.5) + (0.5)^2] / 12 = ~~2.75~~ 2.30 m^3.

(c) V_{eff} = 10.18 + ~~2.75~~ 2.30 = ~~12.93~~ 12.48 m^3.

(d) V_{eff} is the shaded region in Figure A.6.4.3(a).

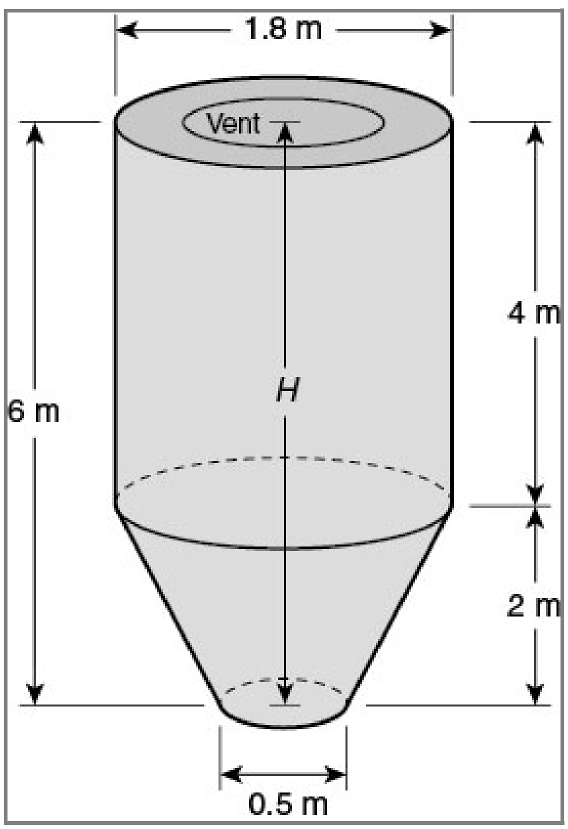
(3) $A_{eff} = V_{eff} / H$ = ~~12.93/6 = 2.155~~ 12.48 / 6 = 2.080 m^2.

(4) $D_{he} = 4 \cdot A_{eff} / p = (4 \cdot A_{eff} / \pi)^{0.5}$, assuming a cylindrical cross section.

(5) D_{he} = ~~1.656~~ 1.627 m.

(6) $L/D = H / D_{he}$ = ~~6/1.656~~ 6 / 1.627 = ~~3.62~~ 3.69 .

Figure A.6.4.3(a) Calculating *L/D* Ratio for a Cylindrical Vessel with a Hopper and a Top Vent.



In this example, D_{he} is less than the diameter of the cylindrical portion of the enclosure; thus *L/D* will be greater than if it had been calculated by taking the actual physical dimensions.

Example 2. Cylindrical enclosure with a hopper and vented at the side:

(1) *H* equals the vertical distance from the bottom of the hopper to the top of the vent = 4 m.

(2) V_{eff} equals the volume of the hopper plus the volume of the cylinder to the top of the vent.

(a) The volume of the cylindrical part = $(\pi \cdot D^2 / 4) \cdot h$ = $[\pi \cdot (1.8)^2 / 4] \cdot 2 = 5.09\ m^3$.

(b) The volume of the hopper, with diameters D_1 and D_2 = $\pi \cdot h \cdot [(D_1)^2 + (D_1 \cdot D_2) + (D_2^2)] / 12$ = π · 2 · [(~~2~~ 1.8)^2 + (~~2~~ 1.8 · 0.5) + (0.5)^2] / 12 = ~~2.75~~ 2.30 m^3.

(c) V_{eff} = 5.09 ~~2.75~~ + 2.30 = ~~7.84~~ 7.39 m^3.

(d) V_{eff} is the shaded region in Figure A.6.4.3(b).

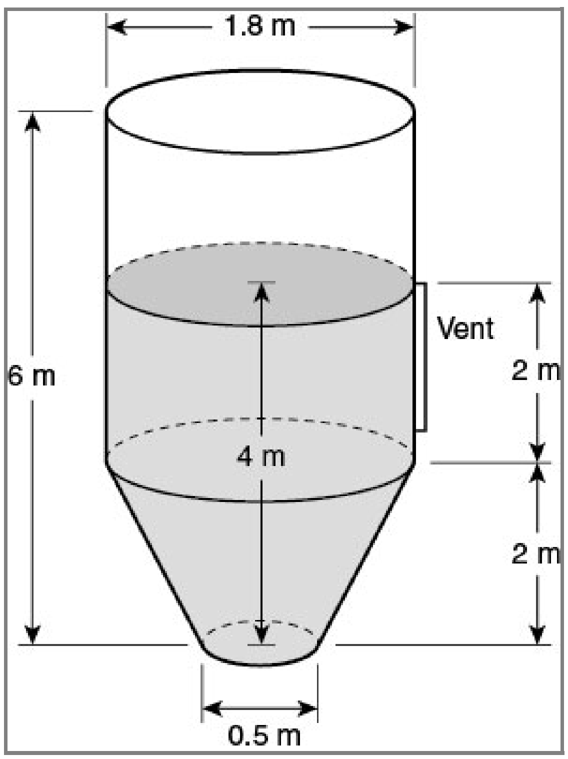
(3) $A_{eff} = V_{eff} / H$ = ~~7.84/4~~ 7.39 / 4 = ~~1.96~~ 1.85 m^2.

(4) $D_{he} = 4 \cdot A_{eff} / p = (4 \cdot A_{eff} / \pi)^{0.5}$, assuming a cylindrical cross section.

(5) D_{he} = ~~1.58~~ 1.53 m.

(6) $L/D = H / D_{he}$ = 4 / ~~1.58~~ 1.53 = ~~2.53~~ 2.61 .

Figure A.6.4.3(b) Calculating *L/D* Ratio for a Cylindrical Vessel with a Hopper and a Side Vent.



Example 3. Rectangular enclosure with a hopper and a side vent:

(1) *H* equals the vertical distance from the bottom of the hopper to the top of the vent = 5 m.

(2) V_{eff} equals the volume of the hopper plus the volume of the rectangular vessel to the top of the vent.

(a) The volume of the rectangular part = $A \cdot B \cdot h = 1.8 \cdot 1.5 \cdot 3 = 8.1\ m^3$.

(b) The volume of the hopper *[see Figure A.6.4.3(c)]* = $(a_1) \cdot h \cdot (b_2 - b_1) / 2 + (b_1) \cdot h \cdot (a_2 - a_1) / 2 + h \cdot$

$(a_2 - a_1) \cdot (b_2 - b_1) / 3 + (a_1) \cdot (b_1) \cdot h = (0.5) \cdot 2 \cdot$

$(1.5 - 0.3) / 2 + (0.3) \cdot 2 \cdot (1.8 - 0.5) / 2 + 2 \cdot$

$(1.8 - 0.5) \cdot (1.5 - 0.3) / 3 + (0.5) \cdot (0.3) \cdot 2 = 2.33\ m^3$.

(c) $V_{eff} = 8.1 + 2.33 = 10.43\ m^3$.

(d) V_{eff} is the shaded region in Figure A.6.4.3(d).

(3) $A_{eff} = V_{eff} / H = 10.43 / 5 = 2.09\ m^2$.

(4) $D_{he} = 4 \cdot A_{eff} / p = (A_{eff})^{0.5}$, assuming a square cross section.

$D_{he} = 1.44$ m.

(5) $L/D = H / D_{he} = 5 / 1.44 = 3.47$.

Figure A.6.4.3(c) Rectangular Hopper.

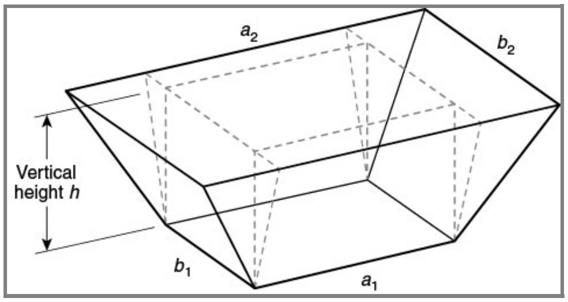
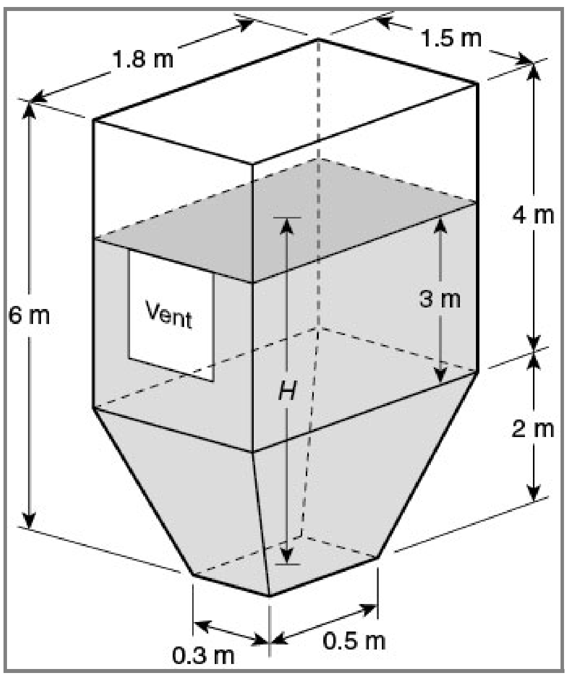


Figure A.6.4.3(d) Rectangular Enclosure with a Hopper and a Side Vent.



Example 4. Rectangular enclosure with a hopper and a side vent located close to the hopper:

(1) *H* equals the vertical distance from the top of the rectangular vessel to the bottom of the vent. *H* is the longest flame path possible because the vent is closer to the hopper bottom than it is to the vessel top = 4.5 m.

(2) V_{eff} equals the volume from the top of the rectangular vessel to the bottom of the vent.

(a) $V_{eff} = A \cdot B \cdot h$

(b) $V_{eff} = 1.8 \cdot 1.5 \cdot 4.5 = 12.15\ m^3$.

(c) V_{eff} is the shaded region in Figure A.6.4.3(e).

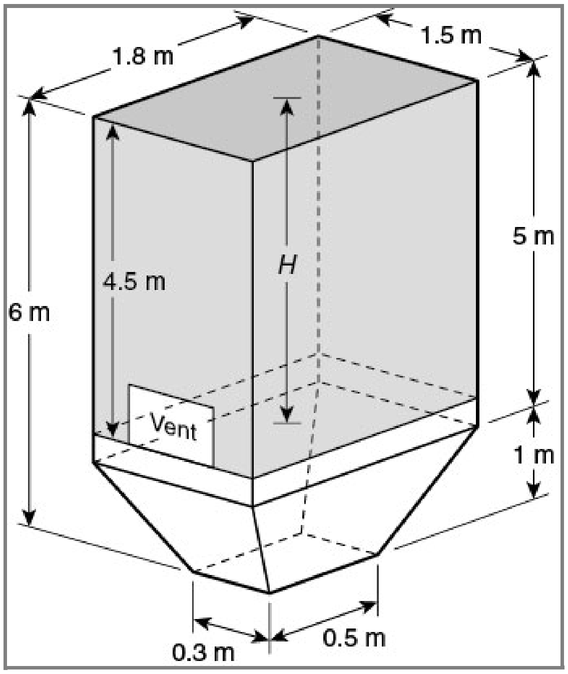
(3) $A_{eff} = V_{eff} / H = 12.1 / 4.5 = 2.7\ m^2$.

(4) $D_{he} = 4 \cdot A_{eff} / p = 4 \cdot A_{eff} / [2 \cdot (A + B)]$.

$D_{he} = 4 \cdot 2.7 / [2 \cdot (1.8 + 1.5)] = 1.64$ m.

(5) $L/D = H / D_{he} = 4.5 / 1.64 = 2.74$.

Figure A.6.4.3(e) Rectangular Enclosure with a Hopper and a Side Vent Close to the Hopper.



Example 5. General calculation of the volume of a hopper.

(1) Rectangular hopper:

$$V = \frac{(a_1)\cdot(h)\cdot(b_2 - b_1)}{2} + \frac{(b_1)\cdot(h)\cdot(a_2 - a_1)}{2} + \frac{(h)\cdot(a_2 - a_1)\cdot(b_2 - b_1)}{3} + (a_1)\cdot(b_1)\cdot h \quad \textbf{[A.6.4.3a]}$$

(2) Conical hopper:

$$V = \pi \cdot (h) \frac{\left[(D_1)^2 + (D_1 \cdot D_2) + (D_2)^2\right]}{12} \quad \textbf{[A.6.4.3b]}$$

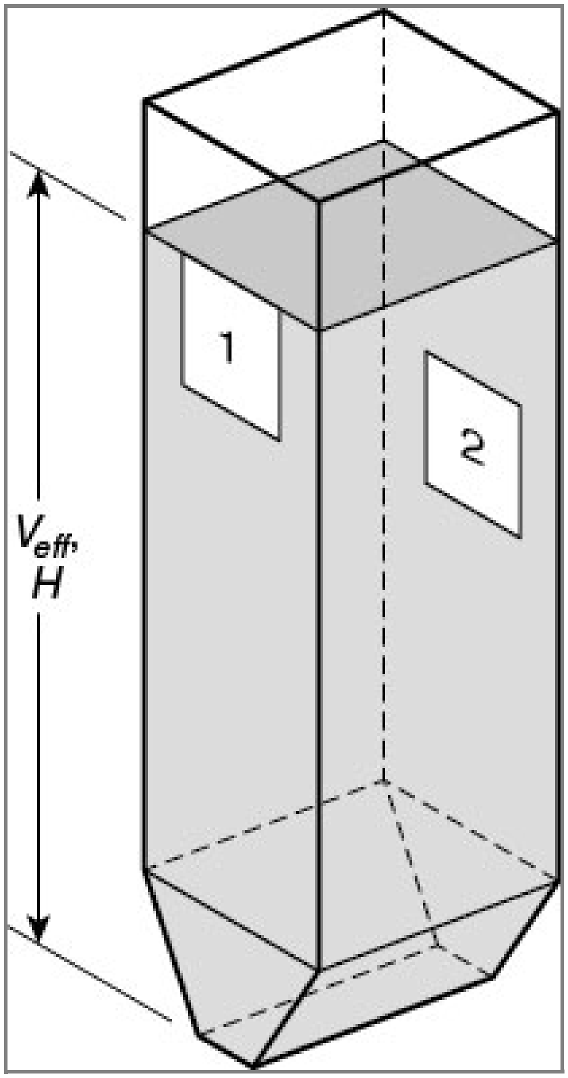
where:

D_1 = diameter of the base

D_2 = diameter of the top

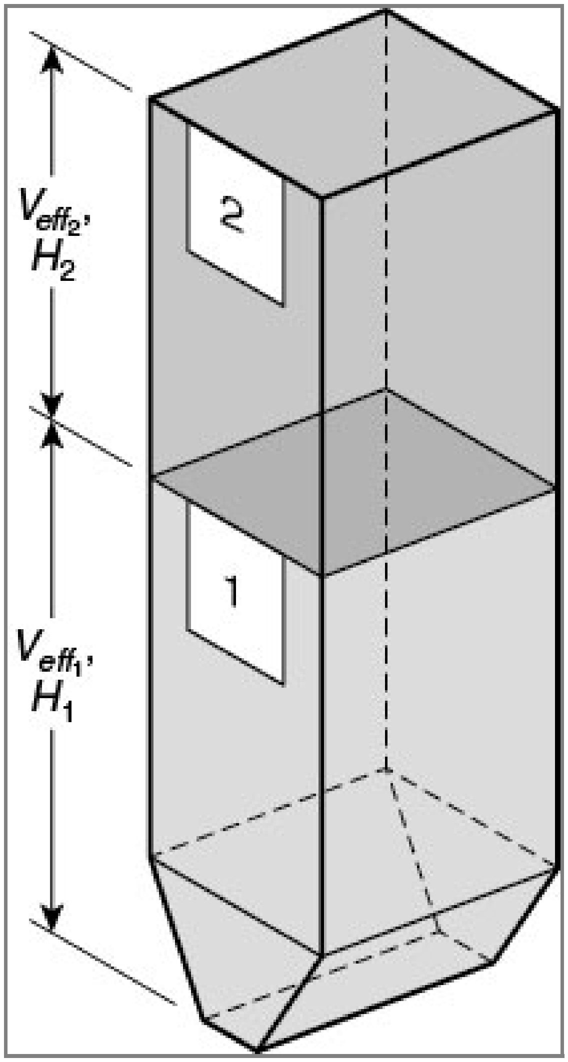
Example 6. Two vents, slightly offset vertically but on opposite sides of the enclosure *[see Figure A.6.4.3(f)]*. Because the vents overlap along the vertical axis, V_{eff} equals the volume from the bottom of the rectangular vessel to the top of the highest vent.

Figure A.6.4.3(f) Rectangular Enclosure, with a Hopper and Two Vents on Opposite Sides of the Enclosure.



Example 7. Two vents located on the same vertical line, offset from each other along the central axis, with the upper vent top located at the top of the enclosure *[see Figure A.6.4.3(g)]*. With multiple vents along the central axis, V_{eff} for the bottom vent is the volume from the bottom of the enclosure to the top of the lowest vent. V_{eff} for the next vent is the volume from the top of the lower vent to the top of the upper vent.

Figure A.6.4.3(g) Rectangular Enclosure with a Hopper and Two Vents on the Same Vertical Line.



Supplemental Information

File Name	Description	Approved
68_FR_21_A.6.4.3.docx	For staff use only	

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 11:21:21 EDT 2021

Committee Statement

Committee Statement: The calculations are being revised to match the measurements in the figure for D1.

Response Message: FR-21-NFPA 68-2021

Public Input No. 6-NFPA 68-2018 [Section No. A.6.4.3]

Public Input No. 14-NFPA 68-2019 [Section No. A.6.4.3]

First Revision No. 32-NFPA 68-2021 [Section No. A.6.9.1]

A.6.9.1

Even with complete extinguishment of flame, the area immediately surrounding the vent can experience overpressure and radiant energy. It is not possible to expect absolute retention of burnt and unburnt particulates, as demonstrated by testing. A minimal release is unavoidable and needs to be recognized where toxic or chemically active materials are being processed.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue Jul 27 21:41:19 EDT 2021

Committee Statement

Committee Statement: This revision was developed by NFPA staff for editorial purposes, in accordance with 4.3.9.3.2 and 4.3.9.3.3 of the Regulations Governing the Development of NFPA Standards (www.nfpa.org/regs).

Response Message: FR-32-NFPA 68-2021

First Revision No. 19-NFPA 68-2021 [Section No. A.8.2.1.2]

A.8.2.1.2

Example Problem

Given the following conditions, calculate A_{v0}:

V = 10 m^3

P_{red} = 5 bar-g

$P_{initial}$ = 2 bar-g

P_{max} = 8.5 bar-g (at atmospheric conditions)

K_{St} = 290 bar-m/s

P_{stat} = ~~2.6~~ <u>2.2</u> bar-g

Solution

Starting in Section 8.2 and recognizing that $P_{initial}$ is above the upper atmospheric limit of 0.2 bar-g, 8.2.1.2 should be followed for determination of the minimum vent area requirement (A_{v0}). From Equation 8.2.1.2,

$$A_{v0} = 1\cdot10^{-4}\cdot\left[1+1.54\cdot\left(\frac{P_{stat}-P_{initial}}{1+P_{effective}}\right)^{4/3}\right]\cdot K_{St}\cdot V^{3/4}\sqrt{\frac{1}{\Pi_{effective}}-1} \quad \textbf{[A.8.2.1.2a]}$$

where:

$P_{effective}$ = 1 / 3$P_{initial}$ (bar-g) = 1 / 3 · (2) = 0.667 bar-g

P^E_{max} = [(P_{max} + 1) · ($P_{initial}$ + 1) / (1 bar-abs) − 1] = [(8.5 + 1) · (2 + 1) / (1) − 1] = 27.5 bar-g

$\Pi_{effective}$ = (P_{red} − $P_{effective}$) / (P^E_{max} − $P_{effective}$) = (5 – 0.666) / (27.5 – 0.667) = 0.161

~~$$A_{v0} = 1\cdot10^{-4}\left[1+1.54\cdot\left(\frac{2.6-2}{1+0.667}\right)^{4/3}\right]\cdot290\cdot10^{3/4}\sqrt{\frac{1}{0.161}-1}$$~~

~~$$A_{v0} = 0.518 \text{ m}^2$$~~

$$A_{v0} = 1\cdot10^{-4}\left[1 \quad \textbf{[A.8.2.1.2b]}\right.$$

$$A_{v0} = 0.406 \text{ m}$$

Discussion

Where the application would have been based on a $P_{initial}$ within the atmospheric range, Equation 8.2.1.1 would yield a vent area requirement of ~~0.888~~ <u>0.738</u> m^2. The resulting reduction of vent area requirement where $P_{initial}$ is above atmospheric, but the rest of the variables remain the same, can be expected as the pressure difference between P_{stat} and $P_{initial}$ is less than in the atmospheric case. Where this is the case, the deflagration is allowed less time to develop prior to the opening of the vent and thus requires less vent area.

Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Thu May 27 10:56:31 EDT 2021

Committee Statement

Committee Statement:	The example has been edited so that the value used for Pstat aligns with the limitations located in 8.2.1.3(4). The committee will also review the limitations in 8.2.1.3 to ensure that they are correct.
Response Message:	FR-19-NFPA 68-2021

Public Input No. 7-NFPA 68-2018 [Section No. A.8.2.1.2]

First Revision No. 10-NFPA 68-2021 [Section No. E.1]

Global FR-28

E.1 Estimating Method.

Fundamental burning velocity, S_u, is taken as the largest value of laminar burning velocity, S, obtained by any mixture of a flammable gas in air. S_u is determined experimentally and is a characteristic of any particular fuel whether as a single component or as a mixture of flammable components.

The value of S_u can be estimated using the method given here if an experimental value of S_u is not available. Other methods can be used to estimate S_u, such as the maximum experimental safe gap (MESG) correlation in Schampel [125].

Britton proposed the following correlation for estimating S_u [122]:

$$S_u = 1666.1 - 34.228\left(-\Delta H_c / \chi_{OF}\right) + 0.18039\left(-\Delta H_c / \chi_{OF}\right)^2 \qquad \textbf{[E.1]}$$

where:

S_u = fundamental burning velocity (cm/s)

ΔH_c = heat of combustion of the fuel (kcal/mole)

χ_{OF} = stoichiometric ratio of oxygen to fuel

For fuel species consisting of carbon, hydrogen, oxygen, nitrogen, or halogens ($C_cH_hO_mN_nX_x$) with stoichiometric coefficients c, h, m, n, x, the stoichiometric ratio of oxygen to fuel is calculated as follows:

$$\chi_{OF} = c + (h\text{-}x\text{-}2m)/4$$

χ_{OF} can be used to calculate the stoichiometric ratio of the fuel in air as follows:

$$C_{st} = 100/(1 + 4.773\chi_{OF})$$

Example:

Methane (CH_4)

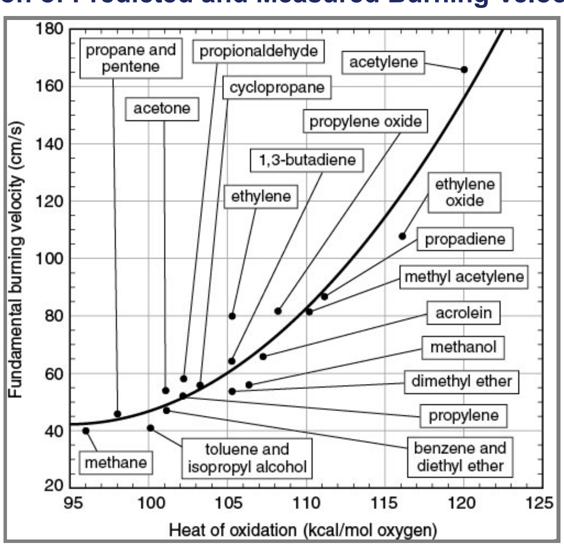
ΔH_c = −192 kcal/mole fuel

χ_{OF} = c + (h-x-2m) / 4 = 1 + (4-0-0) / 4 = 2

$-\Delta H_c/\chi_{OF}$ = (192 kcal/mole fuel) / (2 moles ~~fuel~~oxygen per mole of ~~oxygen~~fuel) = 96 kcal/mole oxygen

Figure E.1, from Britton [122], compares the predictions made with the expression given in Equation E.1 with laminar burning velocity (LBV) data. The LBV data are from NFPA 68 (NACA tube data with a reference value of 46 cm/s for propane).

Figure E.1 Comparison of Predicted and Measured Burning Velocities.



Submitter Information Verification

Committee: EXL-AAA

Submittal Date: Tue May 25 12:51:37 EDT 2021

Committee Statement

Committee Statement: The current units of the denominator do not match the definition of the stoichiometric ratio and do not match the intended units of the answer.

Response Message: FR-10-NFPA 68-2021

Public Input No. 8-NFPA 68-2018 [Section No. E.1]

First Revision No. 5-NFPA 68-2021 [Chapter L]

Annex L Informational References

L.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

L.1.1 NFPA Publications.

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

NFPA 30, *Flammable and Combustible Liquids Code*, ~~2018~~ 2021 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, ~~2015~~ 2019 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, ~~2018~~ 2021 edition.

NFPA 35, *Standard for the Manufacture of Organic Coatings*, ~~2016~~ 2021 edition.

NFPA 52, *Vehicular Natural Gas Fuel Systems Code*, ~~2016~~ 2019 edition.

NFPA 58 , *Liquefied Petroleum Gas Code* , 2023 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*, ~~2017~~ 2020 edition.

NFPA 67, *Guide on Explosion Protection for Gaseous Mixtures in Pipe Systems*, ~~2016~~ 2019 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, ~~2014~~ 2019 edition.

NFPA 400, *Hazardous Materials Code*, ~~2016~~ 2019 edition.

NFPA 484, *Standard for Combustible Metals*, ~~2015~~ 2019 edition.

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

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, ~~2017~~ 2020 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems*, ~~2015~~ 2019 edition.

NFPA 5000®, *Building Construction and Safety Code®*, ~~2018~~ 2021 edition.

Fire Protection Guide to Hazardous Materials, ~~2001~~ 2010 edition.

L.1.2 Other Publications.

L.1.2.1 ANSI Publications.

American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI Z535.4, *Product Safety Signs and Labels,* 2011, reaffirmed 2017 .

L.1.2.2 API Publications.

American Petroleum Institute, ~~1220 L. Street, N.W., Washington, DC 20005-4070~~ 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001-5571 .

API RP 752, *Management of Hazards Associated with Location of Process Plant Permanent Buildings*, 2009.

L.1.2.3 ASCE Publications.

American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191–4400.

ASCE, *Design of Blast-Resistant Buildings in Petrochemical Facilities*, 2010.

ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, ~~2010~~ 2016 .

L.1.2.4 ASTM Publications.

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

ASTM D5680, *Standard Practice for Sampling Unconsolidated Solids in Drums or Similar Containers,* 2014.

ASTM E502, *Standard Test Method for Selection and Use of ASTM Standards for the Determination of Flash Point of Chemicals by Closed Cup Methods,*~~2007, reapproved 2013~~ 2020 .

ASTM E582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures,*~~2007, (2013 e1)~~ 2021 .

ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases),* 2009, reapproved 2015.

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, ~~2012A~~ 2019 .

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2014.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* 2003, reapproved ~~2013~~ 2019 .

L.1.2.5 CCPS Publications.

Center for Chemical Process Safety, 3 Park Avenue, 19th Floor, New York, NY 10016.

Guidelines for Consequence Analysis of Chemical Releases, 1999.

Guidelines for Safe Handling of Powders and Bulk Solids, 2004.

L.1.2.6 CENELEC Publications.

European Committee for Electrotechnical Standardization, CEN-CENELEC Management Centre, 17, Avenue Marnix, 4th floor, B-1000 Brussels.

EN 13237, *~~Potentially Explosive Atmospheres~~ potentially explosive atmospheres — Terms and ~~Definitions~~ definitions for ~~Equipment~~ equipment and ~~Protective Systems Intended~~ protective systems intended for ~~Use~~ use in ~~Potentially Explosive Atmospheres~~ potentially explosive atmospheres* , 2012.

EN 14460, *Explosion ~~Resistant Equipment~~ resistant equipment* , ~~2006~~ 2018 .

EN 14797, *Explosion venting devices* , 2006.

L.1.2.7 FM Global Publications.

FM Global, 270 Central Avenue, P.O. Box 7500, Johnston, RI 02919.

FM Global Property Loss Prevention Data Sheet 1-28, *Wind Design*, ~~2007~~ 2020 .

L.1.2.8 ISO Publications.

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

ISO 6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dust in air,* 1985, confirmed 2005 .

L.1.2.9 NACE Publications.

NACE International, 15835 Park Ten Place, Houston, TX 77084-4906.

National Association of Corrosion Engineers Handbook, 2nd edition, 1991.

L.1.2.10 U.S. Government Publications.

U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

TM5-1300, *Structures to Resist the Effects of Accidental Explosions,* Department of Defense Explosives Safety Board, 1990.

UFC 3-340-02, *Structures to Resist the Effects of Accidental Explosions*, Department of Defense, 2014.

L.1.2.11 VDI Publications.

The Verein Deutscher Ingenieure (Association of German Engineers), Platz 1, Düsseldorf, 40468 Germany.

VDI 3673, *Pressure Venting of Dust Explosions* , 1995.

L.1.2.12 Other Publications.

Biggs, J. M., *Introduction to Structural Dynamics*, New York: McGraw-Hill, 1964.

Darby, R., *Chemical Engineering Fluid Mechanics*, 2nd Edition, New York: Marcel Dekker, 2001.

Holbrow, P., S. Andrews, and G. A. Lunn, “Dust explosions in interconnected vented vessels,” *Journal of Loss Prevention in the Process Industries*, Vol. 9, No. 1, pp. 91–103 (1996).

Holbrow, P., G. A. Lunn, and A. Tyldesley, “Dust explosion protection in linked vessels: Guidance for containment and venting,” *Journal of Loss Prevention in the Process Industries*, Vol. 12, No. 3, pp. 227–234 (1999).

Lees, F. P., *Lees' Loss Prevention in the Process Industries,* 2nd Edition, Oxford, U.K.: Butterworth–Heinemann, 1996.

Lunn, G. A., P. Holbrow, S. Andrews, and J. Gummer, “Dust Explosions in Totally Closed Interconnected Vessels,” *Journal of Loss Prevention in the Process Industries*, Vol. 9, No. 1, pp. 45–58 (1996).

Moore, P. E., and J. A. Senecal, “Industrial Explosion Protection — How Safe Is Your Process?” Dust Explosion Symposium, Fire Protection Research Foundation, Baltimore, MD, May 13–14, 2009. See www.nfpa.org/assets/files/PDF/Foundation%20proceedings/Industrial_Explosion_Protection.pdf.

Roser, M., “Investigation of dust explosion phenomenon in interconnected process vessels,” Forschungsgesellschaft fur angewandle Systemsicherheit und Arbeitsmedizin PhD Thesis, University of Loughborough.

Roser, M., A. Vogel, S. Radant, W. Malalasekera, and R. Parkin, “Investigations of flame front propagation between interconnected process vessels. Development of a new flame front propagation time prediction model,” *Journal of Loss Prevention in the Process Industries*, Vol. 12, Issue 5, pp. 421–436 (1999).

Yu, X., and Young, K.-J., “ The Dynamic Load Factor of Pressure Vessels in Deflagration Events.”

L.2 Informational References.

Krishna, K., W. Rogers, and M. Sam Mannan, “The use of aerosol formation, flammability, and explosion information for heat-transfer fluid selection,” *Journal of Hazardous Materials* 104, 2003.

~~NFPA 652 , *Standard on the Fundamentals of Combustible Dust* , 2016 edition.~~

L.3 References for Extracts in Informational Sections. (Reserved)

Supplemental Information

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