Report on Proposals F2006 — Copyright, NFPA

Report of the Committee on
Explosion Protection Systems

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Stephen M. Stuart, Marsh USA Incorporated, MI [I]
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(Member Emeritus)

Staff Liaison: Guy R. Colonna

Committee Scope: This Committee shall have primary responsibility for documents on explosion protection systems for all types of equipment and for buildings, except pressure venting devices designed to protect against overpressure of vessels such as those containing flammable liquids, liquefied gases, and compressed gases under fire exposure conditions, as now covered in existing NFPA standards.

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the front of this book.

The Report of the Technical Committee on Explosion Protection Systems is presented for adoption.


When adopted this document will be redesignated as NFPA 68, Standard on Explosion Protection by Deflagration Venting.

This Report has been submitted to letter ballot of the Technical Committee on Explosion Protection Systems, which consists of 28 voting members. The results of the balloting, after circulation of any negative votes, can be found in the report.

68-1
I do not know of anyone who currently uses the whipping hose dispersion system. In regard to C.6 Classification as Noncombustible, there is no disagreement between reference 97 and ASTM E1515 as C.6 implies. C.6 states that ASTM E1515 “specifies the use of a 5 kJ ignition source for MEC.” This is incorrect! Section 5.5 of E1515 says the “recommended ignition source for measuring the MEC of dusts in 20-L chambers is a 2500 or 5000 J pyrotechnic igniter.” ASTM E1515 only “recommends” and does not “specify” a particular ignitor energy. E1515 allows various ignitors to be used, but the ignitor type and energy must be specified in the Report (sec. 13). E1515 definitely does not specify a 5 kJ energy target as claimed in C.6.

MCCOY, S.; Section 7.6.4 Fireball Dimensions, is part of Section 7.6 Effects of Initial Elevated Pressure. 7.6.4 should be a separate Section 7.7 and should be renumbered accordingly since these two sections are not directly related. Section 8.1.2 should be reversed with 8.1.2.2 for clarity. The preferred method of testing with actual material should precede the option to approximate with data from similar material.
Flash Point (secondary) NFPA 68, 2002 ed.
The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid, as specified by test.

Lower Flammable Limit (LFL) (preferred) NFPA 329, 1999 ed.
That concentration of a combustible material in air below which ignition will not occur. Also known as the Lower Explosive Limit (LEL). Mixtures below this limit are said to be “too lean.”

The strength of a material in tension, compression, or shear, respectively, that is the maximum tensile, compressive, or shear stress that the material can sustain, calculated on the basis of the ultimate load and the original or unstrained dimensions.

Substantiation: Adoption of preferred definitions will assist the user by providing consistent meaning of defined terms throughout the National Fire Codes.

Committee Motion: Accept in Principle in Part

Explosion - retain secondary and make it the preferred.

Flammable Limits - retain secondary.

Flammable Limits for Dusts - retain secondary.

Ultimate Strength - remain secondary.

Flash Point - revise to accept the preferred.

Flammable Limits - retain secondary.

Explosion - retain secondary and make it the preferred.

Lower Flammable Limit (LFL).* (secondary) NFPA 68, 2002 ed.
The lowest concentration of a combustible substance in a gaseous oxidizer that will propagate a flame.

The strength of a material in tension, compression, or shear, respectively, that is the maximum tensile, compressive, or shear stress that the material can sustain, calculated on the basis of the ultimate load and the original or unstrained dimensions.

Substantiation: Adoption of preferred definitions will assist the user by providing consistent meaning of defined terms throughout the National Fire Codes.

Committee Motion: Accept in Principle in Part

Explosion - retain secondary and make it the preferred.

Flammable Limits - retain secondary.

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Committee Motion: Accept in Principle in Part

Explosion - retain secondary and make it the preferred.

Flammable Limits - retain secondary.

The strength of a material in tension, compression, or shear, respectively, that is the maximum tensile, compressive, or shear stress that the material can sustain, calculated on the basis of the ultimate load and the original or unstrained dimensions.

Substantiation: Adoption of preferred definitions will assist the user by providing consistent meaning of defined terms throughout the National Fire Codes.
5.6.14.5 Deflagration vents with hinged enclosures are less effective than open vents or vents with lightweight rupture diaphragms. The efficiency of a specific hinged closure is dependent on its design details and can be measured experimentally [104]. In view of the reduced efficiency of hinged enclosures, lightweight rupture diaphragms are recommended. However, b a s e d on industrial experience, acceptable vent performance can be achieved with hinged closures, provided the following conditions are met:

Substantiation: The formulas are wrong. It is widely accepted that Kst and volume strongly affect the inertia factor. The graph provides compromise transitions.

Committee Meeting Action: Reject
Committee Statement: The recommendation is no longer applicable to the document as alternate material has been accepted by the Committee. See committee action on Proposal 68-3 (Log #CP5).

Number Eligible to Vote: 28
Ballot Results: Affirmative: 20
Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Sheddrick, K., Zalosh, R.

Substantiation: The formulas are wrong, and will be replaced with 2.5 lbs/ft². Adding one or two higher categories (with heavy restrictions) will utilize some FM technology to allow important regions without penalty.

Committee Meeting Action: Reject
Committee Statement: The recommendation is no longer applicable to the document as alternate material has been accepted by the Committee. See committee action on Proposal 68-3 (Log #CP5).

Number Eligible to Vote: 28
Ballot Results: Affirmative: 20
Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Sheddrick, K., Zalosh, R.

68-9 Log #3 Final Action: Reject
5.6.14.1

This Proposal appears as Comment 68-18 (Log # 55) which was held from the F2001 ROC on Proposal 68-15.
Submitter: Mitchel L. Rooker, BS & B Safety Systems
Recommendation: Replace the formulas with the following table.

<table>
<thead>
<tr>
<th>Gas Service</th>
<th>Vent mass per area</th>
<th>Additional Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 12.2 kg/m² (2.5 lbs/ft²)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Dust Service</td>
<td>&lt; 12.2 kg/m² (2.5 lbs/ft²)</td>
<td>None</td>
</tr>
<tr>
<td>Dust Service</td>
<td>≥ 12.2 kg/m², and &lt; 17 kg/m² (3.5 lbs/ft²)</td>
<td>Kst &lt; 220 bar-m/sec, and V &gt; 50 m³</td>
</tr>
<tr>
<td>Dust Service</td>
<td>≥ 17 kg/m², and &lt; 25 kg/m² (5.1 lbs/ft²)</td>
<td>Kst &lt; 125 bar-m/sec, and V &gt; 100 m³</td>
</tr>
</tbody>
</table>

Substantiation: The formulas are wrong, and will be replaced with 2.5 lbs/ft². Adding one or two higher categories (with heavy restrictions) will utilize some FM technology to allow important regions without penalty.

Committee Meeting Action: Reject
Committee Statement: The recommendation is no longer applicable to the document as alternate material has been accepted by the Committee. See committee action on Proposal 68-3 (Log #CP5).

Number Eligible to Vote: 28
Ballot Results: Affirmative: 20
Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Sheddrick, K., Zalosh, R.

68-10 Log #5 Final Action: Reject
5.6.14.5

Submitter: Molkov, V. V. Eber, University of Ulster, FireSERT
Recommendation: Revise text to read as follows:

5.6.14.5 Deflagration vents with hinged enclosures are less effective than open vents or vents with lightweight rupture diaphragms. The efficiency of a specific hinged closure is dependent on its design details and can be measured experimentally [104]. In view of the reduced efficiency of hinged enclosures, lightweight rupture diaphragms are recommended. However, b a s e d on industrial experience, acceptable vent performance can be achieved with hinged closures, provided the following conditions are met:

Substantiation: The formulas are wrong, and will be replaced with 2.5 lbs/ft². Adding one or two higher categories (with heavy restrictions) will utilize some FM technology to allow important regions without penalty.

Committee Meeting Action: Reject
Committee Statement: The recommendation is no longer applicable to the document as alternate material has been accepted by the Committee. See committee action on Proposal 68-3 (Log #CP5).

Number Eligible to Vote: 28
Ballot Results: Affirmative: 20
Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Sheddrick, K., Zalosh, R.

68-11 Log #1 Final Action: Accept in Principle
5.8.7.10.1 (New)

This Proposal appears as Comment 68-20 (Log #10) which was held from the F2001 ROC on Proposal 68-15.
Submitter: David C. Kirby, Baker Engineering & Risk Consultants
Recommendation: Add a new Section 5.8, and renumber succeeding paragraphs.

5.8 Fireball Hazard from Vented Deflagrations.
5.8.1 The fireball from a vented gas or dust deflagration presents a hazard to personnel who may be 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 thermal dose is a function of the fireball, heat flux and the exposure time, that is:

\[
Dose = t\left(\frac{I}{10}\right)^{4/3}
\]

Where t is the exposure time (seconds)
I is the heat flux, W/m²
\[
D = \frac{3.1 V}{D_{axial}}
\]

Where: D = axial distance (front-centerline) from vent
V = volume of vented enclosure

The width of the projected flame measured from the centerline of the vent can be calculated as 1/2 D. Add reference to Bartnecht, pg. 573-574.

5.8.3 When dust deflagrations occur there can be far more dust present than there is oxidant to burn it completely. When venting takes place large amounts of unburned dust are vented from the enclosure, and burning continues as the dust mixes with additional air from the surrounding atmosphere. Consequently, a very large and long fireball of burning dust develops that can extend downward as well as upward. The average surface emissive power varies greatly between different

Where test information is not available, the following equation is reasonably conservative when calculating the fireball hazard zone for dusts vented from high-strength enclosures.

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

Where:
- \( D \) = axial distance (front) from the vent
- \( K \) = flame length factor;
- \( K = 10 \) for metal dusts, \( K = 8 \) for chemical and agricultural dusts
- \( V \) = volume of vented enclosure
- \( n \) = number of panels

The maximum flame length can be limited to 60 meters. (Source VDI 3673)

The width of the projected flame measured from the centerline of the vent can be calculated as 1/2 \( D \).

Delete 7.10.

Substantiation: The recommendation is based upon work by a task group of the Committee on Explosion Protection Systems. The proposed new text provides guidance on the fireball hazard for gaseous and dust deflagrations. This new section incorporates research findings from several independent studies.

Committee Meeting Action: Accept in Principle


Add Annex to 7.6.4:

A.7.6.4 The fireball from a vented gas or dust deflagration presents a hazard to personnel who may be 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 affected by 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.

Replace existing equation 8.8 with the following text:

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

Where:
- \( D \) = axial distance (front) from the vent
- \( K = 10 \) for metal dusts, \( K = 8 \) for chemical and agricultural dusts
- \( V \) = volume of vented enclosure
- \( n \) = number of panels

The maximum hazard distance shall be limited to 60 meters.

The width of the projected flame measured from the centerline of the vent shall be calculated as 1/2 \( D \).

Committee Statement: The Committee incorporated elements of the submission in this revision of existing 7.6.4 and 8.9.1 where the requirements to limit fireball dimensions are included for gases and dusts, respectively. The proposed change for gases already exists in Chapter 7; some of the proposed language was added as annex text to the requirement. The proposed change for dusts was accepted as a new relationship (new Equation 8.8) with editorial changes to conform to style.

The Committee accepted the proposed flame length/hazard zone limit of 60 meters based upon reported tests in Winvent program and substantiated in VDI 3673.

Number Eligible to Vote: 28

Ballot Results: Affirmative: 20

Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Shedd, K., Zalosh, R.

Comment on Affirmative:

MORRISON, L.: Although I support the basic intent of this new Chapter I have some concerns with the wording of 6.1.1 and 6.2.3.3.

6.1.1 “…shall be prepared by a person with qualifications acceptable to the authority having jurisdiction.”

In most cases I have been involved with the AHJ does not possess the knowledge of explosions and explosion protection to decide who has such qualifications. The user of the document would be better served by the committee setting the qualifications it considers necessary for performance design. I would suggest that the above clause could be replaced with “…shall be prepared by a professional engineer with knowledge and experience in explosions dynamics and the effects of explosions on structures.”

6.2.3.3 “…vent discharge shall not expose personnel to flame…”

The requirement of this statement is too restrictive and could discourage users from providing any protection, particularly for existing plants. At the design stage of a project this is a laudable objective but in practice it is sometimes difficult to achieve. I would suggest that the expression "unacceptable risk" be inserted between “personnel to” and “flame” and add note could be added to define unacceptable risk as much work has been done on this subject. This would still highlight the need to protect personnel but would, under difficult circumstances, allow the user to manage the risk to an acceptable level.
Committee Statement: The submitter’s concern with respect to an errata has been addressed through a published errata and the proposed new edition of the standard. V is a constraint on the maximum volume for use in the equation. See Committee Action on 68-3 (Log #CPS).

Number Eligible to Vote: 28

Ballot Results: Affirmative: 20

Ballot Not Returned: 8 Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Sheddrick, K., Zalosh, R.

68-16 Log #7 Final Action: Accept in Principle in Part (9.4.5, 9.5.1.1 and 9.5.3).

Submitter: George Frater, Canadian Steel Construction Council

Recommendation: Add new Annex notes to 9.4.5, 9.5.1.1 and 9.5.3 as follows:

A.9.4.5 For additional guidance see Factory Mutual (FM) Global’s Property Loss Prevention Data Sheet 1-44 entitled “Damage-Limiting Construction.”


Substantiation: The Canadian Steel Construction Council (CSCC) is an industry association representing the basic manufacturers of steel used in construction, the fabricators of structural steel, open web steel joists, steel platework, corrugated steel pipe and steel sheet products, to manufacturers of structural fasteners and distributors of steel products. Members of the CSCC who design and manufacture steel cladding systems are finding it extremely difficult to comply with the revised explosion venting requirements in the 1997 Ontario Fire Code (OFC). A recent OFC amendment changed wording in certain articles on explosion venting by striking out “good engineering practice such as described in NFPA 68” and replacing it with “in conformance with NFPA 68.” The NFPA 68 Technical Committee provisions in Chapter 9 deal with explosion vent panel areas and masses. One particular paragraph, namely 9.5.3, limits an explosion vent panel size to 33 ft² and a mass of 2.5 lb/ft². These limits are too small to be practical by the Steel Industry. From one case example involving a professional engineer’s design of an explosion vent panel and its review by Building/Fire Code Officials it is evident that NFPA 68 paragraphs are open for interpretation. When one considers the engineer’s viewpoint it appears that NFPA 68 should be considered as a guideline since it is vague in certain areas. NFPA 68 is titled as a guide and defines guide in Chapter 3 as “advisory or informative in nature and contains only mandatory provisions. One could consider the values on vent panel area and mass, that are prescriptive limits, have been noted by various Building/Fire Code Officials in their precursory review of the guide. They tend to enforce these two limits and make the acceptance of vent panels larger and heavier than the two prave limits difficult and time consuming.

The aforementioned prescriptive limits are based upon a research paper of Howard and Karabinis (1982) as per the referencing in 9.4.5. The paper presents test results from four types of vent panels that ranged in weight of 0.375 lb/ft² to 2.6 lb/ft² and were tested under various explosions within a small test structure building. The test was a 16 in. wide and covered the test structure from the uppermost girt to the top of a reinforced concrete slab on which the test structure sat, thereby making the vent closure to 10 ft x 3. The submitter’s concern with respect to an errata has been addressed through a published errata and the proposed new edition of the standard. V is a constraint on the maximum volume for use in the equation. See Committee Action on 68-3 (Log #CPS).
Chapter 11 Installation, Inspection and Maintenance

11.1 General

11.1.1 This chapter covers the installation, inspection and maintenance procedures necessary for proper function and operation of vent closures for venting deflagrations.

11.1.2 Sections 11.4 (inspection) through 11.10 (employee training) shall be applied retroactively.

11.2 Design Parameters and Documentation.

11.2.1 Data sheets, installation details, and design calculations shall be developed and maintained for each vent closure application, suitable for review by an Authority Having Jurisdiction (AHJ) that verifies a vent area is sufficient to prevent deflagration pressure from exceeding the enclosure strength and identify areas exposed to potential overpressure, event propagation, and fireball effects during venting, including:

a) Manufacturers data sheets and instruction manuals
b) Design specifications
c) General specifications
d) Vent closure specifications
e) End user inspection / maintenance forms
f) User documentation of conformity with applicable standards
g) Vent closure identification
h) Combustible material properties test report
i) Copy of vent identification label
j) Process plan view
k) Process elevation view
l) Vent relief (pressure and fireball) path
m) Proximity of personnel to vent relief path
n) Mechanical installation details
o) Electrical supervision (if provided) installation details
p) Vent restraint installation and design documentation (if required)
q) Process interlocks (if provided)
r) Event deflagration isolation requirements (if required)
s) Employee training requirements

11.3 Installation.

11.3.1 Mounting frames shall be fabricated and mounted so that the vent closure is not stressed in any way that will contribute to fatiguing the vent closure.

11.3.2 Vent closures shall be installed per manufacturer's requirements.

11.3.3 The final installation shall be inspected to verify its conformance with the design.

11.3.4 Vent closure shall be clearly marked (Warning: explosion relief device).

11.4 Inspection.

11.4.1 Vent closures shall be inspected according to 11.4.4 at least annually.

11.4.2 The frequency of the inspection described in 11.4.4 shall be permitted to be increased or decreased based on documented operating experience.

11.4.3 The owner/operator of the facility in which the deflagration vent closures are located shall be responsible for inspecting and maintaining such devices after they are installed.

11.4.4 * The inspector shall verify, as applicable, that the vent inspection determines the following:

a) Opening is free and clear of any obstructions on both sides
b) Discharged material and fireball pathway does not extend into an area normally occupied by personnel or critical process equipment
c) Closure has been properly installed according to manufacturers instructions
d) Closure is not corroded or mechanically damaged
e) Closure is clearly identified with manufacturers information
f) Closure is clearly labeled as an explosion relief device
g) Closure has no damage and is protected from the accumulation of water, snow, ice, or debris after any act of nature
h) Closure has not been painted or coated other than by manufacturer
i) Closure has no buildup of deposits on the inside surfaces or between layers of the vent
j) Closure has not been tampered with
k) Closure shows no fatigue and has not released
l) Closure hinges (if provided) are lubricated and operate freely
m) Closure restraints (if provided) are in place and operational
n) Closure seals, tamper indicators, or vent rupture indicators (e.g., breakwire switches) if provided, are in place
o) Flame-arresting and particulate retention device is being maintained, clean and unobstructed in accordance with the manufacturer's listing
p) Closure has no conditions that will hinder its operation

11.4.5 The owner/operator shall verify by signature on the inspection form that the production process material has not changed since the last inspection.

11.4.6 The vent closure design parameters shall be maintained and made available for management of change review, employee training information, inspection and re-ordering purposes.

11.5 Deficiencies found during inspections shall be reported to the owner/operator.

11.6.1 A record shall be maintained that indicates the date and the results of each inspection and the date and description of each maintenance activity.

11.7 The records of inspections shall be retained for a minimum of three years.

11.8 Management of Change. Management shall implement and maintain written procedures to evaluate proposed changes to facility and processes, both physical and human for the impact on safety, loss prevention and control.

11.8.1 Management of change procedures shall be followed for any change to process, materials, technology, equipment, process flow, exposure, or procedures affecting equipment protected by required calculations in this document.

11.8.2 Management of change documentation shall be available for review by the relevant authority having jurisdiction.

11.8.3 The management of change procedures shall ensure that the following issues are addressed prior to any change:

a) The technical basis for the proposed change
b) The safety and health implications
c) Fire and explosion prevention systems review
d) Whether the change is permanent or temporary
e) Personnel exposure changes
f) Modifications to operating maintenance procedures
g) Employee training requirements
h) Authorization requirements for the proposed change

11.8.4 Implementation of the management of change procedures shall not be required for replacements-in-kind.

11.8.5 Design documentation as required by Chapter 11 shall be updated to incorporate the change.

11.9 Maintenance.

11.9.1 Vent closure maintenance shall be performed after every act of nature or process upset condition to ensure that the closure has not been physically damaged and there is no obstructions including but not limited to snow, ice, water mud or process material that could lessen or impair the efficiency of the vent closure.

11.9.2 An inspection shall be performed in accordance with 11.4.4 after every process maintenance turnaround.

11.9.3 If process material has a tendency to adhere to the vent closure, the vent closure shall be cleaned periodically to maintain vent efficiency.

11.9.4 Process interlocks (if provided) shall be verified.

11.9.5 Known potential ignition sources shall be inspected and maintained.

11.9.6 Records shall be kept of any maintenance and repairs performed.

11.10 Employee Training.

11.10.1 Initial and refresher training shall be provided and training records maintained for employees who are involved in operating, maintaining, and supervising facilities that utilize devices for venting of deflagrations.

11.10.2 Initial and refresher training shall ensure that all employees are knowledgeable about the following:

a) Hazards of their workplace
b) General orientation, including plant safety rules
c) Process description
d) Equipment operation, safe start-up and shutdown, and response to upset conditions
e) The necessity for proper functioning of related fire and explosion protection systems
f) Deflagration vent(s) location, vent relief path, maintenance requirements and practices
g) Housekeeping requirements
h) Emergency response and egress plans

Annex A

A.11.2.1 Sample
# VENT CLOSURE INFORMATION FORM

## CONTACT INFORMATION

<table>
<thead>
<tr>
<th>Company name:</th>
<th>Responsible person:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address:</td>
<td>Title:</td>
</tr>
<tr>
<td>City:</td>
<td>State: Zip code:</td>
</tr>
<tr>
<td>Telephone:</td>
<td>Report writer:</td>
</tr>
</tbody>
</table>

Equipment/process protected:

<table>
<thead>
<tr>
<th>Vent ID number:</th>
<th>Vent location:</th>
</tr>
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<tbody>
<tr>
<td>Vent size:</td>
<td>Vent manufacturer:</td>
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<tr>
<td>Vent type:</td>
<td>Vent model number:</td>
</tr>
<tr>
<td>Vent opening pressure:</td>
<td>Vent construction material:</td>
</tr>
</tbody>
</table>

## HAZARD DETAILS

Name of material:

<table>
<thead>
<tr>
<th>Hazard category:</th>
<th>Dust</th>
<th>Gas</th>
<th>Mist</th>
<th>Vapor</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>K&lt;sub&gt;St&lt;/sub&gt; or K&lt;sub&gt;G&lt;/sub&gt; value of material:</td>
<td>bar-m/sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P<sub>max</sub> value of material:

<table>
<thead>
<tr>
<th>psig</th>
<th>barg</th>
</tr>
</thead>
</table>

## VENT DEVICE DETAILS

<table>
<thead>
<tr>
<th>Mounting frame:</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame type:</td>
<td>Welded</td>
<td>Bolted</td>
</tr>
<tr>
<td>Thermal insulation:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Gasket material:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sanitary sealing:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Vent restraints:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

## PROTECTED ENCLOSURE DETAILS

<table>
<thead>
<tr>
<th>Enclosure location:</th>
</tr>
</thead>
</table>

Normal operating pressure: psig @

<table>
<thead>
<tr>
<th>Normal operating temperature:</th>
<th>°F</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum operating pressure:</td>
<td>psig @</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum operating temperature:</th>
<th>°F</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum vacuum conditions:</td>
<td>psig</td>
<td>in. W.C.</td>
</tr>
</tbody>
</table>
VENT CLOSURE INFORMATION FORM (continued)

Frequency and magnitude of pressure cycles:_________________________________________

Vessel volume and dimensions:_____________________________________________________

Vessel aspect ratio:_______________________________________________________________

Vessel strength:_______________________________________________________________

Design calculations: NFPA 68 Chapter ______

Other information (to be collected and attached):

- Data sheets
- Manufacturer’s instruction, installation, and maintenance manuals
- Vent closure details
- Vent frame
- MSDS (of process material)
- Material $K_{st}/K_{g}$ test report (the value used for the vent design)
- Copy of vent identification label
- Process risk assessment report
- Process plan view showing vent relief path
- Process elevation view showing vent relief path
- Proximity of personnel to vent relief path
- Management of change requirements
- Mechanical installation details
- Manufacturer’s service and maintenance forms
- Verification of conformity documentation
- Vent restraint documentation
- Process interlocks (details)
ANNUAL INSPECTION FORM

USER CONTACT INFORMATION
Company name: _______________________________ Date inspected: _______________
Address: ____________________________________ Time: _______________
City: __________________ State: ________________ Zip code: ____________
Telephone: __________________________________

Inspector’s name: ______________________________
Inspection company: ____________________________
Address: ____________________________________
City: __________________ State: ________________ Zip code: ____________
Telephone: __________________________________

Vent id#: ________________________________
Vent location: ________________________________
Vent manufacturer: ____________________________

INSPECTION
Follow the manufacturer’s recommendations and the following:
Is the vent:

1. Clear of obstructions? □ Yes □ No
2. Corroded? □ Yes □ No
3. Mechanically or physically damaged? □ Yes □ No
4. Clearly labeled: Warning. Explosion relief device? □ Yes □ No
5. Clearly tagged/labeled with manufacturer’s information? □ Yes □ No
6. Protected from ice and snow? □ Yes □ No
7. Painted or coated? (Other than by the manufacturer) □ Yes □ No
8. Showing build-up or deposits? □ Yes □ No
9. Bulging, damaged, or deformed (from original shape)? □ Yes □ No
10. Changed, altered, or tampered with? □ Yes □ No
11. Showing signs of fatigue? □ Yes □ No
12. Provided with fasteners and mounting hardware in place? □ Yes □ No
13. Frame damaged or deformed? □ Yes □ No
14. Released? □ Yes □ No
15. Opening sensor operable and wiring up to current codes? □ Yes □ No
16. Provided with seals, tamper, or other opening indicators intact? □ Yes □ No
17. Provided with restraints in place and attached? □ Yes □ No
18. Provided with hinges lubricated and operating freely? □ Yes □ No
19. Clean and free of contamination? □ Yes □ No

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Figure A.11.4
### ANNUAL INSPECTION FORM (continued)

Looking from the vent outward can you see personnel working or hazardous material being stored in your direct line of sight?  

- Yes  
- No

If yes, please have a process engineer or user supervisor address your findings as you have described below:

<table>
<thead>
<tr>
<th>Abnormal conditions found:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Abnormal conditions corrected at time of inspection:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abnormal conditions that still need attention/addressed:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action required by management:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Process engineer/supervisor notified?  

- Yes  
- No

<table>
<thead>
<tr>
<th>Date addressed:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Action required?  

- Yes  
- No

<table>
<thead>
<tr>
<th>Signature:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Have you observed changes to the process and or its surroundings that should invoke the company’s management of change procedure?  

- Yes  
- No

<table>
<thead>
<tr>
<th>Inspector's signature:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Manager's signature:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Date:  

---

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Figure A.11.4 (continued)
Add the following chemical names in addition to the ASHRAE designation shown in the recommendation:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Chemical Name</th>
<th>Su, cm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFC-23</td>
<td>Difluoromethane</td>
<td>6.7</td>
</tr>
<tr>
<td>HFC-143</td>
<td>1, 1, 2-Trifluoroethane</td>
<td>13.1</td>
</tr>
<tr>
<td>HFC-143a</td>
<td>1, 1, 1-Trifluoroethane</td>
<td>7.1</td>
</tr>
<tr>
<td>HFC-152a</td>
<td>1, 1-Difluoroethane</td>
<td>23.6</td>
</tr>
</tbody>
</table>

Committee Meeting Action: Accept

Recommendation: Add new burning velocity data: HFC-32, 6.7 cm/s; HFC-143, 13.1 cm/s; HFC-143a, 7.1 cm/s; HFC-152a, 23.6 cm/s.

Data should be referenced to literature citation.


86-18 Log #11 Final Action: Accept (Table C.1(a))
Committee Meeting Action: Accept in Principle
See errata (68-02-1), published September 2004.
Committee Statement: The Committee already made the recommended corrections through an errata published (68-02-1) in September 2004. There are now only 2 entries - one for horizontal panels, hinged at the top (value of 1) and all other orientations (value of 0).
Number Eligible to Vote: 28
Ballot Results: Affirmative: 20
Ballot Not Returned: Bruderer, R., Davies, M., Gillis, J., Herrmann, D., Kirby, D., Plunkett, J., Shedrick, K., Zalosh, R.

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 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.

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

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

1.5 Retroactivity.

1.5.1 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.

1.5.1.1 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.

1.5.1.2 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.

1.5.1.3 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.

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

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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>1 m</td>
<td>3.28 ft</td>
</tr>
<tr>
<td></td>
<td>1 in.</td>
<td>25.4 mm</td>
</tr>
<tr>
<td></td>
<td>1 ft</td>
<td>305 mm</td>
</tr>
<tr>
<td></td>
<td>1 μm</td>
<td>1.00 × 10^4 m</td>
</tr>
<tr>
<td>Area</td>
<td>1 m^2</td>
<td>10.8 ft^2</td>
</tr>
<tr>
<td></td>
<td>1 in^2</td>
<td>6.45 cm^2</td>
</tr>
<tr>
<td>Volume</td>
<td>1 L</td>
<td>3.78 L</td>
</tr>
<tr>
<td></td>
<td>1 in^3</td>
<td>231 cm^3</td>
</tr>
<tr>
<td></td>
<td>1 ft^3</td>
<td>264 U.S. gal</td>
</tr>
<tr>
<td></td>
<td>1 m^3</td>
<td>35.3 ft^3</td>
</tr>
<tr>
<td></td>
<td>1 U.S. gal</td>
<td>1055 J</td>
</tr>
<tr>
<td>Pressure</td>
<td>1 atm</td>
<td>760 mm Hg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>101 kPa</td>
</tr>
<tr>
<td></td>
<td>1 psi</td>
<td>14.7 psi</td>
</tr>
<tr>
<td></td>
<td>1 bar</td>
<td>100 kPa</td>
</tr>
<tr>
<td></td>
<td>1 N/m^2</td>
<td>1.00 Pa</td>
</tr>
<tr>
<td></td>
<td>1 kg/cm^2</td>
<td>14.2 psi</td>
</tr>
<tr>
<td>Energy</td>
<td>1 J</td>
<td>2.05 lb*ft (psf)</td>
</tr>
<tr>
<td></td>
<td>1 Btu</td>
<td>1055 J</td>
</tr>
<tr>
<td></td>
<td>1 J</td>
<td>1.00 W-sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.205 lb*ft^2 (psf)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.021 bar-m/sec</td>
</tr>
<tr>
<td>Concentration</td>
<td>1 oz avoirdupois/ft^3</td>
<td>1000 g/m^3</td>
</tr>
</tbody>
</table>

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

- $A$ = Area ($m^2$, $ft^2$, or $in^2$)
- $A_v$ = Internal surface area of enclosure ($m^2$ or $ft^2$)
- $C$ = Constant used in venting equations as defined in each specific use
- $dP/dt$ = Rate of pressure rise (bar/sec or psi/sec)
- $K_G$ = Deflagration index for gases (bar-m/sec)
- $K_r$ = Reaction force constant (lb)
- $K_{SI}$ = Deflagration index for dusts (bar-m/sec)
- $L_n$ = 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)
- $P_{es}$ = Enclosure strength (bar or psi)
- $P_{ex}$ = Explosion pressure (bar or psi)
- $P_{max}$ = Maximum pressure developed in an unvented vessel (bar or psi)
- $P_{0}$ = Initial pressure (bar or psi)
- $P_{red}$ = Reduced pressure [i.e., maximum pressure actually developed during a vented deflagration (bar or psi)]
- $P_{stat}$ = Static activation pressure (bar or psi)
- $dP$ = Pressure differential (bar or psi)
- $S_u$ = Fundamental burning velocity (cm/sec)
- $S_f$ = Flame speed (cm/sec)
- $t_f$ = Duration of pressure pulse (sec)
- $UFL$ = 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.


3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible 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. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

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. Any finely divided solid material that is 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air. [654, 2000]

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 variable, K. (See 3.3.18, \( K_p \) and 3.3.19, \( K_{St} \)).

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

3.3.7 Dust. Any finely divided solid, 420 μm or 0.017 in. or less in diameter (that is, material capable of passing through a U.S. No. 40 Standard Sieve).

3.3.8* Enclosure. A confined or partially confined volume.

3.3.9 Equivalent Diameter. See 3.3.17, Hydraulic Diameter.

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 gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of a liquid, as specified by test.

3.3.15 Fundamental Burning Velocity. See 3.3.1.1.

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

3.3.17* 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.

3.3.18* \( K_g \). The deflagration index of a gas cloud.

3.3.19* \( K_{St} \). The deflagration index of a dust cloud.

3.3.20 Maximum Pressure (\( P_{max} \)). See 3.3.26.1.

3.3.21 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.

3.3.22* 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.

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

3.3.24 Mixture.

3.3.24.1* Hybrid Mixture. A mixture of a flammable gas at greater than 10 percent of its lower flammable limit with either a combustible dust or a combustible mist.
3.3.24.2 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.  

3.3.24.3 Stoichiometric Mixture. A balanced mixture of fuel and oxidizer such that no excess of either remains after combustion. [53, 2004]  

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

3.3.26 Pressure.  

3.3.26.1 Maximum Pressure (Pmax). The maximum pressure developed in a contained deflagration of an optimum mixture.  

3.3.26.2 Reduced Pressure (Pred). The maximum pressure developed in a vented enclosure during a vented deflagration.  

3.3.26.3 Static Activation Pressure (Pstat). 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).  

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

3.3.27.1 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.  

3.3.28 Reduced Pressure (Pred): See 3.3.26.2.  

3.3.29 Replacement-in-Kind. A replacement that satisfies the design specifications. [484, 2002]  

3.3.30 Static Activation Pressure (Pstat). See 3.3.26.3.  

3.3.31 Strength.  

3.3.31.1 Enclosure Strength (Penc). Up to two-thirds the ultimate strength for low-strength enclosures; for high-strength enclosures the enclosure design pressure sufficient to resist Pred.  

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

3.3.32 Vapor. See 3.3.16, Gas.  

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

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

Chapter 4 Fundamentals of Venting of Deflagrations  

4.1 Basic Concepts.  

4.1.1 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:  

Existing Equation 4.2 (no change) (4.1.1)  

4.1.2 For dusts, KSt and Pmax shall be determined in approximately spherical calibrated test vessels of at least 20 L (5.3 gal) capacity per ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts.  

4.1.2.1 The owner/user shall be permitted to test the dust with moisture content and particle size that deviates from those conditions established by the method described in 4.1.2 provided a documented risk assessment acceptable to the authority having jurisdiction has been performed prior to using these KSt values to determine vent sizing.  

4.1.3 The most accurate value of KG shall be determined directly by test, as outlined in Annex C.  

4.1.3.1 If testing cannot be done to determine KG for a particular gas, KG shall be permitted to be approximated by ratioming from the KG of propane (100 bar-m/sec) on the basis of the corresponding fundamental burning velocity (see Annex D) of propane (46 cm/sec) and the fundamental burning velocity of the gas in question. (See Table E.1 for KG values.)  

4.1.3.2 For gases, Pmax 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 (less than 100 joules).  

4.2 Mixtures.  

4.2.1 Gas Mixtures.  

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

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

4.2.2 Dust Mixtures.  

4.2.2.1 Where the hazard consists of a dust mixture, the vent size shall be based on the KG and Pmax of the mixture.  

4.2.2.2 Where the dust mixture composition is not certain, the vent size shall be based on the highest KG and Pmax of all components.  

4.2.3 Hybrid Mixtures.  

4.2.3.1 For hybrid mixtures, the vent size shall be based on the equivalent mixture KSt as determined by test.  

4.2.3.2 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 Pmax = 10 bar and KSt = 500 bar-m/sec.  

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

4.3 Enclosure Design and Support.  

4.3.1 Enclosure Design Pressure Selection Criteria.  

4.3.1.1 Pred shall not exceed two-thirds of the ultimate strength for the vented enclosure, provided deformation of the equipment can be tolerated.  

4.3.1.2 Where deformation cannot be tolerated, Pred shall not exceed two-thirds of the yield strength for the vented enclosure.  

4.3.1.3 For enclosures designed using the ASME Boiler and Pressure Vessel Code, or similar codes, the maximum allowable working pressure, herein designated as Pmax, shall be determined by calculation.  

4.3.1.3.1 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.  

4.3.1.3.2 Given a Pred, Pmax shall be selected based on the following conditions as defined by Equation 4.3.1.3.2a or Equation 4.3.1.3.2b:  

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

\[ P_{\text{max}} \leq \frac{2}{3} F_s P_{\text{max}} \]  

(4.3.1.3.2a)  

(2) Permanent deformation of the enclosure cannot be accepted.  

\[ P_{\text{red}} \leq (2/3) F_s P_{\text{max}} \]  

(4.3.1.3.2b)  

where:  

\[ P_{\text{red}} = \text{maximum pressure developed in a vented enclosure [bar (psi)]} \]  

\[ F_s = \text{ratio of ultimate stress of the enclosure to the allowable stress of the enclosure per the ASME Boiler and Pressure Vessel Code} \]  

\[ P_{\text{max}} = \text{enclosure design pressure [bar (psi)] according to ASME Boiler and Pressure Vessel Code} \]  

\[ F_s = \text{ratio of the yield stress of the enclosure to the allowable stress of the materials of construction of the enclosure per the} \]
4.3.1.4 Ductile design considerations shall be used.

4.3.1.4.1 For materials subject to brittle failure, such as cast iron, special reinforcing shall be considered.

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

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

\[
P_{\text{red}} \leq P_{\text{es}} / DLF \quad (4.3.2)
\]

where:

\[
P_{\text{red}} = \text{maximum pressure developed during venting [bar (psi)]}
\]

\[
P_{\text{es}} = \text{enclosure strength evaluated based on static pressure calculations for either deformation or burst [bar (psi)]}
\]

\[
DLF = X_{a} / X_{s}
\]

\[
X_{a} = \text{maximum dynamic deflection}
\]

\[
X_{s} = \text{static deflection or, in other words, the displacement produced in the system when the peak load is applied statically}
\]

4.3.2.1 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.

4.3.2.2 It shall be permitted to equivalently provide venting sufficient to prevent \( P_{\text{red}} \) from exceeding two-thirds of \( P_{\text{es}} \), evaluated based on static pressure calculations.

4.3.2.3 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.

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

4.3.3.1 Care shall be taken to ensure that the weakest structural element, as well as any equipment or other devices that can be supported by structural elements, is identified.

4.3.3.2 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.

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

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

4.3.4 Relieving Walls or Roof.

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

4.3.4.2 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.

4.3.5 Enclosure Support Criteria.

4.3.5.1* 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.

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

\[
F_{r} = a (DLF) (A_{v}) (P_{\text{red}}) \quad (4.3.5.2)
\]

where:

\[
F = \text{maximum reaction force resulting from combustion venting [kN (lbf)]}
\]

\[
a = \text{units conversion, [100 (1)]}
\]

\[
DLF = 1.2
\]

\[
A_{v} = \text{vent area [m}^{2} \text{ (in.}^{2})]\]

\[
P_{\text{red}} = \text{maximum pressure developed during venting [bar (psi)]}
\]

4.3.5.3* 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.

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

4.3.5.4.1 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. \( P_{\text{red}} \) of each vent panel are equal and less than or equal to 0.1 bar.
4. Vent panels are of equal area.

4.3.5.5* The duration of the reaction force shall be calculated according to Equation 4.3.5.5, which is shown to represent the available duration data within a minus 37 percent and a plus 118 percent [114].

Existing Equation 5.4 (no change) \( (4.3.5.5) \)

where:

\[
I_{f} = \text{duration of pressure pulse after vent opening (sec)}
\]

\[
b = 4.3 \times 10^{-3} \text{ (1.3 \times 10^{-3})}
\]

\[
P_{\text{max}} = \text{maximum pressure developed in an unvented explosion [bar (psi)]}
\]

\[
P_{\text{red}} = \text{maximum pressure developed during venting [bar (psi)]}
\]

\[
V = \text{enclosure volume [m}^{3} \text{ (ft}^{3})]\]

\[
A_{v} = \text{area of vent (without vent duct) [m}^{2} \text{ (ft}^{2})]\]

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

\[
I = 0.52 (F_{r}) (t_{f}) \quad (4.3.5.6)
\]

where:

\[
I = \text{total impulse experienced by supporting structure [kN-sec (lbf-sec)]}
\]

\[
F_{r} = \text{maximum reaction force resulting from combustion venting [kN (lbf)]}
\]

\[
t_{f} = \text{duration of pressure pulse after vent opening (sec)}
\]

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

4.4.1 For silos and other enclosures that can be vented at only one end, the maximum effective vent area to use to determine the expected \( P_{\text{red}} \) shall be the enclosure cross section.

4.4.2 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.

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

4.4.3* \( L/D \) of Elongated Enclosures.
4.4.3.1 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.

4.4.3.2 The maximum flame length along which the flame can travel, \( H \), shall be determined based upon the maximum distance, taken along the central axis, from the farthest end of the enclosure to the opposite end of the next vent.

4.4.3.3 When multiple vents are provided, a single value of \( H \), and L/D shall be permitted to be determined for the enclosure based upon the farthest vent shall be permitted.

4.4.3.4 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.

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

4.4.3.6 Internal volume of dust collector bags, filters, or cartridges shall be permitted to be eliminated when determining the effective volume of an elongated enclosure, when the vent is positioned as required by 7.8.1(1).

4.4.3.7 Partial volume (see Section 7.3) shall not be considered in the determination of effective volume per this section.

4.4.3.8 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.

4.4.3.9 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.

4.4.3.10 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.

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

4.4.3.12 The effective area, \( A_{eff} \), shall be determined by dividing \( V_{eff} \) by \( H \).

4.4.3.13 The effective hydraulic diameter, \( D_{he} \), for the enclosure shall be determined based upon the general shape of the enclosure taken normal to the central axis.

\[
D_{he} = \frac{4 \times A_{eff}}{p}
\]

where:
\[
p = \text{perimeter of the general shape}
\]

4.4.3.14 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:

\[
D_{he} = (4 \times A_{eff} / \pi)^{0.5}
\]

4.4.3.15 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:

\[
D_{he} = (A_{eff})^{0.5}
\]

4.4.3.16 L/D for use in this standard shall be set equal to \( H/D_{he} \).

4.4.4 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 authorities having jurisdiction.

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

4.5 Vent Closure Operation.

4.5.1 The vent opening shall be free and clear.

4.5.2 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.

4.5.2.1 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.

4.5.2.2 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.

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

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

4.5.5 A vent closure shall reliably withstand pressure fluctuations that are below \( P_{stat} \).

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

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

4.6 Consequences of a Deflagration.

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

4.6.2 Property damage and injury to personnel due to material ejection during venting shall be minimized or avoided by locating vented equipment outside buildings and away from normally occupied areas. (See 7.6.4 and Section 8.8 for gases and dusts, respectively.)

4.6.2.1 Deflagration vents shall not be located in positions closer to air intakes than the distances prescribed by the fireball length (see 7.6.4 and Section 8.8).

4.6.2.2 Deflagration vents shall be permitted to be located closer to buildings and normally occupied areas than the distances determined by 7.6.4 or 8.9.1, provided a documented risk assessment acceptable to the authority having jurisdiction has been performed.

4.6.2.3 The provision of a barrier shall be permitted to serve as an alternative means of protection.

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

4.7 Effects of Vent Inertia.

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

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

4.7.3 If the total mass of a closure divided by the area of the vent opening does not exceed the panel densities calculated by Equations 7.2.2.1a and 8.2.6.2 (for gas and dust, respectively), all vent area correlations presented in this standard shall be permitted to be used without correction [112].

4.7.4* 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.

4.8 Effects of Vent Discharge Ducts.

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

4.8.2 A vent duct shall have a cross section at least as great as that of the vent itself.
4.8.3* Vent area calculations shall include the effects of vent ducts. (See Sections 7.4 and 8.5 for gases and dusts, respectively.)

4.8.4 Vent ducts and nozzles with total lengths of less than one hydraulic diameter shall not require a correction to increase the vent area.

4.8.5 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 $P_{red}$.

4.8.5.1 When vent ducts include bends, the support calculations shall include reaction forces based upon the expected $P_{rot}$.

4.9 Venting with Flame Arresting and Particulate Retention.

4.9.1* Where external venting is not feasible, 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.

4.9.2 Particulate retention devices shall be listed and shall be considered only for use within the tested range of $K_{St}$, dust loading, dust type, enclosure volume, and $P_{red}$.

4.9.3* The vent area calculated in Chapters 7 and 8 shall be adjusted using experimentally determined efficiency values. (See Section 10.6.)

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

Chapter 5 General Requirements

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

5.2 Objectives.

5.2.1 Life Safety.

5.2.1.1* 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.

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

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

5.2.2 Property Protection.

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

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

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

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

5.2.3 Hazard Analysis.

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

5.2.3.2 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.

5.3 Compliance Options.

5.3.1 Options. Deflagration venting meeting the goals and objectives of Sections 5.1 and 5.2 shall be provided in accordance with either of the following:

1. Performance-based provisions of 5.3.2
2. Prescriptive-based provisions of 5.3.3

5.3.2 Performance-Based Design. A performance-based design shall be in accordance with Chapter 6 of this standard.

5.3.3 Prescriptive-Based Design. A prescriptive-based design shall be in accordance with Chapter 4 and Chapter 7 through Chapter 11 of this standard.

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

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

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

6.1.3 Maintenance of Design Features.

6.1.3.1 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.

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

6.2 Performance Criteria.

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

6.2.2 Deflagration vents shall limit the reduced pressure ($P_{red}$) within an enclosure and any attached vent ducts to meet the objectives in 5.2.1.1 and 5.2.1.2.

6.2.3 Deflagration Vent Discharge.

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

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

6.2.3.3 The area into which deflagration vents discharge shall not expose personnel to flame, hot gases, hot particles, or projectiles.

6.2.4 Inspection and Maintenance.

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

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

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

Chapter 7 Venting Deflagrations of Gas Mixtures and Mists

7.1 Introduction.

7.1.1* This chapter applies to the design of deflagration vents for enclosures with an $L/D$ of less than or equal to 5 that contain a gas or mist.

7.1.1.1 It is intended that this chapter be used with the information contained in the rest of this standard.

7.1.1.2 In particular, Chapters 4, 9, and 10 shall be reviewed before applying the information in this chapter.

7.1.2 The vent area shall be distributed symmetrically and evenly on the enclosure external surfaces.

7.1.3 The design of deflagration venting for combustible mists shall be based on the $K_{G}$ for propane of 100 bar-m/sec or the equivalent $S_{v}$ for propane of 46 cm/sec unless specific test data are available.

7.2 Venting of Gas or Mist Deflagration in Low-Strength Enclosures.
7.2.1 This section shall apply to the design of deflagration vents for low-strength enclosures that are capable of withstanding reduced pressures, $P_{red}$, of not more than 0.1 bar (1.5 psi).

7.2.2 The minimum required vent area for low-strength enclosures shall be determined by the following equation:

**Existing Equation 6.1 (no change)** (7.2.2)

where:

- $A_v$ = vent area [m² (ft²)]
- $C$ = venting parameter
- $A_S$ = internal surface area of enclosure [m² (ft²)]
- $P_{red}$ = maximum pressure developed in a vented enclosure during a vented deflagration [bar (psi)]

7.2.2.1 The venting parameter ($C$) shall be defined by the following equations for fundamental burning velocity ($S_u$) less than 60 cm/sec:

For $C$ (bar$^{1/2}$):

$$C = 1.57 \times 10^{-5} (S_u)^2 + 1.57 \times 10^{-4} (S_u) + 0.0109$$  \hspace{1cm} (7.2.2.1a)

For $C$ (psi$^{1/2}$):

$$C = 6.1 \times 10^{-5} (S_u)^2 + 6.1 \times 10^{-4} (S_u) + 0.0416$$  \hspace{1cm} (7.2.2.1b)

7.2.2.2 Figure 7.2.2.2 shall be used to determine values of venting parameters ($C$). A relationship between the venting parameter ($C$) and burning velocity of the fuel is shown in Figure 7.2.2.2. This relationship shall be considered valid for applications with flammable vapor and mists with burning velocities up to and including 60 cm/sec.

7.2.2.3 The design of deflagration venting for mists shall be based on the venting parameter for propane.

7.2.2.4 $P_{red}$, in this application, shall not exceed $P_{es}$ (in bar or psi, not to exceed 0.1 bar or 1.5 psi).

7.2.2.5* The vent area determined by Equation 7.2.2 shall be adjusted for vent mass when the vent mass exceeds $M_t$ as calculated in Equation 7.2.2.5.

$$M_t = (6.67 P_{red}^{0.2} V^{0.5} K_G^{0.5})^{0.67}$$  \hspace{1cm} (7.2.2.5)

7.2.2.6* If $M > M_t$, the vent area shall be increased by adding the calculated area, $\Delta A_v$, from Equation 7.2.2.6:

$$\Delta A_v = A_v (0.0075) M_t^{0.6} K_G^{0.5} / n^{0.3} V P_{red}^{0.2}$$   \hspace{1cm} (7.2.2.6)

where:

- $M$ = mass of vent panel (kg/m²)
- $M_t \leq 40$ kg/m²
- $A_v$ = vent area calculated by Equation 7.2.2

7.2.2.7 If $K_G$ is less than 75 bar-m/sec, $K_G = 75$ shall be used in the Equation 7.2.2.6.

7.2.2.8 For cross sections other than those that are circular or square, the effective diameter shall be permitted to be taken as the hydraulic diameter, 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.

7.2.2.9 Therefore, for enclosures with venting restricted to one end, the venting equation constraints shall apply as follows:

**Existing Equation 6.2 (no change)** (7.2.3.3)

7.2.3.2 For cross sections other than those that are circular or square, the effective diameter shall be permitted to be taken as the hydraulic diameter, 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.

7.2.3.3 Therefore, for enclosures with venting restricted to one end, the venting equation constraints shall apply as follows:

**Existing Equation 6.2 (no change)** (7.2.3.3)
where:

\[ L_3 = \text{longest dimension of the enclosure [m (ft)] measured to the center of the vent} \]
\[ A = \text{cross-sectional area [m}^2 (\text{ft}^2)] \text{ normal to the longest dimension} \]
\[ p = \text{perimeter of cross section [m (ft)]} \]

7.2.3.4 If an enclosure can contain a highly turbulent gas mixture and the vent area is restricted to one end, or if the enclosure has many internal obstructions and the vent area is restricted to one end, then the \( L/D \) of the enclosure shall not exceed 2, or the following equation shall be used:

**Existing Equation 6.3 (no change) (7.2.3.4)**

7.2.3.5 Where the dimensional constraints on the enclosure are not met, the alternate methods described in Chapters 7 through 9 shall be considered for solutions.

7.2.3.6 An alternate value of \( C \) shall be permitted to be used where large-scale tests are conducted for a specific application.

7.2.4 Calculation of Internal Surface Area.

7.2.4.1 The internal surface area, \( A_S \), shall include the total area that constitutes the perimeter surfaces of the enclosure that is being protected.

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

7.2.4.1.2 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.

7.2.4.1.3 Surface corrugations shall be neglected, as well as minor deviations from the simplest shapes.

7.2.4.1.4 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.

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

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

7.2.5* Methods to Reduce Vent Areas.

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

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

7.2.6 Vent Design. See also Section 4.4.

7.2.6.1 The vent closure shall be designed, constructed, installed, and maintained so that it releases readily, moves out of the path of the combustion gases, and does not become a hazard when it operates.

7.2.6.2* The total weight of the closure assembly, including any insulation or hardware, shall comply with the requirements in Section 4.7.

7.2.6.3* The construction material of the closure shall be compatible with the environment to which it is to be exposed.

7.2.6.4* For low-strength enclosures, \( P_{red} \) shall exceed \( P_{stat} \) by at least 0.024 bar (0.35 psi).

7.2.6.5 If an enclosure is subdivided into compartments by walls, partitions, floors, or ceilings, then each compartment that contains a deflagration hazard shall be provided with its own vent.

7.2.6.6 Each closure shall be designed and installed to move freely without interference by obstructions, such as ductwork or piping, so that the flow of combustion gases is not impeded. (See 4.5.1.)

7.2.6.7* Guarding shall be provided to prevent personnel from falling against vent closures.

7.2.6.8* Measures shall be taken to protect the closures against accumulations of snow and ice.

7.2.6.9* A lightweight roof shall be permitted to be considered sacrificial, provided its movement can be tolerated and is not hindered by ice or snow.

7.2.6.10 In such cases, it shall be necessary to strengthen the structural members of the compartment so that the reduced vent area available is equivalent to the vent area needed.

7.2.6.11 The minimum pressure needed for the weakest structural member shall be obtained by substituting the values for the available area, the internal surface area, and the applicable \( C \) value for the variables in Equation 7.2.2 and then calculating \( P_{red} \), the maximum allowable overpressure.

7.2.6.12 The vent area shall still be distributed as evenly as possible over the building’s skin.

7.3 Venting of Gas or Mist Deflagration in High-Strength Enclosures.

7.3.1* This section shall apply to enclosures that are capable of withstanding \( P_{red} \) of more than 0.1 bar (1.5 psi).

7.3.2* Basic Principles.

7.3.2.1 The user shall refer to 3.3.30.1 and Chapter 4 for specific comments relating to enclosure strength.

7.3.2.2 The vent shall be designed to prevent the deflagration pressure inside the vented enclosure from exceeding two-thirds of the enclosure strength.

7.3.2.3 Vent closures shall open dependably.

7.3.2.3.1 The proper operation of vent closures shall not be hindered by deposits of snow, ice, paint, sticky materials, or polymers.

7.3.2.3.2 Operation of vent closures shall not be prevented by corrosion or by objects that obstruct the opening of the vent closure, such as piping, air-conditioning ducts, or structural steel.

7.3.2.4 Vent closures shall withstand exposure to the materials and process conditions within the enclosure that is being protected.

7.3.2.5 Vent closures shall withstand ambient conditions on the nonprocess side.

7.3.2.6 Vent closures shall reliably withstand fluctuating pressure differentials that are below the design release pressure and shall also withstand any vibration or other mechanical forces to which they can be subjected.

7.3.3 Vent Area Calculations.

7.3.3.1 The length-to-diameter ratio, \( L/D \), of the enclosure determines the equation(s) that shall be used for calculating the necessary vent area.

7.3.3.1.1 For noncircular enclosures, the value that shall be used for diameter is the hydraulic diameter.

7.3.3.1.2 When the enclosure includes changes in diameter, such as in a cone or hopper, then the hydraulic diameter shall be modified accordingly, and becomes the effective diameter (see 7.6.3).

7.3.3.2* For \( L/D \) values of 2 or less, Equation 7.3.3.2, from [101], shall be used for calculating the necessary vent area, \( A_s \), in \( m^2 \):

**Existing Equation 6.5 (no change) (7.3.3.2)**

\[
K = \text{bar-m/sec}
\]
\[
P_0 = \text{bar}
\]
\[
P_{red} = \text{bar}
\]
\[
V_{min} = \text{m}
\]

7.3.3.2.1 Where the following constraints apply:

\[
\frac{KG}{P_{red}} \leq 550 \text{ bar-m/sec}
\]
\[
P_{red} \geq 2 \text{ bar and at least 0.05 bar} > P_{stat}
\]
\[
V \leq 1000 \text{ m}^2
\]
7.3.3.2.2 Initial pressure before ignition ≤ 0.2 bar.

7.3.3.3* L/D Values from 2 to 5.

7.3.3.3.1 For L/D values from 2 to 5, and for \( P_{\text{red}} \) no higher than 2 bar, the required vent area, \( A_v \), calculated from Equation 7.3.3.2, shall be increased by adding more vent area, \( \Delta A \), calculated from Equation 7.3.3.7 as follows:

**Existing Equation 6.6 (no change)**

**7.3.3.3.1**

7.3.3.3.2 Equation 7.3.3.7 shall be subject to the limitations stated in 7.3.3.4.

7.3.3.3.3 For long pipes or process ducts where L/D is greater than 5, the guidelines in Chapter 9 shall be used.

7.3.3.4 In addition to calculating the vent area using Equations 7.3.3.2 and 7.3.3.7, the vent area shall be permitted to be determined by the use of the graphs in Annex H.

7.3.3.5 The restrictions given for Equation 7.3.3.2 shall also apply to the graphs in Annex H.

7.3.3.6* The vent area determined by Equation 7.3.3.2 shall be adjusted for vent mass when the vent mass exceeds \( M_f \), calculated from Equation 7.3.3.1.

\[
M_f = (6.67 P_{\text{red}}^{0.2} V^{0.3} V K_g^{0.5})^{0.67} 
\]

**7.3.3.6**

where:

\( M_f \) = threshold mass (kg/m²)

\( P_{\text{red}} \) = bar

\( n \) = number of panels

\( V > 1 \text{ m}^3 \)

\( K_g \leq 250 \)

7.3.3.7* If \( M > M_f \), the vent area shall be increased by adding the calculated area, \( \Delta A \), from Equation 7.3.3.6:

\[
\Delta A = A_v (0.0075) M^{0.6} K_g^{0.5} / n^{0.3} V P_{\text{red}}^{0.2} 
\]

**7.3.3.7**

where:

\( M \) = mass of vent panel (kg/m²)

\( M \leq 40 \text{ kg/m²} \)

\( A_v \) = vent area calculated by Equation 7.3.3.2

7.3.3.7.1 If \( K_g \) is less than 75 bar-m/sec, \( K_g = 75 \) shall be used in the equation \( V > 1 \text{ m}^3 \).

7.4* Effects of Vent Ducts.

7.4.1* Where using Equations 7.3.3.2 and 7.3.3.7 with vent ducting, a lower value shall be used in place of \( \gamma A_v \).

7.4.2 The lower value, \( P'_{\text{red}} \), shall be determined for gases using Figure 7.4.2, or it shall be permitted to be calculated using Equations 7.4.2.3 and 7.4.2.4.

**FIGURE 7.4.2 Maximum Pressure Developed during Venting of Gas, with and without Vent Ducts. [101]** [Existing Figure 5.8.2, 2002 ed. (no change)]

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

7.4.3.1 If longer ducts are needed, \( P'_{\text{red}} \) shall be determined by appropriate tests.

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

7.4.3.3 For vent ducts with lengths of less than 3 m (10 ft), the following equation shall be used to determine \( P'_{\text{red}} \):

**Existing Equation 6.8 (no change)**

**7.4.2.3**

7.4.3.4 For vent ducts with lengths of 3 m to 6 m (10 ft to 20 ft), the following equation shall be used:

**Existing Equation 6.9 (no change)**

**7.4.2.4**

7.4.3 The vented material discharged from an enclosure during a deflagration shall be directed to a safe outside location to avoid injury to personnel and to minimize property damage. (See Section 4.8.)

7.4.4* If it is necessary to locate enclosures that need deflagration venting inside buildings, vents shall not discharge within the building.

7.4.4.1* Vent ducts shall be used to direct vented material from the enclosure to the outdoors.

7.4.5* A vent duct shall have a cross section at least as great as that of the vent itself.

7.4.6* Vent ducts shall be as straight as possible.

7.4.6.1 If bends are unavoidable, they shall be as shallow-angled as practical (that is, they shall have as long a radius as practical).

7.4.7 Where vent ducts vent through the roof of an enclosure, consideration shall be given to climatic conditions. (See Section 4.5.)

7.5* Effects of Initial Turbulence and Internal Appurtenances for Enclosures with Initial Pressures Near Atmospheric. Hydrogen \( K_g (250 \text{ bar-m/sec}) \) shall be used for venting initially turbulent gases that have values, in the quiescent state, that are close to or less than that of propane.

7.6 Effects of Initial Elevated Pressure.

7.6.1 The maximum pressure developed during the venting from the initially elevated pressure shall be calculated using the following equation:

**Existing Equation 6.10 (no change)**

**7.6.1**

where:

\( P_{\text{red,2}} \) = actual maximum pressure (bar abs) developed by the deflagration in a vented enclosure when the initial elevated pressure before ignition is \( P_2 \) (bar abs)

\( P_{\text{red,1}} \) = \( P_{\text{red}} \) as determined in Equations 7.3.3.2 and 7.3.3.7 (converted to bar abs)

\( P_2 \) = elevated initial pressure before ignition (bar abs)

\( P_1 \) = atmospheric pressure (1.0 bar abs)

7.6.2 Figure 7.6.2 shall not be extrapolated beyond \( A_v V^{2/3} = 0.35 \).

**FIGURE 7.6.2 Value of Exponent, \( \gamma \), as a Function of \( A_v / V^{2/3} \). [59] [Existing Figure 6.8.1, 2002 ed. (no change)]**

7.6.3 For calculations that involve elevated pressure, the following procedure shall be used.

7.6.3.1* The value that is used for \( P_2 \) shall be chosen to represent the likely maximum pressure at which a flammable gas mixture can exist at the time of ignition. It shall be permitted to be as low as the normal operating pressure.

7.6.3.2* The enclosure shall be located to accommodate the blast wave.

7.6.4* Fireball Dimensions.

7.6.4.1 The hazard zone from a vented gas deflagration shall be calculated by the following equation:

\[ D = 3.1 (V / n)^{0.6} \]

**7.6.4.1**
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 less than or equal to 6 handling combustible dusts or hybrid mixtures.

8.1.1.1 This chapter is intended to be used with the information contained in the rest of this standard.

8.1.1.2 In particular, Chapters 4, 7, 10, and 11 shall be reviewed before applying the information in this chapter.

8.1.1.3 Chapter 8 provides a number of equations and calculation procedures that shall be used to treat a variety of vent sizing applications.

8.1.1.4 A general flowchart given in Figure 8.1 demonstrates how these different tools fit together.

8.1.2* The variable $K_{St}$ is a measure of the deflagration severity of a dust and shall be as established by the test requirements of ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts, or ISO 6184/1, Explosion Protection Systems – Part 1: Determination of Explosion Indices of Combustible Dusts in Air.

8.1.3* Where actual material is not available for test, vent sizing shall be permitted to be based upon $K_{St}$ values for similar composition materials of particle size no greater than 63 microns.

8.1.3.1 Where the actual material intended to be produced is smaller than 63 microns, tests shall be performed near the intended particle size.

8.1.3.2 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 The L/D of the enclosure shall be determined according to Section 4.4.

8.2.2 Equation 8.2.2 shall be used to calculate the minimum necessary vent area, $A_{v0}$, in m²:

$$A_{v0} = 1 \cdot 10^{-4} \cdot (1 + 1.54 \cdot P_{stat}^{4/3}) \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max}}{P_{red}}} - 1 \quad (8.2.2)$$

where:
- $A_{v0}$ = vent area calculated from Equation 8.2.2 (m²)
- $P_{stat}$ = nominal static burst pressure of the vent (bar)
- $K_{St}$ = deflagration index (bar-m/sec)
- $V$ = enclosure volume (m³)
- $P_{max}$ = maximum pressure of a deflagration (bar)
- $P_{red}$ = reduced pressure after deflagration venting (bar)

8.2.2.1 Equation 8.2.2 shall apply to initial pressures before ignition of 1 bar absolute ± 0.2 bar.

8.2.2.2* The following limitations shall be applicable to Equation 8.2.2:

1. $5 \text{ bar} \leq P_{max} \leq 12 \text{ bar}$
2. $10 \text{ bar-m/sec} \leq K_{St} \leq 800 \text{ bar-m/sec}$
3. $0.1 \text{ m}^3 \leq V \leq 10,000 \text{ m}^3$

8.2.2.3 When $L/D$ is less than or equal to 2, then $A_{v0}$ shall be set equal to $A_{v1}$.

8.2.3 For $L/D$ values greater than 2 and less than or equal to 6, the required vent area, $A_{v1}$, shall be calculated as follows:

$$A_{v1} = A_{v0} \left[ 1 + 0.6 \left( \frac{L}{D} \right)^{2.75} \cdot \exp(-0.95 \cdot P_{stat}^{2}) \right] \quad (8.2.3)$$

8.2.3.1* It shall be permitted to extend Equation 8.2.3 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.

8.2.4 For situations where vents can be distributed along the major axis of the enclosure, Equations 8.2.2 and 8.2.3 shall be permitted to be applied where $L$ is the spacing between vents along the major axis.

8.2.5 It shall be permitted to determine $A_{v1}$ and $A_{v2}$ by the use of the graphs in Section H.2 for dusts, which are based on Equations 8.2.2 and 8.2.3. (See Section H.2 for an example.)

8.2.5.1 The restrictions noted for the equations shall also apply to the graphs.

8.2.6 Three different general Equations 8.2.3, 8.2.6.7, and 8.2.6.8 shall be applied to the determination of dust deflagration minimum required vent areas.

8.2.6.1 Equation 8.2.3, which produces smallest required vent areas, shall apply to dust handling and storage equipment within which the average air axial velocity, $v_{axial}$, and the tangential velocity, $v_{tan}$, are both less than 20 m/sec during all operating conditions.

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

$$v_{axial} = \frac{Q_{air} \cdot L}{V} \quad (8.2.6.2)$$

where:
- $Q_{air}$ = flow rate through the equipment (m³/sec)
- $L$ = equipment overall length in the direction of the air and product flow
- $V$ = equipment volume (m³)

8.2.6.3* If a circumferential (tangential) air velocity is in the equipment, $v_{tan}$ shall be given by $0.5 \cdot v_{tan,max}$, where $v_{tan,max}$ is the maximum tangential air velocity in the equipment.

8.2.6.4 Values of $Q_{air}$, $v_{axial}$, $v_{tan,max}$, and $v_{tan}$ shall be either measured or calculated by engineers familiar with the equipment design and operation.

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

8.2.6.6 When the maximum value derived of $v_{axial}$ and $v_{tan}$ are less than 20 m/sec, then $A_{v2}$ shall be set equal to $A_{v1}$.

8.2.6.7 When either $v_{axial}$ or $v_{tan}$ is larger than 20 m/sec then $A_{v2}$ shall be determined from the following equation:

$$A_{v2} = \left[ 1 + \frac{(Max(v_{axial},v_{tan})-20)}{36} \right] A_{v1} \quad (8.2.6.7)$$

8.2.6.8* Vent areas for buildings in which there is a dust explosion hazard shall be determined from the following Equation 8.2.6.8.

$$A_{v2} = 1.7 \cdot A_{v1} \quad (8.2.6.8)$$
Determine appropriate input parameters (e.g., $K_{ST}$, $P_{max}$, $P_{stat}$, $P_{initial}$, enclosure volume and L/D, vent cover area density)

Are the input parameters within the applicability limits specified in Chapter 8?

- **Yes**: Increase $A_v$ using the procedure described in Section 8.x if the vent cover density exceeds 2.5
- **No**: Reduce $A_v$ using the procedure described in Section 8.3 if the maximum size of the dust cloud limited by design or housekeeping procedures

Is $P_{initial} > 0.2$?

- **Yes**: Calculate minimum vent area for the compact enclosure only (Eq. 8.2.7)
- **No**: Apply enclosure L/D correction (Eq. 8.2.3) if the enclosure L/D > 2

Are vent ducts?

- **Yes**: Apply procedure to account for the vent duct effects (Section 8.5)
- **No**: Apply high turbulence corrections for high velocity equipment or for buildings

Are the input parameters within the applicability limits specified in Chapter 8?

- **No**: Use another chapter or consult an expert
- **Yes**: Calculate minimum vent area for the compact enclosure (Eq. 8.2.2)

Apply enclosure L/D correction (Eq. 8.2.3) if the enclosure L/D > 2

Calculate minimum vent area for the compact enclosure only (Eq. 8.2.7)

Apply procedure to account for the vent duct effects (Section 8.5)

Reduce $A_v$ using the procedure described in Section 8.3 if the maximum size of the dust cloud limited by design or housekeeping procedures

Increase $A_v$ using the procedure described in Section 8.x if the vent cover density exceeds 2.5

**FIGURE 8.1 Dust Explosion Vent Sizing Calculation Flowchart for Chapter 8.**
The required vent areas for these buildings shall be permitted to be reduced through use of the partial volume Equation 8.3.1.

The vent area determined by Equation 8.2.2 shall be adjusted for vent mass when the vent mass exceeds $M_r$, as calculated in Equation 8.2.7.

$$M_r = (6.67 P_{red}^{0.2} n^{0.3} V/K_{st}^{0.5})^{1.67} \quad (8.2.7)$$

where:

- $M_r$ = threshold mass (kg/m²)
- $P_{red}$ = bar
- $n$ = number of panels
- $V$ = volume (m³)
- $K_{st}$ ≤ 250.

If $M > M_r$, the vent area shall be increased by adding the calculated area, $\Delta A$, from equation 8.2.8:

$$\Delta A_y = A_y (0.0075) M^{0.6} K_{st}^{0.5} / n^{0.3} V^{0.2} \quad (8.2.8)$$

where:

- $A_y$ = vent area calculated by Equation 8.2.2
- $M$ = mass of vent panel (kg/m²)
- $M \leq 40$ kg/m²

If $K_{st}$ is less than 75 bar-m/sec, $K_{st} = 75$ shall be used in Equation 8.2.8.

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:

**Existing Equation 7.3 (no change)**

$X_r = \min \left( \frac{M}{A_{vpv}}, \frac{M}{A_{v0}} \right)$

where:

- $A_{vpv}$ = vent area for partial volume deflagration
- $A_{v0}$ = vent area for full volume deflagration as determined from Equations 8.2.2 and 8.2.8
- $X_r = \text{fill fraction} > \Pi$

The minimum required deflagration vent area for the building 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, $A_{f0}$, that are each 0.37 m² (4 ft²) or larger.
2. Weigh each sample and calculate the average mass, $\bar{M}$, (grams), of the floor samples.
3. Collect at least two representative samples from measured sample areas, $A_{sv}$, 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, $A_{svr}$, of these surfaces with dust deposits.
4. Weigh each sample and calculate the average mass, $\bar{M}$, (grams), of the surface samples.
5. Determine the total mass, $M_{sv}$, of combustible dust that could be released from the process equipment in the building.
6. Test the dust samples per ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts, to determine $P_{max}$, $K_{sv}$, and the worst-case concentration, $c_w$, corresponding to the largest value of $K_{sv}$.
7. Using the highest values of $P_{max}$ and $K_{sv}$, the building volume, $V$, and $\Pi = P_{red}P_{max}$, use Equation 7.2.2 to calculate the vent area, $A_{v0}$, needed if the full building volume were filled with combustible dust.
8. Calculate the worst-case building partial volume fraction, $X_r$, from the following equation:

**Existing Equation 7.4 (no change)**

$X_r = \frac{M_{sv} / A_{sv}}{M_{sv} / A_{sv} + M_{f} / A_{f0}}$

where:

- $X_r = \text{worst-case building partial fraction}$
- $\bar{M}_f = \text{average mass (gram) of floor samples}$
- $A_{f0} = \text{measured floor areas}$
- $c_w = \text{worst-case dust concentration}$
- $H = \text{ceiling height of the building}$
- $A_{svr} = \text{total area of surfaces with dust deposits}$
- $A_{sv} = \text{measured sample areas of surfaces with dust deposits}$
- $V = \text{building volume}$
- $M_{sv} = \text{total mass of combustible dust that could be released from the process equipment in the building}$

(a) The lowest value of $c_w$, for the various samples shall be used in the calculation. If a measured value of $c_w$ is not available, a value of 200 g/m³ shall be permitted to be used in this equation.

(b) If measured values of $\bar{M}_f/A_{f0}$ and $\bar{M}_s/A_{svr}$ are not available, and if the facility is to be maintained with cleanliness/maintenance practices in accordance with NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, an approximate value for these ratios shall be permitted to be used, based on a dust layer bulk density of 800 kg/m² and a layer thickness of $0.8 \text{ mm} = 1/32 \text{ in.}$ over the entire floor area and other surfaces defined in (C). The approximate value corresponding to these values is 640 g/m².

9. If the calculated $X_r > 1$, the minimum required vent area is equal to $A_{v0}$.
   (a) If $X_r \leq \Pi$, no deflagration venting is needed.
(b) If \( X_r > \Pi \), the minimum required vent area, \( A_{vpv} \), is calculated from Equation 8.3.1:
\[
A_{vpv} = A_{0} X_r^{-1/3} \sqrt{\frac{(X_r - \Pi)}{(1 - \Pi)}}
\]

8.4 Effects of Initially Elevated Pressure.

8.4.1 When enclosure pressure is initially greater than 0.2 bar, deflagration vents shall only be used when the following conditions are met:

1. Vent duct length \( L/D \) is \( \leq 1 \)
2. \( M \leq MT \)
3. \( v_{x,ax} \) and \( v_{x,tan} \) < 20 m/sec
4. No allowance for partial volume
5. Equation 8.4.2 shall be used to calculate the necessary vent area:
\[
A_{vp} = \frac{A_{vp}}{A_{0}} 10^{-1} \left[ 1 + 1.54 \left( \frac{P_{stat} - P_{\text{effective}}}{P_{\text{effective}}} \right) \right] K_{st} \cdot V^{3/4} \sqrt{\frac{1}{\Pi_{\text{effective}}}} - 1 \quad (8.4.2)
\]

where:
- \( A_{vp} \) = vent area (m²)
- \( P_{stat} \) = static burst pressure of the vent (bar)
- \( P_{\text{effective}} \) = reduced pressure (bar)
- \( P_{\text{effective}} = \frac{1}{3} P_{\text{initial}} \) (bar)
- \( P_{\text{initial}} \) = enclosure pressure at the moment of ignition (bar)
- \( K_{st} \) = deflagration index (determined at initially atmospheric pressure) (bar-m/sec)
- \( V \) = Enclosure volume (m³)
- \( \Pi_{\text{effective}} = (P_{\text{red}} - P_{\text{effective}}) \cdot (P_{\text{max}} + 1) / (1 \text{ bar-abs}) - 1 \) maximum pressure of the unvented deflagration at initially elevated pressure (bar)
- \( P_{\text{max}} \) = maximum pressure of an unvented deflagration initially at atmospheric pressure (bar)

8.4.3 An enclosure shall be permitted to be protected with initially elevated pressure with deflagration vents when the vents are designed according to full scale test data.

8.5 Effects of Vent Ducts.

8.5.1 The effect of vent ducts shall be calculated from the following equation:
\[
A_{v6} = A_{v6} \left( 1 + 1.18 \cdot E_1^{0.8} \cdot E_2^{0.4} \right) \sqrt{\frac{K}{K_{st}}} \quad (8.5.1a)
\]

where:
- \( A_{v6} \) = vent area (m²)
- \( A_{v6} \) = vent area required when a duct is attached to the vent opening (m²)

\[
E_1 = \frac{A_{v6} \cdot L_{\text{dusty}}}{V} \quad (8.5.1b)
\]

\[
E_2 = \frac{10^4 \cdot A_{v6}}{(1 + 1.54 \cdot P_{stat}^{4/3}) \cdot K_{st} \cdot V^{3/4}} \quad (8.5.1c)
\]

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

8.5.3 Equation 8.5.1a shall not be used if the initial pressure exceeds plus or minus 0.2 bar-g.

8.5.4 Equation 8.5.1a shall not be used in conjunction with Equation 8.3.1 (Partial Volume Deflagration).

8.5.5 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.

8.5.6 It shall be permissible to use Equation 8.5.1a for vent ducts equipped with elbows, bird-screens, and rain-covers so long as these obstructions are properly accounted for through the duct resistance coefficient \( K_{st} \).

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

8.5.8 The maximum length of the duct shall be limited to obey the inequality:
\[
L_{\text{eff}} \leq \min \left[ \frac{10,000 \cdot D}{K_{st}}, \frac{11,000}{K_{st}} \right] \quad (8.5.8)
\]

where:
- \( L_{\text{eff}} \) = min(\( L_{\text{dusty}}, L_{\text{dusty}} \))

8.5.9 Table 8.5.9 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 should be directed to a safe outside location (see Section 8.8).

**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 4.3.3).

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

**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 4.5 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 650, *Welded Steel Tanks for Oil Storage*, shall be referenced for guidelines on the design of a frangible, welded roof joint.

**8.6.3.3** Equipment, piping, and other attachments shall not be connected to the roof directly, as they could restrict the roof’s operation as a vent closure.

**8.6.3.4** The remaining portions of the enclosure, including anchoring, shall be designed to resist the calculated $F_{red}$, based on the vent area provided. (See Section 4.3.)

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

**8.7.1** The following three venting alternatives shall be permitted:

1. Locate all of the venting area below the bottom of the bags, filters, or cartridges, as shown in Figure 8.7.1(a). For this case, the vent area shall be permitted to be calculated on the basis of the dirty side only; that is, calculate the volume below the tube sheet, and subtract out the volume occupied by the bags.

2. Locate the vents as shown in Figure 8.7.1(b) and bags are either completely removed or shortened so that they do not extend below the top of the vent for a distance of one vent diameter from the vent. In addition, the bags immediately adjacent to the vent shall be removed and the remaining bags shall be restrained from passing through the vent. For this case, the vent area shall be permitted to be calculated on the basis of the dirty side only; that is, calculate the volume below the tube sheet, and subtract out the volume occupied by the bags.

3. Locate the vents such that the bottom of the vent(s) is at or above the bottom of the bags, as shown in Figure 8.7.1(c) and the row of bags closest to the vent are restrained from passing through the vent. For this case, the volume used to calculate the vent area shall be the entire volume (clean and dirty) below the tube sheet.

**FIGURE 8.7.1(a) Venting of Dust Collectors — Alternative Arrangement 1.** [Existing Figure 7.8.1(a), 2002 ed. (no change)]

**FIGURE 8.7.1(b) Venting of Dust Collectors — Alternative Arrangement 2.** [Existing Figure 7.8.1.2, 2002 ed. (no change)]

**FIGURE 8.7.1(c) Venting of Dust Collectors — Alternative Arrangement 3.** [Existing Figure 7.8.1(b), 2002 ed. (no change)]

### Table 8.5.9 Combination Rules and Limitations for NFPA 68 Dust Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Application</th>
</tr>
</thead>
</table>
| Vent Ducts    | $0.8 \leq P_{\text{a}} \leq 1.2 \text{ bar abs}$  
Panel density $\leq 2.5 \text{ lb/ft}^2$ 
Allow Partial Volume $1 \leq L/D \leq 6$ (calculate vent duct effect last) |
| Partial Volume| Allow Vent Duct 
Panel density $\leq 2.5 \text{ lb/ft}^2$ 
$0.8 \leq P_{\text{a}} \leq 1.2 \text{ bar abs}$ 
$1 \leq L/D \leq 6$ (calculate vent duct effect last) |
| Elevated Initial Pressure | No Vent Duct 
Panel density $\leq 2.5 \text{ lb/ft}^2$ 
$0.2 \leq P_{\text{a}} \leq 4 \text{ bar g}$ 
Full Volume Deflagration 
$1 \leq L/D \leq 6$ (calculate elevated initial pressure effect last) |
| Panel Inertia | $0.8 \leq P_{\text{a}} \leq 1.2 \text{ bar-a}$ 
No Vent Duct 
$2.6 \text{ lb/ft}^2 < \text{ Panel density } < 4 \text{ lb/ft}^2$ 
Allow Partial Volume $1 \leq L/D \leq 6$ |

---

### Fireball Dimensions.

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

8.8.3 If the clean air plenum contains dust, then a separate vent on the clean air side shall be calculated based on the clean air side volume.

### Fireball Dimensions.

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

8.8.5 A documented risk assessment shall be permitted to be used to reduce the hazard distances calculated in 8.8.2 and 8.8.3.

8.8.6 In the case of dust deflagration venting, the distance, $D$, shall be expressed by Equation 8.8.2.1.

$$D = K \left( \frac{V}{n} \right)^{1/3} \quad (8.8.2)$$

where:

- $D =$ axial distance (front) from the vent [m (ft)]
- $K =$ flame length factor
- $K = 10$ for metal dusts, $K = 8$ for chemical and agricultural dusts
- $V =$ enclosure volume (m$^3$)
- $n =$ number of panels

8.8.6.1 Axial distance, calculated by Equation 8.8.2.1, shall be limited to 60 m. [104]

8.8.6.2 The width of the projected flame measured from the centerline of the vent shall be calculated as one-half $D$.

8.8.6.3 The height of the fireball shall be defined to be the same dimension $D$, with half the height located below the center of the vent and half the height located above.

8.8.6.4 Where venting is from a cubic vessel, $P_{\text{max,a}}$ shall be indicated approximately by Equation 8.8.3 [108]:

$$P_{\text{max,a}} = \frac{K_{\text{St}} V}{A_v} \quad (8.8.3)$$

where:

- $P_{\text{max,a}} =$ external pressure (bar)
- $P_{\text{red}} =$ reduced pressure (bar)
- $A_v =$ vent area (m$^2$)
- $V =$ enclosure volume (m$^3$)
- $K_{\text{St}} < 200$ bar-m/sec
- $P_{\text{max}} \leq 9$ bar
8.8.4 For longer distances, \( r \) (in meters), the maximum external pressure, \( P_{\text{max},r} \) shall be indicated approximately by Equation 8.8.4:

**Existing Equation 7.10 (no change) (8.8.4)**

\[
\text{where:} \quad P_{\text{max},r} = \text{maximum external pressure} \\
P_{\text{max},a} = \text{external pressure (bar)} \\
D = \text{maximum length of fireball (m)} \\
r = \text{distance from vent} \geq 0.2 \text{ D (m)}
\]

8.8.5 Equations 8.8.2, 8.8.3, and 8.8.4 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: \(P_{\text{red}} \leq 1 \text{ bar}\)
3. Static activation pressure: \(P_{\text{stat}} \leq 0.1 \text{ bar}\)
4. Deflagration index: \(K_{\text{St}} \leq 200 \text{ bar-m/sec}\)

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

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

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

1. \(\Delta P = 1.74 P_0 \left( \frac{V_1}{V_0} \right)\)
2. \(V_0 = \text{free volume of building}\)
3. \(V_1 = \text{volume of protected equipment}\)
4. \(P_0 = \text{ambient pressure (14.7 psia or 1.013 bar abs)}\)
5. \(\Delta P = \text{pressure rise in the building (in same units as} P_0)\)

8.10* Deflagration Venting of Enclosures Interconnected with Pipelines.

8.10.1* 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 a \(P_{\text{stat}} < 0.2 \text{ bar}\).
2. Enclosures of volumes within 10 percent of each other shall be vented as determined by Equations 7.2.2 and 7.2.2.1a.
3. If enclosures have volumes that differ by more than 10 percent, the vents for both enclosures shall be designed as if \(P_{\text{red}}\) equals 1 bar or less. The enclosure shall be designed with \(P_{\text{p}}\) equal to minimum 2 bar.
4. If it is not possible to vent the enclosure with the smaller volume in accordance with this standard, then the smaller enclosure shall be designed for the maximum deflagration pressure, \(P_{\text{max}}\), 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, Standard on Explosion Prevention Systems, in order for the deflagration venting of smaller enclosures to be effective.

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 (3 psi).

9.1.2 This chapter applies 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 does not apply to vent discharge ducts.

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 cross-sectional area 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 (2 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.

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

[Existing Figure 8.4.3, 2002 ed. (no change)]

9.2.10.2 The maximum pressure during deflagration venting, \(P_{\text{red}}\), in a pipe or duct shall be no greater than fifty 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/sec or Less.

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

**FIGURE 9.2.10.2.1.1 Maximum Pressure Developed during Deflagration of Propane/Air Mixtures Flowing at 2 m/sec or Less in a Smooth, Straight Pipe Closed at One End.**

[Existing Figure 8.5.2, 2002 ed. (no change)]

9.2.10.2.2 For other pipe diameters, \(P_{\text{red}}\) shall be determined by interpolation of Figure 9.2.10.2.1.1.

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

9.2.10.2.2.1* The maximum pressure during deflagration venting, \(P_{\text{red}}\), in a pipe or duct that conveys dusts shall be estimated from Figure 9.2.10.2.2.1.
9.2.10.2.2 For dusts having other values of $K_{St}$, $P_{red}$ shall be determined by interpolation.

9.2.11 For system flow velocities greater than 2 m/sec and for gases with fundamental burning velocities greater than 60 cm/sec (2 ft/sec), additional vent area shall be provided in accordance with Section 9.3.

9.2.12 For systems having an initial flow velocity greater than 20 m/sec, for gases having a burning velocity more than 1.3 times that of propane, or for dusts with $K_{St} > 300$, vents shall be placed no more than 2 m (6.6 ft) apart.

9.3* Multiple Deflagration Vents on a Pipe or Duct.

9.3.1 Figure 9.3.1 shall be used to determine the maximum distance between each vent for a maximum pressure during deflagration venting of 0.17 bar (2.5 psi).

9.3.1.1 Figure 9.3.1 shall apply to system flow velocities up to 20 m/sec (66 ft/sec).

9.3.1.2 Figure 9.3.1 shall also apply to dusts with a $K_{St}$ less than or equal to 300 bar-m/sec and to propane.

9.3.2 For gases other than propane, the maximum pressure during deflagration and the distances between vents shall be calculated using Equations 9.3.2a and 9.3.2b, which are limited to fundamental burning velocities below 60 cm/sec (2 ft/sec).

Existing Equation 8.1 (no change) (9.3.2a)

Existing Equation 8.2 (no change) (9.3.2b)

where:

- $P_{red,x}$ = maximum pressure predicted for gas [bar (psi)]
- $P_{red,p}$ = 0.17 bar (2.5 psi) — maximum pressure for propane
- $L_x$ = distance between vents for gas [m (ft)]
- $L_p$ = distance between vents for propane [m (ft)]
- $S_{u,x}$ = fundamental burning velocity of gas
- $S_{u,p}$ = fundamental burning velocity of propane

Chapter 10 Details of Deflagration Vents and Vent Closures

10.1* Normally Open Vents.

10.1.1 Louvered Openings.

10.1.1.1 Increases in $P_{red}$ due to louvered openings shall be accounted for in a documented system design.

10.1.1.2 The pressure drop through the louvered vent shall be determined by gas flow calculations, and $P_{red}$ shall be adjusted.

10.1.2 Hangar-Type Doors. Large hangar-type or overhead doors shall be permitted to be installed in the walls of rooms or buildings that contain a deflagration hazard.

10.1.2.1 The doors shall be permitted to be opened to provide sizeable unobstructed vents during the operation of a process or of equipment in which there is an inherent deflagration hazard.

10.1.2.2 The opening shall be considered to be a vent only when the door is not in place.

10.1.2.3 Interlocks with process systems that create a deflagration hazard shall be provided to ensure that the doors are open when the process is in operation.

10.2 Normally Closed Vents.

10.2.1 The vent closure manufacturer or designer shall be responsible to document the value and tolerance of the $P_{stat}$ of a vent closure where installed according to the manufacturer’s recommendation in the intended application.

10.2.2 Testing shall be carried out to establish the $P_{stat}$ for any closure release mechanism, with the mechanism installed on the vent closure and tested as a complete assembly.

10.2.2.1 The requirement in 10.3.2 shall apply to all types of closure mechanisms, including pull-through fasteners; shear bolts; spring-loaded, magnetic, and friction latches; and rupture diaphragms.

10.2.2.2 For field-fabricated vent closures, the designer shall document that the entire assembly releases at the $P_{stat}$ specified.

10.2.2.2.1 The documentation shall include the design $P_{red}$, $P_{stat}$, enclosure surface area, closure area, panel mass per unit area, types of fasteners, spacing, and quantity.

10.2.2.2.2 The design records and installation drawings shall be maintained by the building owner and operator.

10.2.2.3 Where vent closure mechanisms or fasteners are used, they shall be listed for the application.

10.2.3 The vent closure shall be designed to release at the calculated pressure and shall be compatible with the service conditions to which it is to be exposed.

10.2.3.1 Vent closures shall be designed for their expected temperature range.

10.2.4 The closure shall be designed to withstand natural forces such as wind or snow loads, operating conditions such as internal pressure fluctuations and internal temperature, and the effects of corrosion.

10.3 Types of Building or Room Vent Closures. The following types of vent closures shall be permitted to be used with low-strength enclosures such as those covered by Chapter 7.

10.3.1 Hinged Doors, Windows, and Panel Closures. Hinged doors, windows, and panel closures shall be designed to swing outward and have latches or similar hardware that automatically release under the calculated release pressure.

10.3.1.1 Friction, spring-loaded, or magnetic latches of the type used for doors on industrial ovens shall be permitted to be used.

10.3.1.2 For personnel safety, the door or panel shall be designed to remain intact and to stay attached.

10.3.1.3 Materials that tend to fragment and act as shrapnel shall not be used.

10.3.2 Shear and Pull-Through Fasteners. Listed shear and pull-through fasteners shall be permitted to be used where the vent design calls for large vent areas, such as the entire wall of a room.

10.3.2.1 At locations where personnel or equipment can be struck by flying vent closures, tethering of the vent closure or other safety measures shall be required.

10.3.2.2* Where restraint is required, any vent restraint design shall be documented by the designer.

10.3.2.3 No restraint for any vent closure shall result in restricting the required vent area or slowing the response time of the closure.

10.3.2.4 Any hardware added to a vent closure shall be included when determining the total mass of the closure, subject to Section 4.8.

10.4 Restraints for Large Panels. Any vent restraint design shall be documented by the designer.

10.4.1 No restraint for any vent closure shall result in restricting the vent area.

10.4.2* Any hardware added to a vent closure shall be included when determining the total mass of the closure, subject to Section 4.8.
10.4.4* Where the vent closure panel is a double-wall type (such as an insulated sandwich panel), single-wall metal vent panel restraint systems shall not be used.

10.4.4* The restraint system shown in Figure 10.4.4 shall be used for double-wall panels.

FIGURE 10.4.4 An Example of a Restraint System for Double-Wall Insulated Metal Vent Panels. [Existing Figure 9.5.3, 2002 ed. (no change)]

10.4.4.1 The panel area shall be limited to $3.1 \text{m}^2$ (33 ft$^2$), and its mass shall be limited to 12.2 kg/m$^2$ (2.5 lb/ft$^2$).

10.4.4.2 Forged eyebolts shall be required.

10.4.4.3 Alternatively, a “U” bolt shall be permitted to be substituted for the forged eyebolt.

10.4.4.4* A shock absorber device with a fail-safe tether shall be provided.

10.5 Equipment Vent Closures.

10.5.1* Hinged Devices. Hinged doors or covers shall be permitted to be designed to function as vent closures.

10.5.1.1* The hinge shall be designed to ensure that the closure device remains intact during venting.

10.5.1.2* Hinged devices shall be permitted to be used on totally enclosed mixers, blenders, dryers, and similar equipment.

10.5.1.3 Charging doors or inspection ports shall be permitted to be designed to serve this purpose where their action does not endanger personnel.

10.5.1.4 Regular maintenance of hinge and spring-loaded mechanisms shall be performed to ensure proper operation.

10.5.1.5 If a hinged vent closure is followed by a vent duct, special consideration shall be given to the clearance between the front edge of the closure panel and the duct wall throughout the course of the opening arc.

10.5.1.5.1 The clearance shall not hinder flow during the venting while the vent closure is swinging open.

10.5.1.5.2 The amount of clearance needed from the front edge of the hinged closure, in the closed position, to the wall of the vent duct shall be approximately half of the length of the hinged closure from the hinge to the front edge.

10.5.1.6* Vacuum breakers shall be permitted to be designed according to Figure 10.5.1.6 and installed to prevent inward deformation, provided they are either built strongly enough to withstand the $P_{\text{red}}$ during venting, or provided they open to leave a clear path.

FIGURE 10.5.1.6 Graph to Determine the Vacuum Relief Area for Vacuum Vents on Enclosures. [104] [Existing Figure 9.6.1.6, 2002 ed. (no change)]

10.5.2* Rupture Diaphragm Devices. Only rupture diaphragms with controlled opening patterns that ensure full opening on initial rupture shall be utilized.

10.6* Flame-Arresting and Particulate Retention Vent Systems.

10.6.1 Flame-arresting and particulate retention vent systems shall be listed for their application.

10.6.2 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.

10.6.3* The following limitations shall apply:

(1) Where a flame-arresting and particulate retention vent system is 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 emissions

(2) A flame-arresting and particulate retention vent system shall be sized to ensure that $P_{\text{red}}$ remains within the enclosure design limits.

Chapter 11 Inspection and Maintenance

11.1 General.

11.1.1 This chapter covers the installation, inspection, and maintenance procedures necessary for proper function and operation of vent closures for venting deflagrations.

11.1.2 Sections 11.4 through 11.10 shall be applied retroactively.

11.2 Design Parameters and Documentation. Data sheets, installation details, and design calculations shall be developed and maintained for each vent closure application, suitable for review by an authority having jurisdiction that verifies a vent area is sufficient to prevent deflagration pressure from exceeding the enclosure strength and identifies areas exposed to potential overpressure, event propagation, and fireball effects during venting, including the following:

(1) Manufacturer’s data sheets and instruction manuals
(2) Design calculations
(3) General specifications
(4) Vent closure specifications
(5) End user inspection/maintenance forms
(6) User documentation of conformance with applicable standards
(7) Vent closure identification
(8) Combustible material properties test report
(9) Copy of vent identification label
(10) Process plan view
(11) Process elevation view
(12) Vent relief (pressure and fireball) path
(13) Proximity of personnel to vent relief path
(14) Mechanical installation details
(15) Electrical supervision (if provided) installation details
(16) Vent restraint installation and design documentation (if required)
(17) Process interlocks (if provided)
(18) Event deflagration isolation requirements (if required)
(19) Employee training requirements

11.3 Installation.

11.3.1 Mounting frames shall be fabricated and mounted so that the vent closure is not stressed in any way that will contribute to fatiguing the vent closure.

11.3.2 Vent closures shall be installed per manufacturer’s requirements.

11.3.3 The final installation shall be inspected to verify its conformance with the design.
11.4.2 Vent closure shall be clearly marked.

**WARNING:** Explosion relief device.

11.4* Inspection.

11.4.1 Vent closures shall be inspected according to 11.4.4 at least annually.

11.4.2* The frequency of the inspection described in 11.4.4 shall be permitted to be increased or decreased based on documented operating experience.

11.4.3 The owner/operator of the facility in which the deflagration vent closures are located shall be responsible for inspecting and maintaining such devices after they are installed.

11.4.4* The inspector shall verify, as applicable, that the vent inspection determines the following:

1. Opening is free and clear of any obstructions on both sides
2. Discharged material and fireball pathway does not extend into an area normally occupied by personnel or critical process equipment
3. Closure has been properly installed according to manufacturer’s instructions
4. Closure is not corroded or mechanically damaged
5. Closure is clearly identified with manufacturer’s information
6. Closure is clearly labeled as an explosion relief device
7. Closure has no damage and is protected from the accumulation of water, snow, ice, or debris after any act of nature
8. Closure has not been painted or coated other than by manufacturer
9. Closure has no buildup of deposits on the inside surfaces or between layers of the vent
10. Closure has not been tampered with
11. Closure shows no fatigue and has not released
12. Closure hinges (if provided) are lubricated and operate freely
13. Closure restraints (if provided) are in place and operational
14. Closure seals, tamper indicators, or vent rupture indicators (e.g., breakwire switches), if provided, are in place
15. Flame-arresting and particulate retention device is being maintained, clean, and unobstructed in accordance with the manufacturer’s listing
16. Closure has no conditions that will hinder its operation

11.4.5 The owner/operator shall verify by signature on the inspection form that the production process material has not changed since the last inspection.

11.5* Vent Closure Design Parameters. The vent closure design parameters shall be maintained and made available for management of change review, employee training information, inspection, and re-ordering purposes.

11.6 Inspection Reports. Deficiencies found during inspections shall be reported to the owner/operator.

11.7 Record Keeping.

11.7.1 A record shall be maintained that indicates the date and the results of each inspection and the date and description of each maintenance activity.

11.7.2 The records of inspections shall be retained for a minimum of 3 years.

11.8 Management of Change. Management shall implement and maintain written procedures to evaluate proposed changes to facility and processes, both physical and human, for the impact on safety, loss prevention, and control.

11.8.1 Management of change procedures shall be followed for any change to process, materials, technology, equipment, process flow, exposure, or procedures affecting equipment protected by requirements in this document.

11.8.2* Management of change documentation shall be available for review by the relevant authority having jurisdiction.

11.8.3 The management of change procedures shall ensure that the following issues are addressed prior to any change:

1. The technical basis for the proposed change
2. The safety and health implications
3. Fire and explosion prevention systems review
4. Whether the change is permanent or temporary
5. Personnel exposure changes
6. Modifications to operating maintenance procedures
7. Employee training requirements
8. Authorization requirements for the proposed change

11.8.4 Implementation of the management of change procedures shall not be required for replacements-in-kind.

11.8.5 Design documentation as required by Chapter 11 shall be updated to incorporate the change.

11.9 Maintenance.

11.9.1 Vent closure maintenance shall be performed after every act of nature or process upset condition to ensure that the closure has not been physically damaged and there is no obstructions including but not limited snow, ice, water, mud, or process material that could lessen or impair the efficiency of the vent closure.

11.9.2 An inspection shall be performed in accordance with 11.4.4 after every process maintenance turnaround.

11.9.3 If process material has a tendency to adhere to the vent closure, the vent closure shall be cleaned periodically to maintain vent efficiency.

11.9.4 Process interlocks, if provided, shall be verified.

11.9.5 Known potential ignition sources shall be inspected and maintained.

11.9.6 Records shall be kept of any maintenance and repairs performed.

11.10 Employee Training.

11.10.1 Initial and refresher training shall be provided and training records maintained for employees who are involved in operating, maintaining, and supervising facilities that utilize devices for venting of deflagrations.

11.10.2 Initial and refresher training shall ensure that all employees are knowledgeable about the following:

1. Hazards of their workplace
2. General orientation, including plant safety rules
3. Process description
4. Equipment operation, safe startup and shutdown, and response to upset conditions
5. The necessity for proper functioning of related fire and explosion protection systems
6. Deflagration vent(s) location, vent relief path, and maintenance requirements and practices
7. Housekeeping requirements
8. Emergency response and egress plans
A.3.2.2 Authority Having Jurisdiction (AHJ). The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items. The means for identifying listed equipment may be the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.
A.4.1.3 The maximum rate of pressure rise can be normalized to determine the $K_d$ value (see Section B.1). It should, however, be noted that the $K_d$ value is not constant and varies, depending on test conditions. In particular, increasing the volume of the test enclosure and increasing the ignition energy can result in increased $K_d$. Although the $K_d$ value provides a means of comparing the maximum rates of pressure rise of known and unknown gases, it should be used as a basis for deflagration vent sizing only if the tests for both materials are performed in enclosures of approximately the same shape and size, and if tests are performed using igniters of the same type that provide consistent ignition energy. Annex D includes sample calculations for $K_d$ values.

Some publications have proposed the calculation of vent areas for gases based on fundamental flame and gas flow properties and experimentally determined constants [26,78,79]. These calculation procedures have not yet been fully tested and are not recommended.

A.4.1.4 The properties of hybrid mixtures are discussed extensively in [3] and [66]. The effective $K_d$ value of most combustible dusts is raised by the admixture of a combustible gas, even if the gas concentration is below the lower flammable limit. The equivalent mixture $K_e$ can be determined by adapting the ASTM E 1226 method to precharge the test vessel with the combustible gas(es), then inject the dust in the normal way.

A.4.2.4 The foams of combustible liquids can burn. If the foam is produced by air that bubbles through the liquid, the bubbles contain air for burning. Combustion characteristics depend on a number of properties such as the specific liquid, the size of the bubble, and the thickness of the bubble film. A more hazardous case occurs if a combustible liquid is saturated with air under pressure; if the pressure over the liquid phase is then released, foam can form with the gas phase in the bubbles preferentially enriched in oxygen. The enrichment occurs because the solubility of oxygen in combustible liquids is higher than that of nitrogen. The increased oxygen concentration results in intensified combustion. Therefore, it is recommended that combustible foams be tested carefully relative to design for deflagration venting.

A.4.3.1.1 The maximum pressure that is reached during venting, $P_{max}$, exceeds the pressure at which the vent device releases, $P_{stat}$. The amount by which $P_{max}$ exceeds $P_{stat}$ is a complicated function of rate of pressure development within the enclosure, vent size, and vent mass. Where deflagration vent area to enclosure volume ratio is large, $P_{max}$ approaches $P_{stat}$. As the vent area is reduced, $P_{max}$ increases and approaches $P_{max}$ as the vent area goes to zero.

A.4.3.1.3 Figure A.4.3.1.3 shows a curve that is a general representation of a stress-strain curve for low-carbon steel.

FIGURE A.4.3.1.3 Stress-Strain Curve for Low-Carbon Steel. (Existing Figure A.5.3.3.2, 2002 ed. (no change))

In the context of pressure vessels, the maximum allowable accumulation of pressure, above the maximum allowable working pressure (MAWP), during the postulated relief scenario is used to determine the minimum open area of the relieving device. Stated differently, the maximum pressure in the vessel is allowed to exceed MAWP during the release. Equations 4.3.1.3.2a and 4.3.1.3.2b similarly indicate that for ratios of ultimate stress or yield stress to allowable stress greater than 1.5, $P_{max}$ could be chosen to exceed MAWP during the deflagration.

A.4.3.2 The dynamic load factor (DLF) is defined as the ratio of the maximum dynamic deflection to the deflection which would have resulted from the static application of the peak load, $P_{max}$, which is used in specifying the load-time variation. Thus the DLF is given by:

$$DLF = \frac{X}{X_s}$$

where:

- $X = \text{static deflection or, in other words, the displacement produced in the system when the peak load is applied statically}$
- $X_s = \text{maximum dynamic deflection}$

For a linear elastic system subjected to a simplified dynamic load, the maximum response is defined by the DLF and maximum response time, $t_m$. $T_m$ is the duration of the load, called $t_i$ in 4.3.5.5. and $T_i$ is the natural period of the structure. The DLF and time ratio, $T/T_m$, are plotted versus the time ratio $t_i/T_m$ in Figures A.4.3.2 and A.4.3.5.1 for A.4.3.2(2) and A.4.3.2(1) below, respectively.

Two simplified loading curves with a total impulse (force $\times$ time) of (1) are discussed as follows:

(1) A triangular load with an initial amplitude of 2 force units and a duration of 1 time unit

(2) A triangular pulse load with an initial amplitude of 0 force units, rising linearly to 2 force units at time of one-half time unit, and falling linearly to 0 force units at a total duration of 1 time unit.

For the situation inside a vented enclosure, the deflagration develops in an idealized triangular pulse. A.4.3.2(2). The pressure builds at least to the point the vent closure opens, $P_{max}$, and continues to rise to $P_{max}$ after reaching $P_{max}$. The pressure in the enclosure falls. In this case the maximum value of DLF would be approximately 1.5. Therefore design for a static pressure of two-thirds of yield or burst means that the maximum deflections during the event would reach yield or burst pressure, depending on the design choice. Since deflagration testing is done on supposed worst-case mixtures, this is a reasonable design value. For a stiff enclosure with a small natural period, $T_m$ and a typical deflagration, $T/T_m > 1$ and DLF will be less than the maximum 1.5.

FIGURE A.4.3.2 Maximum Response of Elastic One-Degree-of-Freedom System for Triangular Pulse Load. (Courtesy of Department of Defense Explosives Safety Board.)

Figure A.4.3.2 is Figure 3-52 from TM5-1300, Structure to Resist the Effects of Accidental Explosions, Department of Defense Explosives Safety Board, 1990.
Both maximum values for the supporting structure are higher than the experimental results by Faber [46], which bound the value of DLF as 1.2. Since the actual shape of the load curve is intermediate between the two cases, it is recommended that the experimental limiting value be used instead of either of the theoretical limits.

Figure A.4.3.5.1 is Figure 3-49 from TM5-1300, Structure to Resist the Effects of Accidental Explosions, Department of Defense Explosives Safety Board, 1990.

A.4.3.5.2 An example of the calculation of reaction force, \(F_r\), during venting for the following conditions is as follows:

1. \(A_v = 1 \text{ m}^2 = 1550 \text{ in.}^2\)
2. \(P_{red} = 1 \text{ bar} = 14.5 \text{ psi}\)
3. \(F_r = (1)(1.2)(1550)(14.5) = 26,970 \text{ lbf}\)

A.4.3.5.3 In the absence of specific test information or combustion modeling results for the pressure versus time, a combined collapse failure mechanism for structural supports can be evaluated against both idealized pulse and triangular wave loads and be designed based on the maximum DLF.

A.4.3.5.4 The installation of vents of equal area on opposite sides of an enclosure cannot be depended upon to prevent thrust in one direction only. It is possible for one vent to open before another. Such imbalance should be considered when designing restraints for resisting reaction forces.

A.4.3.5.5 Knowing the duration can aid in the design of certain support structures for enclosures with deflagration vents. Reference [114] contains several general equations that approximate the duration of the thrust force of a dust deflagration. These equations apply only to enclosures without vent ducts. This material was contained in the NFPA 68 Impulse Task Force Report to the full committee, September 15, 1999.

A.4.3.5.6 The determination of total impulse uses an equivalent static force, which represents the force-time integrated area as a rectangular pulse with height equal to \(F_r\) and a width equal to \(t_f\). The equivalent static force, \(F_s\), to be used for calculating total impulse is based on a load factor of 0.52, as established from test results [46].

\[ F_s = 0.52 (F_r) \]

For additional information on derivation of DLF and for use of the total impulse values, refer to textbooks on structural dynamics, such as J. M. Biggs, Introduction to Structural Dynamics.

An example of the calculation of duration of reaction force, \(t_f\), and total impulse, \(I\), resulting from venting for the following conditions is as follows:

1. \(V = 20 \text{ m}^3\)
2. \(P_{max} = 8 \text{ bar}\)
3. \(P_{red} = 0.4 \text{ bar}\)
4. \(A_v = 1.4 \text{ m}^2\)
5. \(t_f = (0.0043)(8/0.4)^{0.5}(20/1.4)\)
6. \(t_f = 0.27 \text{ sec}\)

The reaction force is determined as in 4.3.5.2:

7. \(F_r = (100)(1.2)(1.4)(0.4)\)
8. \(F_r = 67 \text{ kN}\)
9. \(I = (0.52)(67)(0.27)\)
10. \(I = 9.4 \text{ kN-sec} = 9400 \text{ N-sec}\)

A.4.4 The \(P_{red}\) developed in a vented enclosure decreases as the available vent area increases. If the enclosure is small and relatively symmetrical, one large vent can be as effective as several small vents of equal combined area. For large enclosures, the location of multiple vents to achieve uniform coverage of the enclosure surface to the greatest extent practicable is recommended. Rectangular vents are as effective as square or circular vents of equal area.

A.4.4.3 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
3. \(V_{eff} = (\pi D^2/4)\times h = (\pi (1.8)^2)/4 \times 4 = 10.18 \text{ m}^3\)
4. \(V_{eff} = 10.18 + 4.25 = 12.93 \text{ m}^3\)
5. \(V_{eff}\) is the shaded region in Figure A.4.4.3(a).
6. \(A_{eff} = V_{eff} / H\)
7. \(A_{eff} = 12.93 / 6.2 = 2.155 \text{ m}^3\)
8. \(A_{eff}\) is the cross section of the cylindrical part of the enclosure
9. \(D_{he} = 4 \times A_{eff} / \pi = (4 \times 2.155 / \pi)^{0.5}\)
10. \(D_{he} = 1.656 \text{ m}\)
11. \(L/D = H/D_{he} = 6/1.656 = 3.62\)

Cylindrical enclosure with a hopper and vented at the side

**FIGURE A.4.4.3(a) Calculating L/D Ratio for a Cylindrical Vessel with a Hopper and a Top Vent.**
Example 3.

(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

The volume of the cylindrical part = \((\pi \times D^2/4) \times h = (\pi \times (1.8)^2 \times 2) = 5.09 \text{ m}^3\)

The volume of the hopper, with diameters \( D_1 \) and \( D_2 = \pi \times h \times [(D_1)^2 + (D_1D_2) + (D_2)^2] / 12 = \pi \times 2 \times [(2)^2 + (2 \times 0.5) + (0.5)^2] / 12 = 2.75 \text{ m}^3\)

\[ V_{eff} = 5.09 + 2.75 = 7.84 \text{ m}^3 \]

\( V_{eff} \) is the shaded region in Figure A.4.4.3(b)

(3) \( A_{eff} = V_{eff} / H = 7.84 / 4 = 1.96 \text{ m}^2 \)

(4) \( D_{he} = 4 \times A_{eff} / \pi \), assuming a cylindrical cross section

\( D_{he} = 1.58 \text{ m} \)

(5) \( L/D = H / D_{he} = 4 / 1.58 = 2.53 \)

Example 4.

(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

\[ V_{eff} = A \times B \times h = 1.8 \times 1.5 \times 4.5 = 12.15 \text{ m}^3 \]

\( V_{eff} \) is the shaded region in Figure A.4.4.3(d).

(3) \( A_{eff} = V_{eff} / H = 12.15 / 4.5 = 2.7 \text{ m}^2 \)

(4) \( D_{he} = 4 \times A_{eff} / W_p = 4 \times A_{eff} / [2 \times (A + B)] \)

\( D_{he} = 4 \times 2.7 / [2 \times (1.8 + 1.5)] = 1.64 \text{ m} \)

(5) \( L/D = H / D_{he} = 4.5 / 1.64 = 2.74 \)
Example 5. General calculation of the volume of a hopper.

(1) Rectangular hopper

\[ V = \frac{(a_1)(h)(b_2-b_1)}{2} + \frac{(b_1)(h)(a_2-a_1)}{2} + \frac{h)(a_2-a_1)(b_2-b_1)}{3} + \frac{(a_1)(b_1)(h)}{2} \]

(2) Conical hopper

\[ V = \frac{\pi}{12}(h)(D_1^2 + (D_1D_2) + (D_2^2) \]

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.4.3.3(e)]. Since 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.

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.4.3.3(g)]. With multiple vents along the central axis, \(V_{eff}\) for the next vent is the volume from the bottom of the lowest vent to the top of the upper vent.

A.4.4.4 The design of deflagration vents and vent closures necessitates consideration of many variables, only some of which have been investigated in depth. The technical literature reports extensive experimental work on venting of deflagrations in large enclosures. Equations have been developed that can be used for determining the necessary vent areas for enclosures [101]. The calculated vent area depends on several factors including the size and strength of the enclosure, the characteristics of the fuel/oxidant mixture, and the design of the vent itself. The design techniques use one or more empirical factors that allow simplified expressions for the vent area. The design factors are the result of analyses of numerous actual venting incidents and venting tests that have allowed certain correlations to be made. The user of this standard is urged to give special attention to all precautionary statements.

The reduced pressure, \(P_{red}\), in a vented gas deflagration can be reduced significantly in certain situations by lining the enclosure interior walls with an acoustically absorbing material, such as mineral wool or ceramic fiber blankets. These materials inhibit acoustic flame instabilities that are responsible for high flame speeds and amplified pressure oscillations in deflagrations of initially quiescent gas–air mixtures in unobstructed enclosures.

Data in [45] show the effects of using 50 mm (2 in.) thick glass wool linings for propane deflagrations in a 5.2 m³ (184 ft³) test vessel that is equipped with a 1 m² (10.8 ft²) vent for which \(P_{stat}\) equals 24.5 kPa (3.6 psi). The value of \(P_{red}\) is 34 kPa (4.9 psi) in the unlined vessel and 5.7 kPa (0.8 psi) (that is, a reduction of 83 percent) where the glass wool lining is installed on two of the vessel interior walls.

Data in [37] illustrate the effects of a 76 mm (3 in.) thick mineral wool lining for natural gas deflagrations that are centrally ignited in a 22 m³ (777 ft³) test vessel that is equipped with a 1.1 m² (11.8 ft²) vent for which \(P_{stat}\) equals 8 kPa (1.2 psi). The measured values of \(P_{red}\) are approximately 60 kPa (8.7 psi) in the unlined vessel and approximately 8 kPa (1.2 psi) (that is, a reduction of 87 percent) where the lining is placed on the floor and three walls of the vessel.

Similar dramatic reductions in \(P_{red}\) have been obtained in propane deflagration tests in a 64 m³ (2260 ft³) enclosure using ceramic fiber blankets on three interior walls [102,103].

A detailed discussion of the role of acoustic flame instabilities in vented gas deflagrations can be found in [43]. Acoustic flame instabilities and enclosure wall linings are important factors in unobstructed, symmetrical enclosures with ignition near the center of the enclosure. Other types of flame instabilities, such as those described in [44], that are not influenced by enclosure wall linings can have a greater influence on \(P_{red}\) in other situations.

Situations can occur in which it is not possible to provide calculated deflagration venting as described in Chapters 7 and 8. Such situations do not justify the exclusion of all venting. The maximum practical amount of venting should be provided, since some
A.4.4.5 The equations in Chapters 7 and 8 do not precisely predict the necessary vent area for all enclosures under all conditions. Certain data indicate that the gas-venting equations do not provide sufficient venting in every case [44, 98, 99]. Also, tests that involve extreme levels of both congestion and initial turbulence demonstrate that pressures that exceed those indicated by the equations can occur [42, 87]. Currently, however, the use of the equations is recommended based on successful industrial experience.

As the vent area increases, the reduced pressure for a given static activation pressure of the vent closure decreases. Open vents are generally more effective than covered vents. Vents with lightweight closures are more responsive than those with heavy closures.

A.4.5.1 If the vent discharges into a congested area, the pressure inside the vented enclosure increases. A major blast pressure can be caused by the ignition of unburned gases or dusts outside the enclosure.

If vents are fitted with closure devices that do not remain open after activation (i.e., self-closing), it should be recognized that a vacuum can be created where gases within the enclosure cool. Vacuum within the enclosure could result in equipment damage.

A.4.5.7 In some cases, ensuring dependable operation can necessitate replacing a vent closure.

A.4.6 Deflagration venting is provided for enclosures to minimize structural damage to the enclosure itself and to reduce the probability of damage to other structures. In the case of buildings, deflagration venting can prevent structural collapse. However, personnel within the building can be exposed to the effects of flame, heat, or pressure.

Damage can result if a deflagration occurs in any enclosure that is too weak to withstand the pressure from a deflagration. For example, an ordinary masonry wall [200 mm (8 in.) brick or concrete block, 2 m (10 ft) high] cannot withstand a pressure difference from one side to the other of much more than 0.03 bar (0.5 psi).

Flames and pressure waves that emerge from an enclosure during the venting process can injure personnel, ignite other combustibles in the vicinity, result in ensuing fires or secondary explosions, and result in pressure damage to adjacent buildings or equipment. The amount of a given quantity of combustible mixture that is expelled from the vent, and the thermal and pressure damage that occurs outside of the enclosure, depends on the volume of the enclosure, the vent opening pressure, and the magnitude of \( P_{\text{red}} \). In the case of a given enclosure and a given quantity of combustible mixture, a lower vent opening pressure results in the discharge of more unburned material through the vent, resulting in a larger fireball outside the enclosure. A higher vent opening pressure results in more combustion taking place inside the enclosure prior to the vent opening and higher velocity through the vent. (See also Section 4.2.3.) The fireball from vented dust deflagrations is potentially more hazardous than from vented gas deflagrations, because large quantities of unburned dust can be expelled and burned during the venting process.

Deflagration venting generates pressure outside the vented enclosure. The pressure is caused by venting the primary deflagration inside the enclosure and by venting the secondary deflagration outside the enclosure.

A.4.7.1 Table A.4.7.1 demonstrates the effect of vent mass on \( P_{\text{red}} \).

### Table A.4.7.1 Reduced Pressure (\( P_{\text{red}} \)) Developed During Deflagration Venting Influenced by Mass of Vent Closure — 5 Percent Propane in Air, Enclosure Volume = 2.6 m$^3$ [95]

<table>
<thead>
<tr>
<th>Vent Closure Mass</th>
<th>Static Opening Pressure (( P_{\text{stat}} )) (m-bar)</th>
<th>Vent Closure Response Time (m-sec)</th>
<th>Reduced ( P_{\text{red}} ) (m-bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/m$^2$</td>
<td>lb/ft$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3563</td>
<td>0.073</td>
<td>103</td>
<td>14.5</td>
</tr>
<tr>
<td>3.32</td>
<td>0.68</td>
<td>96</td>
<td>31.0</td>
</tr>
<tr>
<td>11.17</td>
<td>2.29</td>
<td>100</td>
<td>42.6</td>
</tr>
<tr>
<td>20.79</td>
<td>4.26</td>
<td>100</td>
<td>54.0</td>
</tr>
</tbody>
</table>

Notes:
(1) \( L/D = 2.3 \).
(2) Test series reported = #17, #1, #3, and #4.
(3) \( A_1 = 0.56 \text{ m}^2 \) (6.0 ft$^2$).

A.4.7.2 The preponderance of the available test data indicates that \( P_{\text{red}} \) increases with panel density. These data have been used to develop the equations in this document. However, a limited amount of data demonstrates exceptions to this trend, especially for initially quiescent gas mixtures where venting-induced turbulence dominates \( P_{\text{red}} \)

The greater the mass of the closure, the longer the closure takes to clear the vent opening completely for a given vent opening pressure. Conversely, closures of low mass move away from the vent opening more quickly, and venting is more effective.

A.4.7.3 The free area of a vent does not become fully effective in relieving pressure until the vent closure moves completely out of the way of the vent opening. Until this occurs, the closure obstructs the combustion gases that are issuing from the vent.

In general, a hinged vent closure results in a higher \( P_{\text{red}} \) than does a rupture diaphragm. The hinged vent closure with its geometric area, \( A_1 \), mass, and static relief pressure, \( P_{\text{stat}} \), is tested in position on an enclosure under suitable conditions of gas \( K_G \) or dust \( K_{St} \) and ignition that closely replicate the intended installation. The \( P_{\text{red}} \) is determined experimentally under these conditions, and \( P_{\text{red}} \) is related to a corresponding vent area, \( A_2 \), for an inertia-less vent closure such as a rupture diaphragm, which relieves at the same \( P_{\text{stat}} \) and gives the same \( P_{\text{red}} \).

The venting efficiency is given by the following equation:

Existing Equation 5.7 (no change) (A.4.7.3)

\[
E = \text{venting efficiency}
\]

\[
A_2 = \text{vent area for inertia-less vent closure}
\]

\[
A_1 = \text{vent area for hinged vent closure}
\]

For similarly designed hinged closures, the vent area determined by use of equations in Chapter 7 or Chapter 8 should be corrected by dividing by the demonstrated fractional efficiency of the hinged vent closure. This correction would include the otherwise modeled effect of increased inertia. Annex F provides an alternative method to account for hinged closures when dealing with dusts.

A.4.8.3 The addition of a vent duct can substantially increase the pressure developed in a vented enclosure.

A.4.9.1 Even with complete retention of particulates, the immediate area surrounding the vent can experience overpressure and radiant energy. Such overpressure and radiant energy pose personnel concerns in occupied facilities.

A.4.9.3 The retention of particulates results in a loss of venting efficiency.

A.4.9.4 Venting indoors affects the building that houses the protected equipment due to increased pressurization of the surrounding volume. (See also Section 8.9.) Venting indoors increases the potential for secondary explosions. Particulate deposits in the immediate area can be dislodged by the pressure wave and generate a combustible dust cloud.
The nature of a deflagration event is such that personnel in an enclosure where a deflagration occurs do not have time to exit to a place of safety. Personnel in the space will be subject to flame and pressure effects. General safety guidelines of other standards should be consulted for advice on how to prevent hazardous atmospheres or restrict access.

Treatment of interconnected enclosures needs to be considered and explained.

For example, information can be found in API 752, Table 3.

No venting recommendations are currently available for fast-burning gases with fundamental burning velocities greater than 1.3 times that of propane, such as hydrogen. Recommendations are unavailable because the recommended method allows for initial turbulence and turbulence-generating objects, and no venting data have been generated that address conditions for fast-burning gas deflagrations. The user is cautioned that fast-burning gas deflagrations can readily undergo transition to detonation. NFPA 69, Standard on Explosion Prevention Systems, provides alternate measures that should be used.

Equation 7.2.2 was developed from the results of tests and the analysis of industrial accidents. Deflagration vents have been effective in mitigating the consequences of many industrial building explosions. However, it should be noted that flames and pressure waves from an explosion can be hazardous, as described in 7.2.3 and 7.2.4. Furthermore, test work has demonstrated that deflagrations of flammable gas mixtures in enclosures that contain turbulence-inducing objects (such as process equipment, pipework, cable trays, and so forth) can develop pressures significantly higher than predicted by Equation 7.2.2. It is therefore recommended that building vents should be used in addition to taking measures to minimize the potential for flammable gas accumulations in enclosures.

Numerous methods have been proposed for calculating the vent closure area [23–27]. Some venting models use the surface area of the enclosure as a basis for determining vent area. Analysis of available data [30–45] shows that such methods overcome certain deficiencies associated with previous methods of calculating vent area.

Use of Figure 7.2.2.2 provides a way to interpolate between the vent parameter provided to accommodate a range of fuels. Methane (previously included in the vent parameter table) has been left out of the curve deliberately since flame speeds in methane/air mixtures do not accelerate as much with turbulence as with other hydrocarbons with similar fundamental burning velocity. The shape of the curve beyond 46 cm/sec was developed based on limited data with fuels of higher burning velocity.

The following information is offered to aid the user in determining an appropriate burning velocity (and ultimately vent parameter C) to use when dealing with aerosols (mists).

The burning velocity of aerosols varies according to the fuel to air ratio, droplet diameter, and vapor-fuel-to-total-fuel ratio (Ω). This is illustrated in Figure A.7.2.2.2 (a). The burning velocity ratio is the ratio of the mist fundamental burning velocity to that of the pure vapor. The effect of increased burning velocity in the range of 5 to 35 microns is believed to be evident primarily in fluids of relatively low volatility such as heat transfer fluids that can be released above their atmospheric boiling point. In these circumstances, they can form an aerosol consisting of very small droplets that can fall into the 5 to 35 micron range.

The general effect of burning velocity on liquid mists released below their flash points in the order of 50 μm as compared with dusts of similar particle size and vapors is shown in Figure A.7.2.2.2(b) from Lees.

The dimensionless Spalding mass transfer number (B) is defined as:

\[ B = \frac{q_s H + C_p(T_g - T_f)}{L + C_p(T_b - T_f)} \]

where:

- \( q_s \) = mass ratio of fuel to air at stoichiometric concentration
- \( H \) = heat of combustion

Figure A.7.2.2.2(a) Burning Velocity Predictions Versus Aerosol Droplet Size at Different Values of \( \Omega \).
**Sample Calculations.**

Consider a 6.1 m × 9.2 m × 6.1 m (20 ft × 30 ft × 20 ft) (length × width × height) dispensing room for Class I flammable liquids. The anticipated flammable liquids have fundamental burning velocities less than 1.3 times that of propane [see Table C.1(a)]. The room is located against an outside wall and, in anticipation of deflagration venting requirements, the three inside walls are designed to withstand a $P_{\text{req}}$ value of 0.05 bar (0.69 psi). For most flammable liquids, Figure 7.2.2.2 specifies a venting equation constant, $C$, of 0.17. The internal surface area of the room, 297 m² (3200 ft²), is determined by the following equation:

$$A_v = \frac{(0.17)(3200)}{0.69} = 61 \text{ m}^2 (655 \text{ ft}^2)$$

This area is more than is available in the outside wall, so modification is necessary.

**Step 2.** If the wall strength were increased to resist a $P_{\text{req}}$ of 0.072 bar (1.04 psi), a vent area of 50 m² (533 ft²) would be needed. This wall strength can usually be achieved and is recommended over the common wall strength intended to resist a $P_{\text{req}}$ of 0.048 bar (0.69 psi).

**Step 3.** Consider the building illustrated in Figure A.7.2.6.9(a), for which deflagration venting is needed. The building is to be protected against a deflagration of a hydrocarbon vapor that has the burning characteristics of propane. The maximum $P_{\text{req}}$ that this building can withstand has been determined by structural analysis to be 3.45 kPa (0.5 psi).

**FIGURE A.7.2.6.9(a) Building Used in Sample Calculation (Not to Scale) (Version I).** [Existing Figure 6.2.9.2, 2002 ed. (no change)]

**Step 4.** Divide the building into sensible geometric parts (Parts 1 and 2) as shown in Figure A.7.2.6.9(b).

**FIGURE A.7.2.6.9(b) Building Used in Sample Calculation (Not to Scale) (Version II).** [Existing Figure 6.2.9.3, 2002 ed. (no change)]

**Step 5.** Calculate the total internal surface area of each part of the building.

**Part 1 Surface Area ($A_{S1}$)**

<table>
<thead>
<tr>
<th>Part</th>
<th>Area $A_{S1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>51.8 m × 9.15 m = 474 m²</td>
</tr>
<tr>
<td>Roof</td>
<td>51.8 m × 9.65 m = 499 m²</td>
</tr>
<tr>
<td>Rear wall</td>
<td>51.8 m × 6.1 m = 316 m²</td>
</tr>
<tr>
<td>Front wall</td>
<td>36.6 m × 9.15 m × 15.25 m × 3.05 m = 381 m²</td>
</tr>
<tr>
<td>Side walls (rectangular part)</td>
<td>2 × 9.15 m × 6.1 m × 111 m²</td>
</tr>
<tr>
<td>Side walls (triangular part)</td>
<td>2 × 30 ft × 20 ft = 1200 ft²</td>
</tr>
<tr>
<td>Total Part 1: $A_{S1}$</td>
<td>1809 m² (19,472 ft²)</td>
</tr>
</tbody>
</table>

**Part 2 Surface Area ($A_{S2}$)**

<table>
<thead>
<tr>
<th>Part</th>
<th>Area $A_{S2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>15.25 m × 9.15 m = 139 m²</td>
</tr>
<tr>
<td>Roof</td>
<td>15.25 m × 9.15 m = 139 m²</td>
</tr>
<tr>
<td>Front wall</td>
<td>15.25 m × 6.1 m = 93 m²</td>
</tr>
<tr>
<td>Side walls</td>
<td>2 × 9.15 m × 6.1 m = 111 m²</td>
</tr>
<tr>
<td>Total Part 2: $A_{S2}$</td>
<td>483 m² (5200 ft²)</td>
</tr>
</tbody>
</table>

---

**C**$_{pa}$ = specific heat of air

**C**$_{p}$ = specific heat of the fuel

$T$ = temperature of the gas (g), boiling point of the fuel (b), surface of the fuel (s)

$L$ = latent heat of vaporization

At the time of this writing, the committee is unaware of any aerosol testing that has definitively correlated deflagrations of small droplet diameter (0 to 30 micron) aerosols to vent area. The information is provided as a word of warning.

A.7.2.2.5 Where $K_o$ is greater than 250 bar-m/sec, it is necessary to perform testing or apply alternate explosion protection methods per NFPA 69.

A.7.2.2.6 Where $M$ is greater than 40 kg/m² or $K_o > 250$, it is necessary to perform testing or apply alternate explosion protection methods per NFPA 69, Standard on Explosion Prevention Systems.

A.7.2.3 The form of the venting equation is such that there are no dimensional constraints on the shape of the room, provided the vent area is not applied solely to one end of an elongated enclosure (see Section 7.6 for other general vent considerations).

A.7.2.4.1.5 Such rooms include adjoining rooms separated by a partition incapable of withstanding the expected pressure.

A.7.2.5 The calculated vent area, $A_v$, can be reduced by increasing the value of $P_{\text{red}}$. The value of $P_{\text{red}}$ should not be increased above 0.1 bar (1.5 psi) for the purpose of design under this chapter. If $P_{\text{red}}$ is increased above 0.1 bar (1.5 psi), the methods of Section 6.3 should be followed.

The calculated vent area, $A_v$, can be reduced if applicable large-scale tests demonstrate that the flammable material has a smaller constant, $C$, than indicated in Figure 7.2.2.2.

The need for deflagration vents can be eliminated by the application of explosion prevention techniques described in NFPA 69, Standard on Explosion Prevention Systems.

A.7.2.6.2 See Section 4.8 for restrictions on vent closure weight where using Equation 7.2.2 without consideration for vent closure efficiency.

A.7.2.6.3 Some closures, on activation, are blown away from their mounting points. Brittle materials can fragment, producing projectiles. Each installation should be evaluated to determine the extent of the hazard to personnel from such projectiles. Additionally, it should be recognized that the vented deflagration can discharge burning gases, posing a personnel hazard. For further information, see National Association of Corrosion Engineers Handbook.

A.7.2.6.4 Deflagration vent closures should release at a $P_{\text{stat}}$ value that is as low as practical, yet should remain in place when subjected to external wind forces that produce negative pressures, to prevent vents from being pulled off. In most cases, a $P_{\text{stat}}$ value of 0.01 bar (0.14 psi) is acceptable. In areas subject to severe windstorms, release pressures up to 0.015 bar (0.21 psi) are used. In any case, locating vents at building corners and eave lines should be avoided due to the higher uplift pressures in such areas. In hurricane areas, local building codes often require higher resistance to wind uplift. In such situations, the limitations of $P_{\text{stat}}$ in 6.2.8.5 should be recognized, and strengthened internal structural elements should be provided.

A.7.2.6.7 A vent closure can open if personnel fall or lean on it.

A.7.2.6.8 The criteria for the design of roof-mounted closures are basically the same as those for wall closures.

A.7.2.6.9 Situations can arise in which the roof area or one or more of the wall areas cannot be used for vents, either because of the location of equipment, or because of exposure to other buildings or to areas normally occupied by personnel.
Step 6. Thus, the total internal surface area for the whole building, $A_{v}$, is expressed as follows:

$$A_v = 1809 \text{ m}^2 (19,472 \text{ ft}^2) + 483\text{ m}^2 (5200 \text{ ft}^2) = 2292 \text{ m}^2 (24,672 \text{ ft}^2)$$

Step 7. Calculate the total vent area, $A_{v}$, needed using Equation 6.1:

$$A_{v} = \frac{C(A_{v})}{P_{red}^{1/2}}$$

where:

$$C = 0.045 \text{ bar}^{1/2} (0.17 \text{ psi})^{1/2} \text{ from Figure 7.2.2.2}$$

$$A_{v} = 2292 \text{ m}^2 (24,672 \text{ ft}^2)$$

$$P_{red} = 3.45 \text{ kPa} (0.5 \text{ psi})$$

Step 8. Substituting these values:

$$A_{v} = \frac{(0.17)(24,672)}{0.8^{1/2}} = 5932 \text{ ft}^2 (551 \text{ m}^2)$$

Step 9. The total vent area needed of 5932 ft$^2$ (551 m$^2$) should be divided evenly over the outer surface of the building and should be apportioned between the parts in the same ratio as their surface area.

Step 10. Total vent area of Part 1:

$$A_{v1} = A_{v} \left( \frac{A_{v1}}{A_{v}} \right) = 5932 \left( \frac{19,472}{24,672} \right) = 4682 \text{ ft}^2 (435 \text{ m}^2)$$

Step 11. Total vent area of Part 2:

$$A_{v2} = A_{v} \left( \frac{A_{v2}}{A_{v}} \right) = 5932 \left( \frac{5200}{24,672} \right) = 1250 \text{ ft}^2 (116 \text{ m}^2)$$

Step 12. Check to determine whether sufficient external surface area on the building is available for venting.

Step 13. In Part 1, the vent area needed [435 m$^2$ (4682 ft$^2$)] can be obtained by using parts of the front, rear, and side walls or by using the building roof.

Step 14. In Part 2, the vent area needed [116 m$^2$ (1250 ft$^2$)] can be obtained by using parts of the front and side walls or by using the building roof.

Step 15. Note that only the outer “skin” of the building can be used for vent locations; a deflagration cannot be vented into other parts of the building.

A.7.3.1 Enclosures include process vessels, silos, and other process equipment.

A.7.3.2 Certain basic principles are common to the venting of deflagrations of gases, mists, and dusts. The principles include, but are not limited to, those discussed in 7.3.2.

The maximum pressure that is reached during venting, $P_{red}$, always exceeds the pressure at which the vent device releases, in some cases it is significantly higher. Maximum pressure is affected by a number of factors.

A.7.3.3.2 Equation 7.8 is derived from tests made under the following conditions:

1. Volumes of test vessels: 2.4 m$^3$, 10 m$^3$, 25 m$^3$, and 250 m$^3$; L/D of test vessels approximately 1
2. Initial pressure: atmospheric
3. $P_{sur}$: 0.1 bar to 0.5 bar
4. Ignition energy: 10 J
5. Stationary gas mixture at time of ignition
6. No turbulence inducers

A.7.3.3.3 Equation 7.3.3.2 was developed based on the following considerations:

1. Flame speeds and values of $P_{red}$ increase rapidly in elongated vessels with $L/D$ greater than the maximum value for which Equation 7.2.2 is applicable.
2. Gases with higher values of $K_{r}$ are more prone to flame acceleration in elongated vessels.
3. Limited data on flame speeds and pressures are available in Section 5.1 of [101] for propane deflagrations in an open-ended vessel with $L/D$ of approximately 5.

A.7.3.3.5 Where $K_{r}$ is greater than 250 bar-m/sec, it is necessary to perform testing or apply alternate explosion protection methods per NFPA 69, Standard on Explosion Prevention Systems.

A.7.3.3.6 Where $M$ is greater than 40 kg/m$^2$ or $K_{r} > 250$, it is necessary to perform testing or apply alternate explosion protection methods per NFPA 69, Standard on Explosion Prevention Systems.

A.7.4 The deflagration vent area requirement is increased where a vent discharge duct is used. Where a deflagration is vented through a vent duct, secondary deflagrations can occur in the duct, reducing the differential pressure available across the vent. The sizing equations and graphs in Section H.1 are based on venting deflagrations to atmosphere without vent ducts.

A.7.4.1 The use of a vent duct with a cross section greater than that of the vent can result in a smaller increase in the pressure that develops during venting, $P_{red}$, than where using a vent duct of an equivalent cross section [93], but this effect is difficult to quantify because of limited test data.

Vent ducts should be as short and as straight as possible. Any bends can cause dramatic and unpredictable increases in the pressure that develops during venting.

It should be noted that $P_{red}$ is still the maximum pressure developed in a vented deflagration. $P_{red}$ is not an actual pressure.

A.7.4.2 Testing has been done with 3 m (10 ft) and 6 m (20 ft) duct lengths. The effect of ducts longer than 6 m (20 ft) has not been investigated.

A.7.4.4 Flames and pressure waves that discharge from the enclosure during venting represent a threat to personnel and could damage other equipment.

A.7.4.4.1 If a vented enclosure is located within buildings, it should be placed close to exterior walls so that the vent ducts are as short as possible.

A.7.4.5 The use of a vent duct with a larger cross section than that of the vent can result in a smaller increase in the pressure that develops during venting ($P_{red}$) than if using a vent duct of an equivalent cross section [93], but this effect is difficult to quantify because of limited test data. A special requirement for vent duct cross sections in situations where the vent closure device is a hinged panel is discussed in 4.7.3.

A.7.4.6 In general, any bends can cause increases in the pressure that develops during venting.

A.7.5 In many industrial enclosures, the gas phase is present in a turbulent condition. An example is the continuous feed of a flammable gas/oxidant mixture to a catalytic partial oxidation reactor. Normally this mixture enters the reactor head as a high-velocity turbulent flow through a pipe. As the gas enters the reactor head, still more turbulence develops due to the sudden enlargement of the flow cross section. Appurtenances within an enclosure enhance turbulence.

If the gas system is initially turbulent, the rate of deflagration increases [3,35]. In such a case, Equations 7.2.2.6 and 7.2.3.3 do not apply directly. It has been found that initially turbulent methane and propane exhibit high values.

The susceptibility of a turbulent system to detonation increases with increasing values of the quiescent. In particular, compounds that have values close to that of hydrogen are highly susceptible to detonation when ignited under turbulent conditions. It should be noted that venting tends to inhibit the transition from deflagration to detonation, but it is not an effective method of protecting against the effects of a detonation once the transition has occurred. Where the likelihood for detonation exists, alternate solutions, such as those in NFPA 69, Standard on Explosion Prevention Systems, should be considered.
In many industrial enclosures, the gas phase is present in a turbulent condition. Internal appurtenances within a vented enclosure can cause turbulence [55,102]. If the gas system is initially turbulent, the rate of deflagration is increased relative to that observed in initially quiescent conditions [3,35]. In such a case, the equations do not apply directly. It has been found that initially turbulent methane and propane exhibit $K_{S}$ values similar to that of initially quiescent hydrogen.

A.7.6.3.1 On the other hand, if pressure excursions are likely during operation, it can be the maximum pressure excursion during operation, or the pressure at the relief valve when in the fully open position.

A.7.6.3.2 Venting from enclosures at initially elevated pressures results in severe discharge conditions.

A.7.6.4 The fireball from a vented gas or dust deflagration presents a hazard to personnel who may be 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.

A.8.1.1 Current vent sizing methodology is based upon $K_{S}$, as determined by ASTM E 1226 or the similar ISO 6184-1. Determination of $K_{S}$ values by methods other than these would be expected to yield different results. Data from the Hartmann apparatus should not be used for vent sizing. Also, the 20 L test apparatus is designed to simulate results of the 1 m$^3$ chamber; however, the igniter discharge makes it problematic to determine $K_{S}$ values less than 50 bar-m/sec. Where the material is expected to yield $K_{S}$ values less than 50 bar-m/sec, testing in a 1 m$^3$ chamber might yield lower values.

The $K_{S}$ value needs to be verified by specific test of a dust that has been created by the process that created the dust. There are reasons why this needs to be done.

The shape and particle size distribution of the dust is affected by the mechanical abuse that the material has undergone by the process that has created it in the first place. An example of this is a polymeric dust created by the suspension polymerization of styrene (in water) results in a particle shape that are spherical (resembling small spheres).

A polymeric dust created by sending a bulk polymerized polystyrene block through a hammermill results in a dust that has been fractured and has many sharp edges and points. Even if the sieve size distribution of the two types of particles are similar, the specific surface area of the spherical particles can be much smaller than the particles generated by hammermill. The $K_{S}$ values for these two samples will be different. The rate of pressure rise for the spherical particles will be slower than the dust sample created by the hammermill operation.

A.8.1.2 The $K_{S}$ values of dusts of the same chemical composition vary with physical properties such as the size and shape of the dust particle and moisture content. The $K_{S}$ values published in tables are, therefore, examples and represent only the specific dusts tested. (See Annex B.) Mechanical processes that increase particle specific surface area, such as grinding, typically increase the $K_{S}$ value. The $K_{S}$ value needs to be verified by specific test of a dust that has been created by the process that created the dust. There are reasons why this needs to be done.

The shape and particle size distribution of the dust is affected by the mechanical abuse that the material has undergone by the process that has created the dust in the first place. An example of this is a polymeric dust created by the suspension polymerization of styrene (in water) results in a particle shape that are spherical (resembling small spheres).

A polymeric dust created by sending a bulk polymerized polystyrene block through a hammermill results in a dust that has been fractured and has many sharp edges and points. Even if the particle size distribution of the two types of particles are similar, (suspension polymerization particles versus hammermill generated dusts) the $K_{S}$ values for these two samples will be different. The rate of pressure rise for the spherical particles will be slower than the dust sample created by the hammermill operation.

It will be permissible, for design purposes, to accept the $K_{S}$ values subjected to a process similar to the final process design but radical changes in the process involving differences in the type of particle shape require verification of the $K_{S}$ values.

A.8.2.2.2 Unlike its counterparts in previous editions of NFPA 68, Equation 7.2.2 was derived as a best fit to test data (half of the data was underpredicted and half of the data was overpredicted) with optimum concentrations of various dusts. There is no safety factor in it other than the understanding that most accidental dust deflagrations occur at nonoptimum conditions. This equation applies to both low-strength and high-strength enclosures. The new equation results in significantly lower vent areas for low-strength enclosures as compared to the previous edition of NFPA 68.

A.8.3.2.1 Conventional, top-fed bins, hoppers, and silos are not expected to have large volumes occupied by homogeneous, worst-case dust concentrations. Furthermore, high turbulence regions in these enclosures are usually limited to the top of the enclosure.

A.8.2.6.3 The tangential velocity in particulate processing equipment can be generated either by a tangential inlet flow (as in most cyclone dust collectors) or by internal parts within the equipment (as in blenders, hammermills, etc.). In the case of tangential inlet flow, $v_{tan} = Q_{air}/A_{in}$ where $Q_{air}$ is the tangential inlet air flow rate (m$^3$/s), and $A_{in}$ is the inlet cross-sectional area (m$^2$). In the case of equipment with rotating internal parts,

\[ v_{tan_{max}} = 2(3.14)N r / 60 \]  

where:

- $N$ = number of revolutions per minute of the moving parts
- $r$ = radial length (m) of the largest moving part

In the case where the tangential flow is generated by stationary guide vanes and similar internal parts, the determination of $v_{tan_{max}}$ is more complicated and requires expert analysis or testing.

A.8.2.6.8 The use of a velocity of 20 m/sec and 56 m/sec to separate the vent area requirements is based on a combination of the data used to derive Equation 8.2.3 (the general area correlations) and the Tammamini 1990 data shown in the Figure A.8.2.6.8 showing how the effective $K_{S}$ varies with the root-mean-square (rms) turbulence velocity in the vented enclosure. The figure is based on values of $K_{S}$ calculated from the nomographs in NFPA 68, plotted as a function of the mean turbulence intensity in the time period when the pressure rise is between 20 percent and 80 percent of maximum value. Since it is very difficult to measure rms turbulence velocities in operating equipment, a turbulence intensity of 10 percent has been assumed, such that the effective rms turbulence velocity is 10 percent of the average air velocity in the operating equipment. Therefore most users would be able to calculate the average velocity to decide which vent area equation to use.

![FIGURE A.8.2.6.8 Explosion Severity for Vented Tests in the FMRC 2250 ft$^3$ Chamber.](image-url)
A.8.2.7 Where \( K_{st} \) is greater than 250 bar-m/sec, see Annex F for guidance.

A.8.2.8 Where \( M \) is greater than 40 kg/m\(^2\) or \( K_{st} > 250 \), see Annex F for guidance.

A.8.3 Dust concentrations in some process equipment and buildings are inherently limited to only a fraction of the enclosure volume.

A.8.3.2 Figure A.8.3.2 illustrates the limits of partial volume corrections. At low normalized reduced pressures, \( \Pi \), the vent ratio approaches the fill fraction to the 1/6th power. When fill fraction approaches \( \Pi \), both the vent ratio and the necessary vent area approach zero. Subsections 8.3.3 and 8.3.4 provide guidance on the determination of the fill fraction for process vessels and for buildings, respectively.

**FIGURE A.8.3.2 Partial Volume Vent Area Reduction.** [Existing Figure 7.3.1, 2002 ed. (no change)]

A.8.3.3 The fill fraction in a spray dryer depends on the dryer design. In the case of a top-loading conical dryer without any recirculation or co-feed of dry product, measurements have indicated that the dry powder concentrations exist only in the bottom portion of the dryer, which typically occupies 20 percent to 35 percent of the total dryer volume.

**Process Equipment Example.** A 100 m\(^3\) spray dryer with a length/diameter ratio of 1.8 is processing a material with a \( P_{max} \) of 10 bar and a \( K_{st} \) of 100 bar-m/sec at the dryer operating temperature. The deflagration vent design is to be based on a \( P_{red} \) of 0.50 bar and a \( P_{stat} = 0.10 \) bar. Tests by the manufacturer, submitted and approved by the authority having jurisdiction, have shown that the dry material is confined to the conical lower section of the dryer, which has a volume of 33.3 m\(^3\). Therefore, \( X_r = 0.3333 \), and \( \Pi = 0.50/10 = 0.050 \).

**Step 1.** Using Equation 8.2.2,

\[
A_v = 1 \cdot 10^{-4} \left[1 + 1.54(0.10)^{4/3}\right] \cdot 100 \cdot (100)^{3/4} \cdot \sqrt{\frac{1}{0.050} - 1}
\]

**Step 2.** The partial volume vent area for this application is as follows:

\[
A_{vp} = (1.48) \cdot (0.333)^{0.630} \cdot \sqrt{\frac{(0.333 - 0.050)}{1 - 0.050}} = 1.16 \text{ m}^2
\]

**Step 3.** Therefore vent panels with a total vent area of at least 1.16 m\(^2\) should be installed on the conical lower section of the dryer.

A.8.3.4 See Annex I.

A.8.5 The flow resistance coefficient \( K \) for this correlation is defined on the static pressure drop, \( \Delta P \), from the enclosure to the duct exit at a given the average duct flow velocity, \( U \), i.e.

\[
K \equiv \frac{\Delta P}{\frac{1}{2} \rho U^2}
\]

Another convention used by some reference books is to define \( K \) on the total pressure drop or on another velocity scale. The user should ensure that the loss coefficients used in the calculations is consistent with the definition of \( K \) adopted for the vent duct calculations. See reference [115] for additional information.

Example problem is based upon installation as shown in Figure A.8.5.

**FIGURE A.8.5 Example Vent Duct Installation.**

**Example conditions:**

<table>
<thead>
<tr>
<th>GIVEN:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure volume, ( V ) (m(^3))</td>
<td>25</td>
</tr>
<tr>
<td>Enclosure ( L/D )</td>
<td>4</td>
</tr>
<tr>
<td>Vent Diameter, ( D_v ) (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Duct Diameter, ( D_v ) (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>( \varepsilon ) (mm)</td>
<td>0.26</td>
</tr>
<tr>
<td>Elbows</td>
<td>2 \times 90^\circ</td>
</tr>
<tr>
<td>Elbow flow resistance</td>
<td>2 \times 1.2 = 2.4</td>
</tr>
<tr>
<td>Rain cover flow resistance</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**CALCULATE:**

\[
P_{red}
\]

These input parameters are provided for demonstration purposes. Refer to [115] for additional discussion on how they were selected.

**Solution:**

(1) Compute the Friction factor for the problem

For practically all vent ducts, the Reynolds number is so large that fully turbulent flow regime will be applicable. In this regime, the friction factor is only a function of the ratio of the internal duct surface effective roughness (\( \varepsilon \)) to duct diameter. Duct friction factor can thus be calculated using the equation:

\[
f = \frac{1}{1.14 + 2 \cdot \log \left( \frac{D_v}{\varepsilon} \right)}
\]

(A.8.5)

The effective roughness for smooth pipes and clean steel pipes are typically 0.0015 mm, and 0.046 mm, respectively. Recognizing that the pipes used repeatedly in combustion events could be corroded, a value of \( \varepsilon = 0.26 \) mm is assumed.
From Equation A.8.5, \( f = 0.013 \)

\[
\frac{f(L)}{(D_a)} = 0.107
\]

\( K_{inlet} = 1.5 \)

\( K_{elbows} = 2.4 \)

\( K_{red} = 0.75 \)

\( K = 4.757 \)

(2) Assume a \( P_{req} \) value = 1 barg

(3) From Equation 8.2.2

\[
A_0 = 1.10^{-4} \left[ 1 + 1.54 \times (0.25)^{4/3} \right] \times 200 \times (25)^{3/4} \times \frac{8}{P_{req} - 1}
\]

\( A_0 = 0.735 \text{ m}^2 \)

(4) From Equation 8.2.3

\[
A_1 = 0.0735 \left[ 1 + 0.6 \times (4 - 2)^{0.75} \times \exp(-0.95 \times (P_{req})^2) \right]
\]

\( A_1 = 1.02 \text{ m}^2 \)

(5) From Equation 8.5.1b, and using the intended vent area of 1.77 m²,

\[
E_1 = \frac{(1.77) \times (12)}{25}
\]

\( E_1 = 0.85 \)

(6) From Equation 8.5.1c, and using the intended vent area of 1.77 m²,

\[
E_2 = \frac{10^4 \times (1.77)}{(1 + 1.54 \times (0.25)^{4/3}) \times (200) \times (25)^{3/4}}
\]

\( E_2 = 6.37 \)

(7) From Equation 8.5.1a, with \( A_s \) equal to \( A_1 \), assuming no increase for turbulence

\[
A_0 = (1.02) \times (1 + 1.18 \times (0.85)^{0.4} - (6.37)^{0.4}) \times \frac{4.757^{1/3}}{1.5}
\]

\( A_0 = 5.77 \text{ m}^2 \)

(8) Go back to step 2 above, changing \( P_{req} \) until the \( A_0 \) calculated in step 8 is equal to the specified vent area of 1.77 m².

A trial and error process (or the goal seek button in Microsoft Office Excel) satisfy the requirement in step 9 when \( P_{req} = 3.52 \) barg.

(9) Equation 8.5.8 shows that there is no DDT propensity for this particular application.

\[
L_{eff} \leq \min \left[ \frac{10,000 \times (1.5)}{200}, \frac{11,000}{200} \right]
\]

\( L_{eff} \leq \min [75, 55] \)

\[
L_{dust} = (8 - 3.52) \times \frac{(25)}{(1.77)}
\]

\( L_{dust} = 63 \text{ m} \)

Since \( L_{dust} = 12 \text{ m} \), \( L_{eff} = \min (12, 63) = 12 \text{ m} \leq 55 \text{ m} \); therefore DDT is not expected.²

A.8.6.1 For deflagration venting accomplished by means of vent closures located in the sidewall of the enclosure, the closures should be distributed around the wall near the top.

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

A.8.8 When dust deflagrations occur there can be far more dust present than there is oxidant to burn it completely. When venting takes place large amounts of unburned dust are vented from the enclosure and burning continues as the dust mixes with additional air from the surrounding atmosphere. Consequently, a very large and long fireball of burning dust develops that can extend downward as well as upward. The average surface emissive power varies greatly between different types of dusts; metal dusts tending to be much worse than, for example, agricultural dusts. [113]

A.8.8.2 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.

A.8.9 Even with complete retention of flame and particulates, the immediate area surrounding the vent can experience overpressure and radiant energy. Venting indoors has an effect on the building that houses the protected equipment due to increased pressurization of the surrounding volume [111].

A.8.10 Interconnections between separate pieces of equipment present a special hazard. A typical case is two enclosures connected by a pipe. Ignition in one enclosure causes two effects in the second enclosure. Pressure development in the first enclosure forces gas through the connecting pipe into the second enclosure, resulting in an increase in both pressure and turbulence. The flame front is also forced through the pipe where it becomes a large ignition source. The overall effect depends on the relative sizes of the enclosures and the pipe, as well as on the length of the pipe. This phenomenon has been investigated by Barknecht, who discovered that the effects can be significant. Pressures that develop in the pipeline itself can also be high, especially if a deflagration changes to a detonation. Where such interconnections are necessary, deflagration isolation devices should be considered, or the interconnections should be vented. Without successful isolation or venting of the interconnection, vent areas calculated based on the design described herein can be inadequate because of the creation of high rates of pressure rise [58,66].

Equations 7.2.2 and 7.2.2.1a can give insufficient vent area if a dust deflagration propagates from one vessel to another through a pipeline [98]. Increased turbulence, pressure piling, and broad-flame jet ignition results in increased deflagration violence. Such increased deflagration violence results in an elevated deflagration pressure that is higher than that used to calculate vent area in Equations 7.2.2 and 7.2.2.1a.

A.8.10.1 Interconnecting pipelines with inside diameters greater than 0.3 m (1 ft) or longer than 6 m (20 ft) are not covered in this standard. Alternate protection measures can be found in Chapter 9 of this document and in NFPA 69, Standard on Explosion Prevention Systems.

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

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

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

1. Deflagrations in pipes and ducts with large length-to-diameter \( L/D \) ratios can transition to detonations. Flame speed acceleration increases and higher pressures are generated as \( L/D \) increases.

2. Pipes and ducts frequently contain devices such as valves, elbows, and fittings or obstacles. Such devices cause turbulence and flame stretching that promote flame acceleration and increased pressure.

3. Deflagrations that originate in a vessel precompress the combustible material in the pipe or duct and provide a strong flame front ignition of the combustible material in the pipe...
A dryer that handles a dust whose $K_{ST}$ is 190 is 2 m (6.6 ft) in diameter and 20 m (65.6 ft) long and is designed with a single vent. What is the pressure that can occur during a vented explosion?

(1) **Maximum Allowable Length.** According to Figure 9.2.10.1, an $L/D$ of approximately 25 is allowable. The dryer has an $L/D$ of 10, so this is acceptable.

(2) **Maximum Pressure.** According to Figure 9.2.10.2.2.1, a pressure of approximately 0.5 bar (7.3 psi) develops in such dryer equipment by means of the deflagration of the specified dust. Therefore, the equipment should have a design pressure of at least this value.

A.9.3 A straight duct that is 1 m (3.3 ft) in diameter and 100 m (330 ft) long is to be protected by deflagration vents. It contains a hydrocarbon–air mixture that has properties similar to those of propane. What is the vent spacing needed to limit the deflagration pressure to 0.17 bar (2.5 psi), where the vents are designed to open at 0.05 bar (0.73 psi)? Figure 9.3.1 specifies that the vents should be placed no more than 7.6 m (25 ft) apart. In order to meet this requirement, a vent should be placed at each end, and 13 additional vents should be evenly spaced along the duct.

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

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

A.10.4.2 Specially designed fasteners that fail, under low mechanical stress, to release a vent closure are commercially available, and some have been tested by listing or approval agencies.

A.10.4.3 Where large, lightweight panels are used as vent closures, it is usually necessary to restrain the vent closures so that they do not become projectile hazards. The restraining method shown in Figure A.10.4.3 illustrates one method that is particularly suited for conventional single-wall metal panels. The key feature of the system includes a 50 mm (2 in.) wide, 10-gauge bar washer. The length of the bar is equal to the panel width, less 50 mm (2 in.) and less any overlap between panels. The bar washer/vent panel assembly is secured to the building structural frame using at least three 10 mm (3/8 in.) diameter through-bolts.

**FIGURE A.10.4.3 An Example of A Restraint System for Single-Wall Metal Vent Panels.** [Existing Figure 9.5.1, 2002 ed. (no change)]

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

The stiffness of the double-wall panel is much greater than that of a single-wall panel. The formation of the plastic hinge occurs more slowly, and the rotation of the panel can be incomplete. Both factors tend to delay or impede venting during a deflagration.
A.10.5.1 Closures that are held shut with spring-loaded, magnetic, or friction latches are most frequently used for this form of protection.

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

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

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

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

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

FIGURE A.10.5.2 Typical Rupture Diaphragm. [Existing Figure 9.6.2.1, 2002 ed. (no change)]

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

A.10.6 Deflagration venting systems have been developed that have a rupture membrane for venting and a flame-arresting element. As a deflagration is vented through the system, any burned and unburned dust is retained within the device. Combustion gases are cooled, and no flame emerges from the system. In addition, near-field blast effects (overpressure) are greatly reduced outside the system. (See Section 5.10 and Figure A.10.6.)

FIGURE A.10.6 Example of Flame-Arresting and Particulate Retention Vent System. [Existing Figure 9.7.1, 2002 ed. (no change)]

A.10.6.3 It is essential that the user work closely with the manufacturer to ensure that all of the parameters are addressed for a safe, reliable installation.

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

A.11.3.4 For symbols, placement, and layout refer to ANSI Z-535.

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

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

A.11.5 The vent closure design parameters can include the following items, among others:

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

A.11.8.2 It is recommended that changes be reviewed with life safety system and equipment suppliers.

Annex B Fundamentals of Deflagration

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 General.

B.1.1 Deflagration Requirements. The following are necessary to initiate a deflagration:

(1) Fuel concentration within flammable limits
(2) Oxidant concentration sufficient to support combustion
(3) Presence of an ignition source

B.1.2 Deflagration Pressure.

B.1.2.1 The deflagration pressure, $P$, in a closed volume, $V$, is related to the temperature, $T$, and molar quantity, $n$, by the following ideal gas law equation:

$$ P = \frac{nRT}{V} \quad \text{ (B.1.2.1)} $$

where:

$ R = \text{universal gas constant}$

B.1.2.2 The maximum deflagration pressure, $P_{\text{max}}$, and rate of pressure rise, $dP/dt$, are determined by test over a range of fuel concentrations. (See Annex C.) The value of $P_{\text{max}}$ for most ordinary fuels is 6 to 10 times the absolute pressure at the time of ignition.

B.1.2.3 The value of $(dP/dt)_{\text{max}}$ is the maximum for a particular fuel concentration, referred to as the optimum concentration. (See examples in Figure B.1.2.3.)

FIGURE B.1.2.3 Variation of Deflagration Pressure and Deflagration Index with Concentration for Several Duffs. (Adapted from [51]). [Existing Figure 4.2.3.1, 2002 ed. (no change)]

B.1.2.4 Based on the $K_{St}$ values, dusts have been categorized into three hazard classes (St-1, St-2, and St-3). These classes give an indication of the relative explosibility hazard and deflagration vent sizing requirements, as shown in Table B.1.2.4.

Table B.1.2.4 Hazard Classes of Dust Deflagrations

<table>
<thead>
<tr>
<th>Hazard Class</th>
<th>$K_{St}$ (bar-m/sec)$^*$</th>
<th>$P_{\text{max}}$ (bar)$^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>St-1</td>
<td>≤200</td>
<td>10</td>
</tr>
<tr>
<td>St-2</td>
<td>201–300</td>
<td>10</td>
</tr>
<tr>
<td>St-3</td>
<td>≥300</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes:

(1) The application of Figure H.2(a) through Figure H.2(q) is limited to an upper $K_{St}$ value of 800.

(2) See Annex F for examples of $K_{St}$ values.

* $K_{St}$ and $P_{\text{max}}$ are determined in approximately spherical calibrated test vessels of at least 20 L (5.3 gal) capacity per ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Duffs.

B.1.2.5 Burning Velocity and Flame Speed.

B.1.2.5.1 The burning velocity is the rate of flame propagation relative to the velocity of the unburned gas that is ahead of it. The fundamental burning velocity, $S_{fr}$, is the burning velocity of a laminar flame under stated conditions of composition, temperature, and pressure of the unburned gas. The values of $S_{fr}$ for many gases have been measured and published. (See Annex D.)

B.1.2.5.2 Flame speed, $S_{f}$, is the speed of a flame front relative to a fixed reference point. Its minimum value is equal to the fundamental burning velocity times an expansion factor equal to the ratio of the density of the unburned gas to the density of the burned gas.

B.2 Fuel.
## VENT CLOSURE INFORMATION FORM

**CONTACT INFORMATION**

Company name: ___________________________  
Responsible person: ________________________  
Address: _________________________________  
Title: _________________________________  
City: _______  State: _____  Zip code: _______  
Telephone: _______________________________  
Report writer: ___________________________  

Equipment/process protected: ___________________________  
Vent ID number: ___________________________  
Vent location: ___________________________  
Vent size: _______________________________  
Vent manufacturer: ________________________  
Vent type: _______________________________  
Vent model number: ________________________  
Vent opening pressure: _____________________  
Vent construction material: ___________________  
Vent panel ID: ___________________________  

**HAZARD DETAILS**

Name of material: ___________________________  
Hazard category:  
- [ ] Dust  
- [ ] Gas  
- [ ] Mist  
- [ ] Vapor  
- [ ] Hybrid  
K_S or K_G value of material: ___________________________ bar·m/sec  
P_{max} value of material: ___________________________ psig or barg  

**VENT DEVICE DETAILS**

Mounting frame:  
- [ ] Yes  
- [ ] No  
Frame type:  
- [ ] Welded  
- [ ] Bolted  
Thermal insulation:  
- [ ] Yes  
- [ ] No  
Gasket material: ___________________________  
Sanitary sealing:  
- [ ] Yes  
- [ ] No  
Vent restraints:  
- [ ] Yes  
- [ ] No  

**PROTECTED ENCLOSURE DETAILS**  
*Rectangular Bag House (for example)*

Enclosure location: ___________________________  
Normal operating pressure: ___________________________ psig @ __________  
Normal operating temperature:  
- [ ] _______ °F  
- [ ] _______ °C  
Maximum operating pressure: ___________________________ psig @ __________  
Maximum operating temperature:  
- [ ] _______ °F  
- [ ] _______ °C  
Maximum vacuum conditions:  
- [ ] _______ psig  
- [ ] _______ in. W.C.

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**FIGURE A.11.2 Sample Vent Closure Information Form.**
VENT CLOSURE INFORMATION FORM (continued)

Frequency and magnitude of pressure cycles: _______________________________________
Vessel volume and dimensions: ______________________________________________________
Vessel aspect ratio: _________________________________________________________________
Vessel strength: _______________________________________________________________________
Design calculations: NFPA 68 Chapter ______

Other information (to be collected and attached):

- Data sheets
- Manufacturer's instruction, installation, and maintenance manuals
- Vent closure details
- Vent frame
- MSDS (of process material)
- Material $K_{mi}/K_{ui}$ test report (the value used for the vent design)
- Copy of vent identification label
- Process risk assessment report
- Process plan view showing vent relief path
- Process elevation view showing vent relief path
- Proximity of personnel to vent relief path
- Management of change requirements
- Mechanical installation details
- Manufacturer's service and maintenance forms
- Verification of conformity documentation
- Vent restraint documentation
- Process interlocks (details)
**ANNUAL INSPECTION FORM**

**USER CONTACT INFORMATION**

<table>
<thead>
<tr>
<th>Company name:</th>
<th>Date inspected:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address:</td>
<td>Time:</td>
</tr>
<tr>
<td>City:</td>
<td>State:</td>
</tr>
<tr>
<td>Zip code:</td>
<td></td>
</tr>
<tr>
<td>Telephone:</td>
<td></td>
</tr>
</tbody>
</table>

Inspector's name: ____________________________

Inspection company: __________________________

<table>
<thead>
<tr>
<th>Address:</th>
<th>City:</th>
<th>State:</th>
<th>Zip code:</th>
<th>Telephone:</th>
</tr>
</thead>
</table>

Vent id#: ____________________________

Vent location: ____________________________

Vent manufacturer: ____________________________

**INSPECTION**

Follow the manufacturer's recommendations and the following:

Is the vent:

1. Clear of obstructions? [ ] Yes [ ] No
2. Corroded? [ ] Yes [ ] No
3. Mechanically or physically damaged? [ ] Yes [ ] No
4. Clearly labeled: Warning. Explosion relief device? [ ] Yes [ ] No
5. Clearly tagged/labeled with manufacturer’s information? [ ] Yes [ ] No
6. Protected from ice and snow? [ ] Yes [ ] No
7. Painted or coated? (Other than by the manufacturer) [ ] Yes [ ] No
8. Showing build-up or deposits? [ ] Yes [ ] No
9. Bulging, damaged, or deformed (from original shape)? [ ] Yes [ ] No
10. Changed, altered, or tampered with? [ ] Yes [ ] No
11. Showing signs of fatigue? [ ] Yes [ ] No
12. Provided with fasteners and mounting hardware in place? [ ] Yes [ ] No
13. Frame damaged or deformed? [ ] Yes [ ] No
14. Released? [ ] Yes [ ] No
15. Opening sensor operable and wiring up to current codes? [ ] Yes [ ] No
16. Provided with seals, tamper, or other opening indicators intact? [ ] Yes [ ] No
17. Provided with restraints in place and attached? [ ] Yes [ ] No
18. Provided with hinges lubricated and operating freely? [ ] Yes [ ] No
19. Clean and free of contamination? [ ] Yes [ ] No

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**FIGURE A.11.4 Sample Annual Inspection Form.**
ANNUAL INSPECTION FORM (continued)

Looking from the vent outward can you see personnel working or hazardous material being stored in your direct line of sight?  □ Yes  □ No

If yes, please have a process engineer or user supervisor address your findings as you have described below:

________________________________________________________________________________________________________________________________________________________

Abnormal conditions found:

________________________________________________________________________________________________________________________________________________________

Abnormal conditions corrected at time of inspection:

________________________________________________________________________________________________________________________________________________________

Abnormal conditions that still need attention/addressed:

________________________________________________________________________________________________________________________________________________________

Action required by management:

________________________________________________________________________________________________________________________________________________________

Process engineer/supervisor notified?  □ Yes  □ No

Date addressed:________________________________________________________________________________________

Action required?  □ Yes  □ No

Signature:______________________________________________________________________________________________

Have you observed changes to the process and or its surroundings that should invoke the company’s management of change procedure?  □ Yes  □ No

Inspector’s signature:________________________________________________________________________________________

Manager’s signature:_________________________________________________________________________________________ Date:________________________
B.2.1 General. Any material capable of reacting rapidly and exothermically with an oxidizing medium can be classified as a fuel. A fuel can exist in a gas, liquid, or solid state. Liquid fuels that are dispersed in air as fine mists, solid fuels that are dispersed in air as dusts, and hybrid mixtures pose similar deflagration risks as gaseous fuels.

B.2.2 Concentration. The concentration of a gaseous fuel in air is usually expressed in volume percent (vol %) or mole percent (mol %). The concentrations of dispersed dusts and mists are usually expressed in units of mass per unit volume, such as grams per cubic meter (g/m$^3$).

B.2.3 Flammable Gas.

B.2.3.1 Flammable gases are present in air in concentrations below and above which they cannot burn. Such concentrations represent the flammable limits, which consist of the lower flammable limit, LFL, and the upper flammable limit, UFL. It is possible for ignition and flame propagation to occur between the concentration limits. Ignition of mixtures outside these concentration limits fails because insufficient energy is given off to heat the adjacent unburned gases to their ignition temperatures. Lower and upper flammable limits are determined by test and are test-method dependent. Published flammable limits for numerous fuels are available.

For further information, see NFPA 325, Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids. (Note: Although NFPA 325 has been officially withdrawn from the National Fire Codes®), the information is still available in NFPA's Fire Protection Guide to Hazardous Materials.)

B.2.3.2 The mixture compositions that are observed to support the maximum pressure, $P_{\text{max}}$, and the maximum rate of pressure rise, $(dP/dt)_{\text{max}}$, for a deflagration are commonly on the fuel-rich side of the stoichiometric mixture. It should be noted that the concentration for the maximum rate of pressure rise and the concentration for $P_{\text{max}}$ can differ.

B.2.4 Combustible Dust.

B.2.4.1 Solid particulates smaller than 420 μm (0.017 in.) (capable of passing through a U.S. No. 40 standard sieve) are classified as dusts. The fineness of a particular dust is characterized by particle size distribution. The maximum pressure and $K_F$ increase with a decrease in the dust particle size, as shown in Figure B.2.4.1.

FIGURE B.2.4.1 Effect of Particle Size of Dusts on the Maximum Pressure and Rate of Pressure Rise. [3]

[Unit conversion is incorrect. 3.3 ft$^3$ should be 35.3 ft$^3$.] (Existing Figure 4.3.4.1, 2002 ed. (no change)]

B.2.4.2 Particle Size.

B.2.4.2.1 Dust particle size can be reduced as a result of attrition or size segregation during material handling and processing. Such handling and processing can lead to the gradual reduction of the average particle size of the material being handled and can increase the deflagration hazard of the dust. Minimum ignition energy is strongly dependent on particle size [1]. Figure B.2.4.2.1 illustrates this effect.

FIGURE B.2.4.2.1 Effect of Average Particle Diameter of a Typical Agricultural Dust on the Minimum Ignition Energy. (Unpublished data courtesy of U.S. Mine Safety and Health Administration.) (Existing Figure 4.3.4.2.1, 2002 ed. (no change)]

B.2.4.2.2 A combustible dust that is dispersed in a gaseous oxidizer and subjected to an ignition source does not always deflagrate. The ability of a mixture to propagate a deflagration depends on factors such as particle size, volatile content of solid particles, and moisture content.

B.2.4.3 The predominant mechanism of flame propagation in clouds of most combustible dusts is through the combustion of gaseous flames emitted by the pyrolysis of the combustible material. Some dusts can propagate a flame through direct oxidation at the particle surface. Thus, the chemical and physical makeup of a dust has a direct bearing on its means of propagating a flame when dispersed in air.

B.2.4.4 A minimum dust cloud concentration, commonly known as the lower flammable limit, LFL, and minimum explosible concentration, MEC, can support flame propagation. The LFL of a dust is dependent on its composition and particle size distribution. Large particles participate inefficiently in the deflagration process.

B.2.4.5 Combustible dusts that accumulate on surfaces in process areas can become airborne by sudden air movement or mechanical disturbance. Dusts can pass through ruptured filter elements. In such instances, a combustible dust cloud can become established where it normally would not be present.

B.2.4.6 Combustible dusts do not, for most practical purposes, exhibit upper flammable limits in air. This fact is a consequence of the flame propagation mechanism in dust clouds. Thus, deflagrations cannot usually be prevented by maintaining high dust cloud concentrations.

B.2.4.7 The combustion properties of a dust depend on its chemical and physical characteristics. The use of published dust flammability data can result in an inadequate vent design if the dust being processed has a smaller mean particle size than the dust for which data are available, or if other combustion properties of the dust differ. Particle shape is also a consideration in the deflagration properties of a dust. The flammability characteristics of a particular dust should be verified by test. (See Section B.3.)

The shape and particle size distribution of the dust is affected by the mechanical abuse that the material has undergone by the process that has created the dust in the first place. An example of this is a polymeric dust created by the suspension polymerization of styrene (in water) results in a particle shape that are spherical (resembling small spheres).

A polymeric dust created by sending a bulk polymerized polyhydrocarbon block through a hammermill results in a dust that has been fractured and has many sharp edges and points. Even if the particle size distribution of the two types of particles are similar, (suspension polymerization particles versus hammermill generated dusts) the $K_F$ values for these two samples will be different. The rate of pressure rise for the spherical particles will be slower than the dust sample created by the hammermill operation.

It will be permissible, for design purposes, to accept the $K_F$ values subjected to a process similar to the final process design but radical changes in the process involving differences in the type of particle shape require verification of the $K_F$ values.

B.2.5 Hybrid Mixture.

B.2.5.1 The presence of a flammable gas in a dust–air mixture reduces the apparent lower flammable limit and ignition energy. The effect can be considerable and can occur even though the gas is below its lower flammable limit and the dust is below its lower flammable limit. Careful evaluation of the ignition and deflagration characteristics of the specific mixtures is necessary. (See Figure B.2.5.1)

FIGURE B.2.5.1 Lowest MIE of Hybrid Mixtures Versus Propane Content. [Existing Figure 4.3.5.1, 2002 ed. (no change)]

B.2.5.2 It has been shown that the introduction of a flammable gas into a cloud of dust that is normally a minimal deflagration hazard can result in a hybrid mixture with increased maximum pressure, $P_{\text{max}}$, and maximum rate of pressure rise, $(dP/dt)_{\text{max}}$. An example of this phenomenon is the combustion of polyvinyl chloride dust in a gas mixture. (See Figure B.2.5.2)

FIGURE B.2.5.2 Deflagration Data for Hybrid Mixtures of Polyvinyl Chloride Dust and Methane Gas in Air. [4] (Existing Figure 4.3.5.2, 2002 ed. (no change)]

B.2.5.3 Situations where hybrid mixtures can occur in industrial processes include fluidized bed dryers drying solvent–wet combustible dusts, desorption of combustible solvent and monomer vapors from polymers, and coal-processing operations.

B.2.6 Mist. A mist of flammable or combustible liquids has deflagration characteristics that are analogous to dusts. The lower flammable limit for dispersed liquid mists varies with droplet size in a manner that is analogous to particle size for dusts. The determination of these deflagration characteristics is complicated by droplet dispersion, coalescence, and settling. A typical LFL for a fine hydrocarbon mist is 40 g/m$^3$ to 50 g/m$^3$, which is approximately...
equal to the LFL for combustible hydrocarbon gases in air at room temperature. Mists of combustible liquids can be ignited at initial temperatures well below the flash point of the liquid. [62,63,64,65]

B.3 Oxidant.

B.3.1 The oxidant for a deflagration is normally the oxygen in the air. Oxygen concentrations greater than 21 percent tend to increase the fundamental burning velocity and increase the probability of transition to detonation. Conversely, oxygen concentrations less than 21 percent tend to decrease the rate of combustion. Most fuels have an oxygen concentration limit below which combustion cannot occur.

B.3.2 Substances other than oxygen can act as oxidants. While it is recognized that deflagrations involving the reaction of a wide variety of fuels and oxidizing agents (e.g., oxygen, chlorine, fluorine, oxides of nitrogen, and others) are possible, discussion of deflagration in this standard is confined to those cases where the oxidizing medium is normal atmospheric air consisting of 21 percent volume percent oxygen unless specifically noted otherwise.

B.4 Inert Material.

B.4.1 Inert Gases. Inert gases can be used to reduce the oxidant concentration.

B.4.2 Inert Powder.

B.4.2.1 Inert powder can reduce the combustibility of a dust by absorbing heat. The addition of inert powder to a combustible dust/oxidant mixture reduces the maximum rate of pressure rise and increases the minimum concentration of combustible dust necessary for ignition. See Figure B.4.2.1 for an example of the effect of admixed inert powder. A large amount of inert powder is necessary to prevent a deflagration; concentrations of 40 percent to 90 percent are needed.

B.5 Ignition Sources. Some types of ignition sources include electric (e.g., arcs, sparks, and electrostatic discharges), mechanical (e.g., friction, grinding, and impact), hot surfaces (e.g., overheated bearings), and flames (welding torches and so forth).

B.5.1 One measure of the ease of ignition of a gas, dust, or hybrid mixture is its minimum ignition energy, MIE. The minimum ignition energy is typically less than 1 mJ for gases and often less than 100 mJ for dusts. Minimum ignition energies are reported for some gases and dust clouds [7–17,90,92].

B.5.2 An ignition source such as a spark or a flame can travel from one enclosure to another. A grinding spark (i.e., a hot, glowing particle) can travel a considerable distance and can ignite a flammable mixture along the way. Similarly, stronger ignition sources, such as flame jet ignitions, deserve special consideration. A flame produced by an ignition source in one enclosure can become a much larger ignition source if it enters another enclosure. The increase in the energy of the ignition source can increase the dispersibility of the combustible dust.

B.7 Effect of Turbulence.

B.7.1 Turbulence causes flames to stretch, which increases the net flame surface area that is exposed to unburned materials, which in turn leads to increased flame speed.

B.7.2 Initial turbulence in closed vessels results in higher rates of pressure rise and in somewhat higher maximum pressure than would occur if the fuel/oxidant mixture were initially subject to quiescent conditions. Turbulence results in an increase in the vent area needed. Figure B.7.2 illustrates the effects of turbulence and of fuel concentration.

Annex C Guidelines for Measuring Deflagration Indices of Dusts and Gases

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 General Comments. This annex discusses how the test procedure relates to the venting of large enclosures, but the test procedure is not described in detail. ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts, sets forth a method for determining the maximum pressure and the rate of pressure rise of combustible dusts [96]. Since gases are not addressed in ASTM E 1226, test procedures are discussed in this annex.

ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air, and ASTM E 582, Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures. Reference [92] is a review of ignition energy test methods that have been developed for dusts and gases. (See Figure C.1.)

C.2 Purpose. The purpose of deflagration index measurements is to predict the effect of the deflagration of a particular material (dust or gas) in a large enclosure without carrying out full-scale tests.

C.3 Basic Principles. Figure H.1(a) through Figure H.1(g) and Figure H.2(a) through Figure H.2(k), presented in this guide, and those in VDI 3673 [104] are based on large-scale tests carried out in ventilated vessels using a variety of test materials and vessel sizes [3,47]. For each test material and vessel volume, the maximum reduced deflagration pressure, $P_{red}$, was found for a series of vents with various areas, $A_v$, and opening pressures, $P_{stat}$. Only a single material classification (the $K_G$ or $K_{St}$ index) needs to be experimentally obtained for use with Figure H.1(a) through Figure H.1(g) and Figure H.2(a) through Figure H.2(k). If the volume and mechanical constraints of the enclosure to be protected are known, the user can then determine the venting needed from the figures.

C.3.1 The $K_G$ and $K_{St}$ Indices. The test dusts used during the large-scale tests were classified according to the maximum rate of pressure rise that was recorded when each was deflagrated in a 1 m$^3$ (35 ft$^3$) closed test vessel. The maximum rate of pressure rise found in the 1 m$^3$ (35 ft$^3$) vessel was designated $K_{St}$. $K_{St}$ is not a fundamental material property, but depends on the conditions of the test. The classification work carried out in the 1 m$^3$ (35 ft$^3$) vessel provides the only direct link between small-scale closed vessel tests and the large-scale vented tests on which Figure H.1(a) through Figure H.1(g) and Figure H.2(a) through Figure H.2(k) are based.

It is possible that the $K_G$ index can similarly be determined in a 1 m$^3$ (35 ft$^3$) vessel, but published $K_G$ values correspond to tests made in smaller vessels. The variable $K_G$ is known to be volume-dependent and should not be considered a constant. Its use is restricted to normalizing data gathered under a fixed set of test conditions.
Figure A.11.4 Sample Annual Inspection Form.

C.3.2 Standardization of a Test Facility. The objective of standardization is to validly compare the deflagration behavior of a particular material with others for which full-scale test data are available. Without access to the 1 m$^3$ (35 ft$^3$) vessel in which the original $K_G$ classifications were made, it is essential to standardize the test conditions that are employed using samples tested either in the 1 m$^3$ (35 ft$^3$) vessel or in a vessel that has been standardized to it. ASTM defines the standardization requirements for dusts. Figure H.1(a) through Figure H.1(g) identify a series of gas mixtures that were used in the full-scale tests. The actual $H_1(a)$ through Figure H.1(g) identify a series of gas mixtures that meets certain criteria.

C.3.3 Determination of the $K_G$ and $K_{St}$ Indices. If the maximum rate of pressure rise is measured in a vessel with a volume of other than 1 m$^3$ (35 ft$^3$), Equation C.3.3 is used to normalize the value obtained to that of a 1 m$^3$ (35 ft$^3$) vessel.

Existing Equation B.1 (no change) (C.3.3)

$$P_{max} = \frac{t}{V} \cdot K \cdot P_{max} \text{ (bar-m/sec)}$$

where:

$P = \text{pressure (bar)}$

$t = \text{time (sec)}$

$V = \text{volume (m}^3)\text{)}$

$K = \text{normalized } K_G \text{ or } K_{St} \text{ index (bar-m/sec)}$

The measured maximum deflagration pressure, $P_{max}$, is not scaled for volume, and the experimental value can be used for design purposes. The maximum rate of pressure rise is normalized to a volume of 1 m$^3$ (35 ft$^3$) using Equation C.3.3. If the maximum rate of pressure rise is given in bar per second, and the test volume is given in cubic meters, the equation defines the $K_G$ or $K_{St}$ index for the test material.

Example: The volume of a spherical test vessel is 26 L (0.026 m$^3$), and the maximum rate of pressure rise, determined from the slope of the pressure/time curve, is 8300 psi/sec (572 bar/sec). Substituting these values for the variables in Equation C.3.3, the normalized index equals 572 (0.026)$^{1/3}$, or 169 bar-m/sec.

C.3.4 Effect of Volume on $K_G$ and $K_{St}$. In the case of many initially quiescent gases, the normalized $K_G$ index is found not to be constant but to increase with vessel volume. Figure C.3.3 shows the variation of $K_G$ with vessel volume for methane, propane, and pentane as measured in spherical test vessels [77]. The increase in $K_G$ is related to various flame acceleration effects, as described in [44], [78], and [79]. Therefore, $K_G$ values that are measured in vessels of different sizes cannot be compared directly, even if all other factors affecting $K_G$ are held constant. Any $K_G$ measurement should be made in a spherical vessel at least 5 L (0.005 ft$^3$) in volume, and the values obtained should be used only to interpolate between the venting recommendations of gases that are identified in Figure H.1(a) through Figure H.1(c). (See Section C.4.)

The effect of vessel volume alone on $K_{St}$ values that are obtained for particular dusts has not been well established. Dusts cannot be suspended in a quiescent manner, and the initial turbulence introduces a nonscalable variable. However, it cannot be assumed that $K_{St}$ in Equation C.3.3 is independent of vessel volume. It has been found [47] that $K_{St}$ values that are obtained in the original 1 m$^3$ (35 ft$^3$) classifying vessel cannot be reproduced in spherical vessels with volumes of less than 16 L (0.016 m$^3$) nor in the cylindrical Hartmann apparatus. All existing facilities that have standardized equipment use a spherical test vessel with a volume of at least 20 L (0.02 m$^3$) or a squat cylinder of larger volume [such as the 1 m$^3$ (35 ft$^3$) classifying vessel itself]. The principle of $K_{St}$ standardization in such vessels is to adjust test conditions (particularly initial turbulence) until it can be demonstrated that all dusts yield $K_{St}$ values that are dependent on the vessel volume. The increase in $K_{St}$ with vessel volume is related to various factors, such as the initial turbulence and the vessel geometry.

C.3.5 Effect of Initial Pressure. The initial pressure for deflagration testing is 1 standard atm (absolute pressure of 14.7 psi, 760 mm Hg, or 1.01 bar). Alternatively, a standard pressure of 1 bar can be used with negligible error. If initial pressures are not of standard value, they should be reported, and correction methods should be applied. $P_{max}$ is proportional to initial test pressure, and any difference between initial test pressure and 1 standard atm is multiplied by the deflagration pressure ratio (usually between 7 and 12) in the measured $P_{max}$ value. Measured values are affected to a smaller degree. The effect of initial pressure is most important where tests are conducted at ambient pressure. Ambient pressure can vary from extremes of absolute pressure of 12.9 psi to 15.6 psi (0.89 bar to 1.08
C.4 Gas Testing. The test vessel used for gas testing should be spherical, with a volume of at least 5 L (0.005 m$^3$) and a recommended volume of 20 L (0.02 m$^3$) or greater. Because the only source of initial turbulence is the ignition source employed, it is important that the flame front is not unduly distorted by the ignition process. The ignition source should be centrally located and should approximate a point source. A discrete capacitor discharge carrying no great excess of energy above that needed to ignite the mixture is recommended. Fused-wire igniters and chemical igniters can cause multipoint ignition and should not be used for routine $K_G$ measurements in small vessels.

Standardized gas mixtures, as identified in Figure H.1(a) through Figure H.1(g), can be initially tested in the system. Verification should be made that each gas mixture is well mixed and quiescent immediately prior to ignition. The maximum rates of pressure rise are measured systematically for several compositions close to the stoichiometric mixture until the maximum $K_G$ value has been determined. A table of $K_G$ values is then established for the standardized gases as measured in the test vessel. The values are not necessarily the same as the $K_G$ values determined by using the figures. (See C.3.4.)

To subsequently apply the figures to a test gas, the maximum $K_G$ value for the test gas first has to be determined under conditions identical to those used for standardization. The test material is compared with standardized gases that have $K_G$ values above and below the test value as measured in the test vessel. The vent recommendations are then determined by interpolation of the recommendations for the standardized gases.

A database in which $K_G$ values are given for a wide variety of gases that have been tested under the standardized conditions should be established for the test equipment. $K_G$ values should not be reported unless the database or, at a minimum, the $K_G$ values for the standardized gases, are also reported.

Most flammable gas mixtures at the optimum concentration can be ignited conveniently in small vessels by using a capacitor spark of 100 mJ or less, which can serve as a normal ignition source for standardization. However, the ignition recommendations for certain exceptional gas mixtures can exceed this figure substantially. Before standardization, the ignition recommendations for certain gases may be needed. A number of dust dispersion methods exist. For small vessels, the most common methods used are the perforated ring and the whipping hose. The perforated ring (see [96], ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts) disperses dust placed below the dispersion system. Some time after the dispersion is implied by the ability to achieve consistent and reproducible $K_G$ values in agreement with the established values for the samples that are tested. Poor dispersion leads to low values of $K_{SI}$ and $P_{\text{max}}$ for a particular spherical test vessel [20 L (0.02 m$^3$) or greater] and a particular prepared dust sample:

- (1) Mass of sample dispersed or concentration
- (2) Uniformity of dispersion
- (3) Turbulence at ignition
- (4) Ignition strength

The concentration is not subject to standardization, since it should be varied for each sample that is tested until the maximum $K_{SI}$ has been determined. The maximum $K_{SI}$ usually corresponds to a concentration that is several times greater than stoichiometric. ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts, recommends testing a series of concentrations. Measured $K_{SI}$ is plotted against concentration, and tests continue until the maximum is determined. By testing progressively leaner mixtures, the minimum explosive concentration (lean limit or LFL) can similarly be determined. The limit can be affected by ignition energy.

C.5.2.1 Obtaining a Uniform Dust Dispersion. The uniformity of dust dispersion is implied by the ability to achieve consistent and reproducible $K_{SI}$ values in agreement with the established values for the samples that are tested. Poor dispersion leads to low values of $K_{SI}$ and $P_{\text{max}}$.

A number of dust dispersion methods exist. For small vessels, the most common methods used are the perforated ring and the whipping hose. The perforated ring (see [96], ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts, Annex G.2) disperses the dust. Comparison of these two methods under otherwise identical conditions [77] indicates that they are not necessarily interchangeable and that the dispersion method should be subject to standardization.

C.5.2.2 Standardizing Turbulence at Ignition. During dust injection, the partially evacuated test vessel receives a pulse of air from the air bomb that brings the pressure to 1 atm (absolute) and disperses dust placed below the dispersion system. Some time after the end of injection, the igniter is fired. The following test condition variables affect turbulence at ignition in the test vessel:

- (1) Air bomb volume
- (2) Air bomb pressure
- (3) Initial vessel pressure
- (4) Injection time
- (5) Ignition delay time

References [77] and [80] describe combinations of the variables in C.5.2.2(1) through (5) that have yielded satisfactory results. For example, a 26 L (0.026 m$^3$) test vessel [77] employs a 1 L (0.002 m$^3$) air bomb at absolute pressure of 300 psi (20.7 bar). Having established the air bomb volume and pressure, the initial test vessel reduced pressure and injection time are set so that, after dust injection, the test vessel is at 1 atm (absolute). It should be noted that the air bomb and test vessel pressures do not need to equalize during dust dispersion. Injection time and ignition delay time are set using solenoid valves that are operated by a timing circuit. For standardization, reproducibility of timing is essential, and it is possible that the optimum ignition delay time is approximately 10 milliseconds. Fast-acting valves and accurate timing devices should be employed.
Standardization that uses well-characterized samples (see C.5.1) is considered complete when samples in St-1, St-2, and St-3 dusts have been shown to yield the expected $K_{St}$ (to within acceptable error) with no adjustment of the variables specified in C.5.2.2. In addition, the mode of ignition (see C.5.2.3) should not be changed for standardized testing.

C.5.2.3 Ignition Source. The ignition source can affect determined $K_{St}$ values even if all other variables determined remain constant. It has been found that, in a 1 m$^3$ (35 ft$^3$) vessel, capacitor discharge sources of 40 mJ to 1 J provide $K_{St}$ and $P_{max}$ data comparable to those obtained using a 10 kJ chemical igniter [47]. The same vessel, a permanent spark gap extinguished both $K_{St}$ and $P_{max}$ for a range of samples. References [77] and [81] provide a description of how comparable $K_{St}$ and $P_{max}$ values were obtained in vessels of approximately the same size by using between one and six centrally located electric match igniters rated at 138 J each.

Various types of electrically initiated chemical ignition source devices have provided satisfactory results in many tests. The most popular are two 138 J electric match igniters and two 5 kJ pyrotechnic devices. These ignition sources are not interchangeable, and standardization should be based on a fixed type of igniter. The matches have insufficient power to ignite all combustible dust suspensions. Therefore, any dust that appears to be classified as St-0 should be retested using two 5 kJ pyrotechnic igniters (see Section B.6). The routine use of the pyrotechnic igniter as a standardized source necessitates a method of correction for its inherent pressure effects in small vessels [77]. Therefore, neither source is ideal for all applications.

C.5.3 Dust Preparation for $K_{St}$ Testing. It is necessary for a given dust to be tested in a form that bears a direct relation to the form of that dust in any enclosure to be protected (see Section C.5). Only standardized dusts and samples taken from such enclosures are normally tested in the as-received state. The following factors affect the $K_{St}$:

1. Size distribution
2. Particle shape
3. Contaminants (gas or solid)

Although dusts can be produced in a coarse state, attrition can generate fines. Fines can accumulate in cyclones and baghouses, on surfaces to which the dust adheres, or as fines that are flushed from the routine testing, it is assumed that such fines can be represented by a sample screened to sub-200 mesh (75 micron). For comprehensive testing, cascade screening into narrow-size fractions of constant weight allows $K_{St}$ to be determined for a series of average diameters. Samples taken from the enclosure help in determining representative and worst-case size fractions that are to be tested. If a sufficient sample cannot be obtained as sub-200 mesh (75 micron), it might be necessary to grind the coarse material. Grinding can introduce an error by affecting the shape of the fines produced. The specific surface of a sample, which affects burning rate, depends on both size distribution and particle shape.

Where fines accumulation is considered, the accumulation of additives also has to be considered. Many dust-handling processes can accumulate additives such as antioxidants that are included as only a small fraction of the bulk. Such accumulation can affect $K_{St}$, and, by reducing the ignition energy necessary to ignite the mixture, can increase the probability of a deflagration [77].

Flammable gases can be present in admixtures with dusts (hybrid mixtures), and many accumulate with time as a result of gas desorption from the solid phase. Where this possibility exists, both $K_{St}$ and ignition energy can be affected. The effect of hybrid mixtures cannot be discerned from tests using dust samples that are already pressured in the test vessel. The gas concentration (determined based on partial pressure at the time of ignition) should be systematically varied to determine the range of hybrid $K_{St}$ values that can apply to the practical system.

The use of a whipping hose (see C.5.2.1) or rebound nozzle should avoid the necessity of using inert flow-enhancing additives to help dust dispersion in most cases. Such additives should not be used in testing.

C.6 Classification as Noncombustible. A gas or dust mixture cannot be classified as noncombustible (for example, St-0 dust) unless it has been shown to be nonflammable to a strong chemical ignition source of 10 kJ. If a material fails to ignite over the range of concentrations tested using the standard ignition source, then, after the equipment is checked using a material of known behavior, the test sequence is repeated using a 10 kJ chemical igniter. It is necessary to establish that the strong ignition source cannot yield a pressure history in the vessel that can be confused with any deflagration it produces.

It can be impossible to unequivocally determine whether a dust is noncombustible in the case of small vessels (e.g., the 20 L (0.02 m$^3$) vessel). Such determination is difficult because strong igniters such as 10 kJ pyrotechnics tend to overdrive the flame system, in addition to producing many pressure effects of their own. Cashdollar and Chatrathi [97] have demonstrated the overdriving effect when determining minimum explosible dust concentrations. Mixtures that are considered to be explosible in a 20 L (0.02 m$^3$) vessel do not propagate flame in a 1 m$^3$ (35 ft$^3$) vessel at the same concentration. Cashdollar and Chatrathi recommend the use of a 2.5 kJ igniter for lower flammable limit measurements, which produced results similar to those of the 10 kJ igniter in a 1 m$^3$ (35 ft$^3$) vessel. In standard ASTM E 1515, only a 10 kJ (138 J) igniter is used for MEC testing. The authors further recommend an ignition criterion of an absolute pressure ratio greater than 2 plus a $K_{St}$ greater than 1.5 bar/m/sec.

An alternative to the use of the strong ignition source and its associated pressure effects in small vessels is to test fractions of a finer size than the routine sub-200 mesh (75 micron). Dust ignition energy varies with the approximate cube of particle diameter [77], therefore, the use of electric matches can be extended to identification of St-0 dusts. Similarly, the dust lean limit concentration can be subject to ignition energy effects, which decrease with the sample’s decreasing particle size. Such effects largely disappear where sub-400 mesh samples are tested. In the case of gases, a strong ignition source that consists of capacitance discharges in excess of 10 J, or fused-wire sources of similar energy, can be used. Such sources are routinely used for flammable limit determination.

C.7 Instrumentation Notes. Data can be gathered by analog or digital methods, but the rate of data collection should be capable of resolving a signal of 1 kHz or higher frequency (for digital methods, more than one data point per millisecond). For fast-burning dusts and gases, particularly in small vessels, faster rates of data logging can be necessary to resolve. Data-logging systems include oscilloscopes, oscillographs, microcomputers, and other digital recorders. An advantage of digital methods is that both the thermocouple and subsequent data reduction can be readily automated using computer methods [77]. Further advantage of digital methods is that expansion of the time axis enables a more accurate measurement of the slope of the pressure–time curve than can be obtained from an analog oscilloscope record. When using automated data reduction, it is essential to incorporate appropriate logic to obviate the effect of spurious electrical signals. Such signals can be reduced by judicious cable placement, grounding, and screening, but they are difficult to avoid altogether. It is advantageous to confirm automated values manually using the pressure–time curve generated.

Where gas mixtures are created by the method of partial pressures, it is important to incorporate a gas-temperature measurement device (for example, a thermocouple) to ensure that the mixture is created at a constant temperature. Gas analysis should be used where possible.

It has been found that piezoelectric pressure transducers are satisfactory for deflagration pressure measurements in dust-testing systems as a result of good calibration stability. The transducer should be flush-mounted to the inside wall of the vessel and coated with silicone rubber, thereby minimizing acoustic and thermal effects.

The entire test system should be routinely maintained and subjected to periodic tests using standard materials of known behavior. Soon after initial standardization, large quantities of well-characterized dusts subject to aging or other effects should be prepared. Where stored, these dusts can be used for periodic system performance tests.

Annex D Fundamental Burning Velocities for Select Flammable Gases in Air

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 General. The values of fundamental burning velocity given in Table D.1(a) are based on NACA Report 1300 [82]. For the purpose of this guide, a reference value of 46 cm/sec for the fundamental burning velocity of propane has been used. The compilation given in Perry’s Chemical Engineers’ Handbook [83] is based on the same data as NACA Report 1300. Agreement with more recently published data as presented in Table D.1(b).
<table>
<thead>
<tr>
<th>Gas</th>
<th>Fundamental Burning Velocity (cm/sec)</th>
<th>Gas</th>
<th>Fundamental Burning Velocity (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>54</td>
<td>Ethyl acetate</td>
<td>58</td>
</tr>
<tr>
<td>Acetylene</td>
<td>166*</td>
<td>Ethylene oxide</td>
<td>108</td>
</tr>
<tr>
<td>Acrolein</td>
<td>66</td>
<td>Ethylenimine</td>
<td>46</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>50</td>
<td>Gasoline (100-octane)</td>
<td>40</td>
</tr>
<tr>
<td>Allene (propadiene)</td>
<td>87</td>
<td>n-Heptane</td>
<td>46</td>
</tr>
<tr>
<td>Benzene</td>
<td>48</td>
<td>Hexadecane</td>
<td>44</td>
</tr>
<tr>
<td>n-pentyl-</td>
<td>37</td>
<td>1,5-Hexadiene</td>
<td>52</td>
</tr>
<tr>
<td>1,2-dimethyl-</td>
<td>37</td>
<td>1-Hexene</td>
<td>50</td>
</tr>
<tr>
<td>1,2,4-trimethyl-</td>
<td>39</td>
<td>1-Hexyne</td>
<td>57</td>
</tr>
<tr>
<td>1,2-Butadiene (methylallene)</td>
<td>68</td>
<td>3-Hexyne</td>
<td>53</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>64</td>
<td>HFC-23 Difluoromethane</td>
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<td>2,3-dimethyl-</td>
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<td>HFC-143 1,1,2-Trifluoroethane</td>
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<td>HFC-145a 1,1,2-Trifluoroethane</td>
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<td>HFC-152a 1,1-Difluoroethane</td>
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<td>2-cyclopropyl-</td>
<td>47</td>
<td>Hydrogen</td>
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<td>42</td>
<td>Isopropyl alcohol</td>
<td>41</td>
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<tr>
<td>2,3-dimethyl-</td>
<td>43</td>
<td>Isopropylamine</td>
<td>31</td>
</tr>
<tr>
<td>2-methyl-</td>
<td>43</td>
<td>Jet fuel, grade JP-1 (average)</td>
<td>40</td>
</tr>
<tr>
<td>2,2,3-trimethyl-</td>
<td>42</td>
<td>Jet fuel, grade JP-4 (average)</td>
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<td>42</td>
<td>Methane</td>
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<td>Diphenyl</td>
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<td>Methyl alcohol</td>
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</tr>
<tr>
<td>2,3-dimethyl-</td>
<td>46</td>
<td>1,2-Pentadiene (ethylleneline)</td>
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<tr>
<td>2-ethyl-</td>
<td>46</td>
<td>cis-1,3-Pentadiene</td>
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</tr>
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<td>2-methyl-</td>
<td>46</td>
<td>trans-1,3-Pentadiene (piperylene)</td>
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<td>3-methyl-</td>
<td>49</td>
<td>2-methyl-(cis or trans)</td>
<td>46</td>
</tr>
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<td>1,4-Pentadiene</td>
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<td>58</td>
<td>1,4-Pentadiene (vinylacetylene)</td>
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<td>n-Pentane</td>
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<td>61</td>
<td>2,2-dimethyl-</td>
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<tr>
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<td>58</td>
<td>2,3-dimethyl-</td>
<td>42</td>
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<td>Carbon disulfide</td>
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<tr>
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<td>43</td>
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<td>50</td>
</tr>
<tr>
<td>methyl-</td>
<td>52</td>
<td>2-methyl-</td>
<td>47</td>
</tr>
<tr>
<td>Methy1ene</td>
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<td>methyl-</td>
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<tr>
<td>Cyclopropane</td>
<td>56</td>
<td>Propane</td>
<td>46*</td>
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<tr>
<td>cis-1,2-dimethyl-</td>
<td>55</td>
<td>2-cyclopropyl-</td>
<td>50</td>
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<td>trans-1,2-dimethyl-</td>
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<td>ethyl-</td>
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<td>1-deutero-2-methyl-</td>
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<td>methyl-</td>
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<td>trans-Decalin (decahydro-naphthalene)</td>
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<td>Spiropentane</td>
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<td>Tetralin (tetrahydro-naphthalene)</td>
<td>39</td>
<td>Tetrahydroxypropane</td>
<td>48</td>
</tr>
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</table>

*Gases that have been critically examined in [84] or [85] with regard to fundamental burning velocity. Table D.1(b) compares the selected values from these references with those in Table D.1(a).
Table D.1(b) Comparison of Fundamental Burning Velocities for Selected Gases, Fundamental Burning Velocity (cm/sec)

<table>
<thead>
<tr>
<th>Gas</th>
<th>Andrews and Bradley [84] (in air)</th>
<th>France and Pritchard [85] (in air)</th>
<th>Pmax (in air)</th>
<th>Pmax (in oxygen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene</td>
<td>166</td>
<td>—</td>
<td>158</td>
<td>140</td>
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<td>79</td>
<td>0</td>
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<td>1400</td>
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<td>Methane</td>
<td>40</td>
<td>45</td>
<td>450</td>
<td>43</td>
</tr>
<tr>
<td>Propane</td>
<td>46</td>
<td>—</td>
<td>46</td>
<td>—</td>
</tr>
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</table>

Annex E Deflagration Characteristics of Select Flammable Gases

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

E.1 $K_G$ Values. As stated in Annex C, the $K_G$ value is not constant and varies depending on test conditions such as type and amount of ignition energy, volume of test vessel, and other test conditions. Thus, a single value of $K_G$ for a particular set of test conditions is only one among a continuum of values that vary over the range of test conditions.

Figure C.1 provides $K_G$ values for methane, propane, and pentane over a range of vessel sizes [77].

Table E.1 provides $K_G$ values for several gases. The values were determined by tests in a 5 L (0.005 m³) sphere with ignition by an electric spark of approximately 10 J energy. Where the fuels did not have sufficient vapor pressure, the tests were done at room temperature. Where the fuels did not have sufficient high vapor pressure, the tests were done at elevated temperature, and the test results were then extrapolated to room temperature. The source of the test data is the laboratory of Dr. W. Bartknecht, Ciba Geigy Co., Basel, Switzerland (private communication).

Table E.1 Flammability Properties of Gases 5 L (0.005 m³) sphere; E = 10 J, normal conditions [110]

<table>
<thead>
<tr>
<th>Flammable Material</th>
<th>$P_{max}$ (bar)</th>
<th>$K_G$ (bar-m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetophenone a</td>
<td>7.6</td>
<td>109</td>
</tr>
<tr>
<td>Acetylene</td>
<td>10.6</td>
<td>1415</td>
</tr>
<tr>
<td>Ammonia b</td>
<td>5.4</td>
<td>10</td>
</tr>
<tr>
<td>b-Naphthol c</td>
<td>4.4</td>
<td>36</td>
</tr>
<tr>
<td>Butane</td>
<td>8.0</td>
<td>92</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>6.4</td>
<td>105</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>8.1</td>
<td>115</td>
</tr>
<tr>
<td>Dimethyl formamide a</td>
<td>8.4</td>
<td>78</td>
</tr>
<tr>
<td>Dimethyl sulfoxide a</td>
<td>7.3</td>
<td>112</td>
</tr>
<tr>
<td>Ethane a</td>
<td>7.8</td>
<td>106</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>7.0</td>
<td>78</td>
</tr>
<tr>
<td>Ethyl benzene a</td>
<td>7.4</td>
<td>96</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>6.8</td>
<td>550</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>7.4</td>
<td>45</td>
</tr>
<tr>
<td>Isopropanol a</td>
<td>7.8</td>
<td>83</td>
</tr>
<tr>
<td>Methane</td>
<td>7.1</td>
<td>55</td>
</tr>
<tr>
<td>Methanol a</td>
<td>7.5</td>
<td>75</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>5.0</td>
<td>5</td>
</tr>
<tr>
<td>Methyl nitrite</td>
<td>11.4</td>
<td>111</td>
</tr>
<tr>
<td>Neopentane</td>
<td>7.8</td>
<td>60</td>
</tr>
<tr>
<td>Octanol a</td>
<td>6.7</td>
<td>95</td>
</tr>
<tr>
<td>Octyl chloride a</td>
<td>8.0</td>
<td>116</td>
</tr>
<tr>
<td>Pentane a</td>
<td>7.8</td>
<td>104</td>
</tr>
<tr>
<td>Propane</td>
<td>7.9</td>
<td>100</td>
</tr>
<tr>
<td>South African crude oil</td>
<td>6.8–7.6</td>
<td>36–62</td>
</tr>
<tr>
<td>Toluene a</td>
<td>7.8</td>
<td>94</td>
</tr>
</tbody>
</table>

*Measured at elevated temperatures and extrapolated to 25°C (77°F) at normal conditions.

$E = 100$ J–200 J.

$E = 200°C$ (392°F).

A $K_G$ value for a flammable gas can be approximated from a known $K_G$ value for another flammable gas by the following equation:

**Existing Equation D.1 (no change)**

$$E = 200°C$ (392°F).

$E = 10 J–200 J.$

**E.2 Using New $K_G$ Data.** A method for developing $K_G$ values has not been standardized. As such, values that are determined by a laboratory can deviate from those employed by Bartknecht in developing the correlation coefficients for the vent area equation recommended for use with flammable gases. To maintain consistency in the application of the vent area equations in Chapter 7, $K_G$ data should be adjusted for equivalency with the Bartknecht data as shown in Table E.2. The procedure uses the Bartknecht $K_G$ values for methane (55) and propane (100) as points of reference. The following procedure is recommended.

Table E.2 Gas Explosibility Data as Measured and Adjusted Based on Bartknecht [110]

<table>
<thead>
<tr>
<th>Gas</th>
<th>As Measured</th>
<th>Adjusted</th>
<th>$P_{max}$ (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1-Difluoroethane</td>
<td>59</td>
<td>75</td>
<td>1.7</td>
</tr>
<tr>
<td>Acetone</td>
<td>65</td>
<td>84</td>
<td>7.3</td>
</tr>
<tr>
<td>Dimethyl ether</td>
<td>108</td>
<td>148</td>
<td>7.9</td>
</tr>
<tr>
<td>Ethane</td>
<td>78</td>
<td>103</td>
<td>7.4</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>78</td>
<td>103</td>
<td>7.0</td>
</tr>
<tr>
<td>Ethylene</td>
<td>171</td>
<td>243</td>
<td>8.0</td>
</tr>
<tr>
<td>Isobutane</td>
<td>67</td>
<td>87</td>
<td>7.4</td>
</tr>
<tr>
<td>Methane</td>
<td>46</td>
<td>55</td>
<td>6.7</td>
</tr>
<tr>
<td>Methyl alcohol</td>
<td>94</td>
<td>127</td>
<td>7.2</td>
</tr>
<tr>
<td>Propane</td>
<td>76</td>
<td>100</td>
<td>7.3</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>638</td>
<td>*</td>
<td>6.5</td>
</tr>
</tbody>
</table>

*Not recommended due to excessive extrapolation.

$K_G$ values for several gases. The values were determined by tests in a 5 L (0.005 m³) sphere with ignition by an electric spark of approximately 10 J energy. Where the fuels had sufficient vapor pressure, the tests were done at room temperature. Where the fuels did not have sufficient high vapor pressure, the tests were done at elevated temperature, and the test results were then extrapolated to room temperature. The source of the test data is the laboratory of Dr. W. Bartknecht, Ciba Geigy Co., Basel, Switzerland (private communication).

The values for $P_{max}$ for the two gases can be measured by actual test under near-identical conditions, or both can be calculated for adiabatic combustion conditions. However, one $P_{max}$ cannot be calculated while the other is measured by test. Optimum mixture is a mixture of the composition that yields the highest maximum pressure during combustion. Usually this is not a stoichiometric mixture but a mixture that is slightly richer in fuel gas than stoichiometric.

Equation E.1 produces the most accurate values where the two flammable gases have similar values of $K_G$.

**E.2.1 Develop $K_G$ values for propane and methane using the same equipment and method as employed for obtaining data on other gases of interest.**

**E.2.2 Compute the linear adjustment coefficients, $A$ and $B$, as follows:**

$$B = \frac{K_G \text{ (propane)} - K_G \text{ (methane)}}{K_G \text{ (propane)} - K_G \text{ (methane)}}$$

**Existing Equation D.3 (no change)**

$$E.2.2$$

**E.2.3 The adjusted value of $K_G$ that is determined by the new method is calculated as follows:**

**Existing Equation D.4 (no change)**

$$E.2.3$$

Figure E.2.3 shows the correlation for the data reported in Table E.2.
Annex F Deflagration Characteristics of Select Combustible Dusts

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 Introduction. Table F.1(a) through Table F.1(e) are based on information obtained from Forschungsbericht Staubexplosionen [86].

### Table F.1(a) Agricultural Products

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;Sf&lt;/sub&gt; (bar-m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>33</td>
<td>60</td>
<td>9.7</td>
<td>229</td>
<td>2</td>
</tr>
<tr>
<td>Cellulose pulp</td>
<td>42</td>
<td>30</td>
<td>9.9</td>
<td>62</td>
<td>1</td>
</tr>
<tr>
<td>Cork</td>
<td>42</td>
<td>30</td>
<td>9.6</td>
<td>202</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>28</td>
<td>60</td>
<td>9.4</td>
<td>75</td>
<td>1</td>
</tr>
<tr>
<td>Egg white</td>
<td>17</td>
<td>125</td>
<td>8.3</td>
<td>38</td>
<td>1</td>
</tr>
<tr>
<td>Milk, powdered</td>
<td>83</td>
<td>60</td>
<td>5.8</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Milk, nonfat, dry</td>
<td>60</td>
<td>—</td>
<td>8.8</td>
<td>125</td>
<td>1</td>
</tr>
<tr>
<td>Soy flour</td>
<td>20</td>
<td>200</td>
<td>9.2</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Starch, corn</td>
<td>7</td>
<td>60</td>
<td>10.3</td>
<td>202</td>
<td>2</td>
</tr>
<tr>
<td>Starch, rice</td>
<td>18</td>
<td>60</td>
<td>9.2</td>
<td>101</td>
<td>1</td>
</tr>
<tr>
<td>Starch, wheat</td>
<td>22</td>
<td>30</td>
<td>9.9</td>
<td>115</td>
<td>1</td>
</tr>
<tr>
<td>Sugar</td>
<td>30</td>
<td>200</td>
<td>8.5</td>
<td>138</td>
<td>1</td>
</tr>
<tr>
<td>Sugar, milk</td>
<td>27</td>
<td>60</td>
<td>8.3</td>
<td>82</td>
<td>1</td>
</tr>
<tr>
<td>Sugar, beet</td>
<td>29</td>
<td>60</td>
<td>8.2</td>
<td>59</td>
<td>1</td>
</tr>
<tr>
<td>Tapioca</td>
<td>22</td>
<td>125</td>
<td>9.4</td>
<td>62</td>
<td>1</td>
</tr>
<tr>
<td>Whey</td>
<td>41</td>
<td>125</td>
<td>9.8</td>
<td>140</td>
<td>1</td>
</tr>
<tr>
<td>Wood flour</td>
<td>29</td>
<td>—</td>
<td>10.5</td>
<td>205</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table F.1(b) Carbonaceous Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;Sf&lt;/sub&gt; (bar-m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal, activated</td>
<td>28</td>
<td>60</td>
<td>7.7</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Charcoal, wood</td>
<td>14</td>
<td>60</td>
<td>9.0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Coal, bituminous</td>
<td>24</td>
<td>60</td>
<td>9.2</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>Coke, petroleum</td>
<td>15</td>
<td>125</td>
<td>7.6</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>Lampblack</td>
<td>&lt;10</td>
<td>60</td>
<td>8.4</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>Lignite</td>
<td>32</td>
<td>60</td>
<td>10.0</td>
<td>151</td>
<td>1</td>
</tr>
<tr>
<td>Peat, 22% H₂O</td>
<td>—</td>
<td>125</td>
<td>84.0</td>
<td>67</td>
<td>1</td>
</tr>
<tr>
<td>Soot, pine</td>
<td>&lt;10</td>
<td>—</td>
<td>7.9</td>
<td>26</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table F.1(c) Chemical Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;Sf&lt;/sub&gt; (bar-m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adipic acid</td>
<td>&lt;10</td>
<td>60</td>
<td>8.0</td>
<td>97</td>
<td>1</td>
</tr>
<tr>
<td>Anthraquinone</td>
<td>&lt;10</td>
<td>—</td>
<td>10.6</td>
<td>364</td>
<td>3</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>39</td>
<td>60</td>
<td>9.0</td>
<td>111</td>
<td>1</td>
</tr>
<tr>
<td>Calcium acetate</td>
<td>92</td>
<td>500</td>
<td>5.2</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Calcium acetate</td>
<td>85</td>
<td>250</td>
<td>6.5</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Calcium stearate</td>
<td>12</td>
<td>30</td>
<td>9.1</td>
<td>132</td>
<td>1</td>
</tr>
<tr>
<td>Carboxy- methyl- cellulose</td>
<td>24</td>
<td>125</td>
<td>9.2</td>
<td>136</td>
<td>1</td>
</tr>
<tr>
<td>Dextrin</td>
<td>41</td>
<td>60</td>
<td>8.8</td>
<td>106</td>
<td>1</td>
</tr>
<tr>
<td>Lactose</td>
<td>23</td>
<td>60</td>
<td>7.7</td>
<td>81</td>
<td>1</td>
</tr>
<tr>
<td>Lead stearate</td>
<td>12</td>
<td>30</td>
<td>9.2</td>
<td>152</td>
<td>1</td>
</tr>
<tr>
<td>Methyl-cellulose</td>
<td>75</td>
<td>60</td>
<td>9.5</td>
<td>134</td>
<td>1</td>
</tr>
<tr>
<td>Paraformaldehyde</td>
<td>23</td>
<td>60</td>
<td>9.9</td>
<td>178</td>
<td>1</td>
</tr>
<tr>
<td>Sodium ascorbate</td>
<td>23</td>
<td>60</td>
<td>8.4</td>
<td>119</td>
<td>1</td>
</tr>
<tr>
<td>Sodium stearate</td>
<td>22</td>
<td>30</td>
<td>8.8</td>
<td>123</td>
<td>1</td>
</tr>
<tr>
<td>Sulfur</td>
<td>20</td>
<td>30</td>
<td>6.8</td>
<td>151</td>
<td>1</td>
</tr>
</tbody>
</table>
Table F.1(d) Metal Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>$P_{\text{max}}$ (bar)</th>
<th>$K_{\text{St}}$ (bar·m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>29</td>
<td>290</td>
<td>12.4</td>
<td>415</td>
<td>3</td>
</tr>
<tr>
<td>Bronze</td>
<td>18</td>
<td>750</td>
<td>4.1</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>Iron carbonyl</td>
<td>&lt;10</td>
<td>125</td>
<td>6.1</td>
<td>111</td>
<td>1</td>
</tr>
<tr>
<td>Magnesium</td>
<td>28</td>
<td>30</td>
<td>17.5</td>
<td>508</td>
<td>3</td>
</tr>
<tr>
<td>Zinc</td>
<td>10</td>
<td>250</td>
<td>6.7</td>
<td>125</td>
<td>1</td>
</tr>
<tr>
<td>Zinc</td>
<td>&lt;10</td>
<td>125</td>
<td>7.3</td>
<td>176</td>
<td>1</td>
</tr>
</tbody>
</table>

Table F.1(e) Plastic Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>$P_{\text{max}}$ (bar)</th>
<th>$K_{\text{St}}$ (bar·m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>(poly) Acrylamide</td>
<td>10</td>
<td>200</td>
<td>5.9</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Acrylonitrile</td>
<td>25</td>
<td>—</td>
<td>8.5</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Ethylene (low-pressure process)</td>
<td>&lt;10</td>
<td>30</td>
<td>8.0</td>
<td>156</td>
<td>1</td>
</tr>
<tr>
<td>Epoxy resin</td>
<td>26</td>
<td>30</td>
<td>7.9</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>Melamine resin</td>
<td>18</td>
<td>125</td>
<td>10.2</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Melamine, molded (wood flour and mineral filled phenol-formaldehyde)</td>
<td>15</td>
<td>60</td>
<td>7.5</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>Melamine molded (phenol-cellulose)</td>
<td>12</td>
<td>60</td>
<td>10.0</td>
<td>127</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Methyl acrylate</td>
<td>21</td>
<td>30</td>
<td>9.4</td>
<td>269</td>
<td>2</td>
</tr>
<tr>
<td>(poly) Methyl acrylate, emulsion polymer</td>
<td>18</td>
<td>30</td>
<td>10.1</td>
<td>202</td>
<td>2</td>
</tr>
<tr>
<td>Phenolic resin</td>
<td>&lt;10</td>
<td>15</td>
<td>9.3</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Propylene</td>
<td>25</td>
<td>30</td>
<td>8.4</td>
<td>101</td>
<td>1</td>
</tr>
<tr>
<td>Terpene-phenol resin</td>
<td>10</td>
<td>15</td>
<td>8.7</td>
<td>143</td>
<td>1</td>
</tr>
<tr>
<td>Urea-formaldehyde/ cellulose, molded</td>
<td>13</td>
<td>60</td>
<td>10.2</td>
<td>136</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl acetate/ ethylene copolymer</td>
<td>32</td>
<td>30</td>
<td>8.6</td>
<td>119</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl alcohol</td>
<td>26</td>
<td>60</td>
<td>8.9</td>
<td>128</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl butyral</td>
<td>65</td>
<td>30</td>
<td>8.9</td>
<td>147</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl chloride/ vinyl acetylene emulsion copolymer</td>
<td>107</td>
<td>200</td>
<td>7.6</td>
<td>46</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl chloride/ ethylene/ vinyl acetylene suspension copolymer</td>
<td>35</td>
<td>60</td>
<td>8.2</td>
<td>95</td>
<td>1</td>
</tr>
</tbody>
</table>

For each dust, the tables show the mass median diameter of the material tested as well as the following test results obtained in a 1 m³ (35 ft³) vessel:

1. Minimum explosive concentration
2. Maximum pressure developed by the explosion, $P_{\text{max}}$
3. Maximum rate of pressure rise $(dP/dt)_{\text{max}}$
4. $K_{\text{St}}$ value, which is equivalent to $(dP/dt)_{\text{max}}$ because of the size of the test vessel
5. Dust hazard class as St-1, St-2, or St-3, as defined in Table B.1.2.4

F.2 Explanation of Test Data. The user is cautioned that test data on the flammability characteristics of dusts are sample specific. Dusts that have the same chemical identities, for example, as a chemical, or that are nominally derived from the same sources, such as grain dusts, can vary widely in $K_{\text{St}}$ values. For example, various calcium stearate dusts have been found to have ranges of $K_{\text{St}}$ values that designate the respective dusts as in St-1 through St-3. Therefore, care should be taken in the use of data from these tables.

Annex G Calculation Method for Correction Factor Due to Increased Vent Panel Mass

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

G.1 The following procedure can be used to assess the impact of the vent panel mass on $P_{\text{cor}}$.

G.1.1 Introduction. The mass of vent panels is a factor that can limit the effectiveness of the venting process. To properly assess the influence panel mass contributes, other factors must also be considered, such as the reactivity of the dust, the enclosure volume and the number, shape, size and type of deflagration vents utilized. The procedures for determining the effects of vent panel inertia on deflagration venting are presented in this section. The theoretical development uses mostly absolute pressures, instead of the gauge pressures used in the remainder of this document, and new pressure terms are defined. Pressures are used in bar, bar-abs, and Pascals-abs, thus the reader is cautioned to note units of measure directly following each equation.

G.1.2 The reduced deflagration pressure is first calculated using Equation 8.2.2, based on low-mass vents. Corrections for vessel $L/D$ and Partial Volume can then be added. Next the correction factors for inertia effects are calculated.
G.1.3 The inertia of the panel can manifest itself in the following two ways:

1. As a new factor in the effective vent relief pressure, \( P_{\text{rel}} \), higher than the nominal static value, \( P_0 \), and
2. As a higher reduced pressure, \( P_{\text{rel}} \), after full vent deployment with respect to the \( P_{\text{rel}} \) in the absence of inertia.

The highest pressure during the vented deflagration can occur either at the point of vent relief or later after vent deployment. As inertia of the panel affects both pressures, both effects have to be calculated and the higher value, \( P_{\text{rel}} \) or \( P_{\text{rel}} \), is used as the reduced pressure produced in the vented deflagration.

G.1.3.1 The inertia correction is limited to the following:

1. Vent panel density, \( \sigma_v < 200 \text{ kg/m}^2 \)
2. Nominal static relief pressure, \( P_v < 0.5 \text{ bar} \)

G.1.4 Both inertia effects are evaluated using two dimensionless parameters, \( \Sigma \) and \( \Gamma \). However one term in the parameters is different, the dust reactivity. In the first case, the deflagration index, \( K_{\text{sr}} \), is used to determine \( \Sigma_{\text{sr}} \) and \( \Gamma_{\text{sr}} \). In the second case, the effective mixture reactivity, \( K_{\text{st}} \), is used to determine \( \Sigma_{\text{st}} \) and \( \Gamma_{\text{st}} \).

G.1.5 The deflagration index, \( K_{\text{sr}} \), of a dust is basically the maximum rate of pressure rise generated in a confined deflagration. The effective mixture reactivity is a parameter based on \( K_{\text{sr}} \), but which contains two corrections to account for the effects of the deflagration vent relief pressure and the volume of the protected enclosure. The vent relief pressure correction is the following:

\[
K_{\text{sr},v} = K_{\text{sr}} \left[ 1 + 1.75 \left( \frac{\Delta P_v}{P_v} \right) \right] \quad (G.1.5a)
\]

where:

- \( K_{\text{sr},v} \) = deflagration index with vent relief pressure correction
- \( K_{\text{sr}} \) = deflagration index (bar-m/sec)
- \( \Delta P_v \) = vent relief pressure (bar) = \( P_{\text{rel}} \) - \( P_v \)
- \( P_v \) = initial pressure (bar abs)

The volume correction for Equation (G.1.5a) is the following:

\[
K = K_{\text{sr},v} \left[ \frac{V}{10 \text{ m}^3} \right]^{0.11} \quad (G.1.5b)
\]

where:

- \( K \) = volume correction to deflagration index
- \( V \) = enclosure volume (m³)

This volume correction is applied only where the enclosure volume is greater than 10 m³, otherwise \( K = K_{\text{sr},v} \).

G.1.6 The shape factor for the vent(s) is:

For square panels, \( c_s = 1 \).
For circular panels, \( c_s = 0.886 \).
For rectangular panels, apply the following equation:

\[
c_s = \frac{1 \pm \sqrt{\frac{A_v}{2V}}} {2 \sqrt{\pm}} \quad (G.1.6)
\]

G.1.7 Calculate \( \Sigma_{K_{\text{sr}}} \) and \( \Sigma_{K} \) using Equations G.1.7a and G.1.7b.

\[
\Sigma_{K_{\text{sr}}} = \frac{\sigma_v}{(n^2)} \left( c_s \right) \left( \alpha_{dV} \right) \left( P_v \right) \left( V^{\frac{1}{3}} \right) \left[ \frac{K_{\text{sr}}}{\Delta P_m} \right]^{\frac{1}{2}} \quad (G.1.7a)
\]

\[
\Sigma_{K} = \frac{\sigma_v}{(n^2)} \left( c_s \right) \left( \alpha_{dV} \right) \left( P_v \right) \left( V^{\frac{1}{3}} \right) \left[ \frac{K}{\Delta P_m} \right]^{\frac{1}{2}} \quad (G.1.7b)
\]

where:

- \( \alpha \) = the ratio of the rectangle's smaller side to its longer side
- \( \sigma_v \) = vent panel density (kg/m²)
- \( n \) = number of equal-sized panels
- \( c_s \) = shape factor
- \( \alpha_{dV} \) = constant = 232.5 m/sec
- \( p_v \) = initial pressure (Pascal absolute, N/m²)
- \( V \) = enclosure volume (m³)
- \( K_{\text{sr}} \) = deflagration index (bar-m/sec)
- \( K \) = effective mixture reactivity (bar-m/sec)
- \( \Delta P_m \) = unvented pressure rise (bar) = \( P_{\text{rel}} - P_v \)

G.1.7.1 For hinged vent closures, increase the value of vent panel density, \( \sigma_v \) by 33 percent.

G.1.8 Calculate \( \Gamma_{K_{\text{sr}}} \) and \( \Gamma_{K} \) using Equations G.1.8a and G.1.8b.

\[
\Gamma_{K_{\text{sr}}} = \pm \left( c_s \right) \left( \frac{A_v}{V^{\frac{1}{3}}} \right) \left( \frac{\Delta P_m}{K_{\text{sr}}} \right) \quad (G.1.8a)
\]

\[
\Gamma_{K} = \pm \left( c_s \right) \left( \frac{A_v}{V^{\frac{1}{3}}} \right) \left( \frac{\Delta P_m}{K} \right) \quad (G.1.8b)
\]

where:

- \( \Gamma_{K_{\text{sr}}} \), \( \Gamma_{K} \) = dimensionless parameters
- \( A_v \) = vent area (m²)

G.1.9 Calculate the Pressure function, \( f(P_v) \), using Equations G.1.9a and G.1.9b.

\[
P_v = \frac{P_v - P_v}{P_m - P_v} \quad (G.1.9a)
\]

\[
f(P_v) = \left( 1000 P_v \right)^{0.5} \quad (G.1.9b)
\]

where:

- \( P_v \) = pressure ratio
- \( P_v \) = vent panel static relief pressure (bar abs)
- \( P_m \) = initial pressure (bar abs)
by a deflagration when the conditions are as follows:

G.1.10 Calculate the panel inertia parameter, \( \eta \), using Equation G.1.10.

\[
\eta = \frac{2}{3} - \frac{1}{60} \left[ \text{Max} \{1, f(P_v)\} + 3.2 \left( \frac{mg_\nu}{P_r - p_0} \right) f(P_v) \right] \tag{G.1.10}
\]

where:
- \( \eta \) is panel inertia parameter
- \( m \) is vent gravity coefficient, assisting or slowing vent opening as defined in Table G.1.10.
- \( g \) is gravitational acceleration (m/sec^2)
- \( P_r \) is vent panel static relief pressure (Pascal absolute, N/m^2)
- \( p_0 \) is initial pressure (Pascal absolute, N/m^2)

**Table G.1.10 Value of Vent Gravity Coefficient**

<table>
<thead>
<tr>
<th>Panel Characteristics</th>
<th>Value of ( m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal panel, on top of the vessel</td>
<td>1</td>
</tr>
<tr>
<td>Other orientations</td>
<td>0</td>
</tr>
</tbody>
</table>

G.1.11 The new effective vent relief pressure with inertia can be determined as follows:

\[
P_{\text{si}} = P_r + 0.2 \left[ \frac{\Sigma K_i}{\Gamma_{\text{KSi}}} \right] \Delta P_m \tag{G.1.11}
\]

where:
- \( P_{\text{si}} \) is effective vent relief pressure with inertia (bar abs)
- \( P_r \) is vent panel static relief pressure (bar abs)
- \( \Delta P_m \) is unvented pressure rise (bar) = \( P_m - P_0 \)

G.1.12 The new reduced pressure after full vent deployment can be determined as follows, depending on the value of \( \Gamma_{\text{KSi}} \):

For \( \Gamma_{\text{KSi}} \leq 1 \):

\[
P_r = P_{\text{si}} + \left( P_{\text{si}} - P_0 \right) \left( \Sigma K_i \right) \left( 1.06 \Gamma_{\text{KSi}} \right) \tag{G.1.12}
\]

For \( 1 < \Gamma_{\text{KSi}} < 3 \):

\[
P_r = P_{\text{si}} + \left( P_{\text{si}} - P_0 \right) \left( \Sigma K_i \right) \left( 0.26 \left( \Gamma_{\text{KSi}} - 3 \right) \left( 0.25 - 0.75 \Gamma_{\text{KSi}} \right) \right)
\]

For \( \Gamma_{\text{KSi}} \geq 3 \):

\[
P_r = P_{\text{si}}
\]

where:
- \( P_{\text{si}} \) is the reduced pressure developed with inertia (bar abs)
- \( P_r \) is the reduced pressure developed with low-mass vents, \( P_{\text{red}} \) (bar abs)
- \( P_m \) is unvented deflagration pressure, \( P_{\text{max}} + 1 \) (bar abs)
- \( P_0 \) is initial pressure (bar abs)

G.1.13 Compare the results obtained in Equations G.1.11 and G.1.12. The larger of the two results, \( P_r \) or \( P_{\text{si}} \), represents the new maximum reduced deflagration pressure (bar abs) due to the vent panel inertia effect. The value of \( P_r \) or \( P_{\text{si}} \) must be converted to gauge pressure as \( P_{\text{red}} \) to iterate Equation 7.2.2. If the calculated pressure exceeds the enclosure strength, the user should repeat the calculation with a larger vent area.

G.2 Example Problem. Determine the maximum pressure developed by a deflagration when the conditions are as follows:

1. \( V = 100 \) m^3
2. \( K_{\text{St}} = 200 \) bar-m/sec

(3) \( P_0 = 1 \) bar abs
(4) \( P_{\text{max}} = 9 \) bar abs
(5) \( \sigma = 24.4 \) kg/m^2
(6) \( n = 4 \) (equals square panels vertically mounted, not hinged)
(7) \( A_v = 6 \) m^2
(8) \( P_{\text{stat}} = 0.05 \) bar

The first step is to determine the reduced deflagration pressure developed if zero-mass vents were used.

From Equation 8.2.2, solve for \( \Pi \):

\[
A_v = 1 \cdot 10^{-4} \cdot (1 + 1.54 \cdot P_{\text{stat}}^{4/3}) \cdot K_{\text{St}} \cdot \sigma^{3/4} \cdot \sqrt{\frac{P_{\text{red}}}{P_{\text{stat}}}} - 1
\]

**Existing Equation from 7.1 (no change)**

The reduced pressure is then calculated by

**Existing Equation (no change)**

In order to solve Equation G.1.6, we must first determine the values of \( \Sigma K_i \) and \( \Gamma_{\text{KSi}} \):

**Existing Equation from F.8 (no change)**

and from Equation G.1.9a,

**Existing Equation from F.2 (no change)**

and from Equation G.1.5b,

**Existing Equation from F.1 (no change)**

Now we can solve Equation G.1.10:

**Existing Equation (no change)**

The new pressure due to panel inertia is the larger of the figures determined in Equations G.1.6 and G.1.10. In this example, Equation G.1.10 produced the larger pressure and therefore the new pressure due to panel inertia is 0.273 bar.

**Annex H Alternative Vent Area Methodology**

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

**H.1 Gases.** Figure H.1(a) through Figure H.1(g), which are based on Equations 7.3.3.2 and 7.3.3.3.1, can also be used to determine the vent area. The graphs are permitted to be used as a primary means for determining vent area, or they can be permitted to be used as a backup to verify the vent area calculated by the two equations.

**FIGURE H.1(a) Vent Sizing for Gas; \( P_{\text{stat}} = 0.1 \) bar. [Existing Figure 6.3.3.6(a), 2002 ed. (no change)]**

**FIGURE H.1(b) Vent Sizing for Gas; \( P_{\text{stat}} = 0.2 \) bar. [Existing Figure 6.3.3.6(b), 2002 ed. (no change)]**

**FIGURE H.1(c) Vent Sizing for Gas; \( P_{\text{stat}} = 0.5 \) bar. [Existing Figure 6.3.3.6(c), 2002 ed. (no change)]**
Instructions and an example for using the graphs in Figure H.1(a) through H.1(g) are as follows.

**H.1.1 Factor A.** Select the graph [Figure H.1(a) through Figure H.1(g)] with the appropriate $P_{stat}$ in the caption. Plot a line from the $K_G$ value at the bottom up to the $P_{red}$ line and then read across to the left to determine Factor A.

**H.1.2 Factor B.** If the vessel has an $L/D$ greater than 2, and if $P_{red}$ is less than 2, determine the value of Factor B. Use the graph in Figure H.1(d). Plot a line from the $L/D$ ratio up to the $K_G$ line, and then read across to the left to determine Factor B. If the length-to-diameter is 2 or less, Factor B is equal to 1.0. For values of $L/D$ greater than 5, use Chapter 8.

**H.1.3 Factor C.** Use one of the graphs, Figure H.1(e), Figure H.1(f), or Figure H.1(g). Plot a line from the volume value up to the graph line and then read across to the left to determine Factor C. Using the three factors, determine the vent size as follows:

$$A_V (m^2) = \text{Factor A} \times \text{Factor B} \times \text{Factor C} \quad (H.1.3)$$

**H.1.4 Example Problem.** Determine the vent size needed to protect an enclosure from a gas deflagration when the conditions are as follows:

1. $K_G = 150 \text{ bar-m/sec}$
2. $P_{stat} = 0.2 \text{ bar}$
3. $P_{red} = 0.4 \text{ bar}$
4. $V = 30 \text{ m}^3$
5. $L/D = 4.4$
6. Factor A = 8.65 m
7. Factor B = 2.15 m
8. Factor C = 0.45 m
9. $A_V = \text{Factor A} \times \text{Factor B} \times \text{Factor C} = 8.65 \times 2.15 \times 0.45 = 8.37 \text{ m}^2$

**H.2 Dusts.** Graphs are provided for evaluation of Equation 8.2.2 with corrections for $L/D$ of the enclosure only. The graphs do not address increased turbulence, vent ducts, partial volume, or elevated initial pressures. Instructions and an example for using the graphs in Figure H.2(a) through Figure H.2(k) follow.
**H.2.1 Factor A.** Use one of the graphs in Figure H.2(a) or H.2(b). Plot the line from the $K_s$ at the bottom up to the $P_{stat}$ line and then read across to the left to determine Factor A.

**H.2.2 Factor B.** Use one of the graphs in Figure H.2(c), Figure H.2(d), Figure H.2(e), or Figure H.2(f). Plot a line from the volume at the bottom up to the graph line and then read across to the left to determine Factor B.

**H.2.3 Factor C.** Calculate $\Pi$, the ratio of $P_{red}$ to $P_{max}$. Use one of the graphs in Figure H.2(g), Figure H.2(h), or Figure H.2(i). Plot a line from the $\Pi$ at the bottom up to the graph line and then read across to the left to determine Factor C.
I.1.2 Effect of vent ducts on vent area:


J.9

\[
A_{wp} = (26.5) \times (0.22)^{0.333} \times \sqrt{\frac{(0.22 - 0.011)}{(1 - 0.011)}} = 20 \text{ m}^2
\]

Annex K Bibliography

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

K.1 The following sources are referenced in text by numbers in brackets corresponding to the numbers listed here.


(5) Ibid, p. 50.


(8) Harmanny, A., European Newsletter, pp. 7–10 (April, 1993).


(12) Jacobson, Cooper, and Nagy, op. cit.


(32) Jacobson, Cooper, and Nagy, op. cit.


(91) Howard W. B., private communication.


(94) Bartknecht, W., Dust Explosions, Course, Prevention, Protection, Springer-Verlag, Berlin, Germany, 1989.


(96) ASTM E 1226-88, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts.


(101) Bartknecht, W., “Explosions-Schutz: Grundlagen und Anwendung,” Springer-Verlag, 1993. (German only)


(111) FM Test Report, J1 1X1A8.AF, Class 773, Norwood, MA: 1997.


(114) Task Group report “NFPA 68 Impulse Task Force Report to the Committee on Explosion Protection Systems, September 15, 1999”


Annex I. 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.


L.1.2 Other Publications.

L.1.2.1 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.


L.1.2.2 NACE Publication. National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, TX 77084-4906.


L.1.2.3 Other Publications.


L.2 Informational References. (Reserved)

L.3 References for Extracts in Informational Sections. (Reserved)
**FORM FOR COMMENTS ON NFPA REPORT ON PROPOSALS**  
**2006 FALL REVISION CYCLE**  
**FINAL DATE FOR RECEIPT OF COMMENTS: 5:00 pm EST, 3/3/2006**

For further information on the standards-making process, please contact the Codes and Standards Administration at 617-984-7249

For technical assistance, please call NFPA at 617-770-3000

Please indicate in which format you wish to receive your ROP/ROC  
(electronic paper download)  
(Note: In choosing the download option you intend to view the ROP/ROC from our Website; no copy will be sent to you.)  

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Tel. No.</th>
</tr>
</thead>
</table>

Company ___________________________  
Street Address ____________  
City ____________  
State ____  
Zip ________

Please Indicate Organization Represented (if any)________________________

1. a) NFPA Document Title____________________ NFPA No. & Year __________

   b) Section/Paragraph __________________________

2. Comment on Proposal No. (from ROP): ________________

3. Comment recommends: (check one)  
   new text  
   revised text  
   deleted text

4. Comment (include proposed new or revised wording, or identification of wording to be deleted): (Note: Proposed text should be in legislative format: i.e., use underscore to denote wording to be inserted (inserted wording) and strike-through to denote wording to be deleted (deleted wording).)

   _________________________________________________________________

   __________________________________________________________________

5. Statement of Problem and Substantiation for Comment: (Note: State the problem that will be resolved by your recommendation; give the specific reason for your comment including copies of tests, research papers, fire experience, etc. If more than 200 words, it may be abstracted for publication.) _______________________________________________________________________

   _______________________________________________________________________

   _______________________________________________________________________

6. Copyright Assignment

   a) □ I am the author of the text or other material (such as illustrations, graphs) proposed in this Comment.

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Mail to: Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269  
11/1/2005
Notice of Intent to Make a Motion (NITMAM)

Sequence of Events Leading to Issuance of an NFPA Committee Document

**Step 1 Call for Proposals**

- Proposed new Document or new edition of an existing Document is entered into one of two yearly revision cycles, and a Call for Proposals is published.

**Step 2 Report on Proposals (ROP)**

- Committee meets to act on Proposals, to develop its own Proposals, and to prepare its Report.
- Committee votes by written ballot on Proposals. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Proposals (ROP) is published for public review and comment.

**Step 3 Report on Comments (ROC)**

- Committee meets to act on Public Comments to develop its own Comments, and to prepare its report.
- Committee votes by written ballot on Comments. If two-thirds approve, Reports goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Comments (ROC) is published for public review.

**Step 4 Technical Report Session**

- "Notices of intent to make a motion" are filed, are reviewed, and valid motions are certified for presentation at the Technical Report Session. ("Consent Documents" that have no certified motions bypass the Technical Report Session and proceed to the Standards Council for issuance.)
- NFPA membership meets each June at the Annual Meeting Technical Report Session and acts on Technical Committee Reports (ROP and ROC) for Documents with "certified amending motions."
- Committee(s) vote on any amendments to Report approved at NFPA Annual Membership Meeting.

**Step 5 Standards Council Issuance**

- Notification of intent to file an appeal to the Standards Council on Association action must be filed within 20 days of the NFPA Annual Membership Meeting.
- Standards Council decides, based on all evidence, whether or not to issue Document or to take other action, including hearing any appeals.
The Technical Report Session of the NFPA Annual Meeting

The process of public input and review does not end with the publication of the ROP and ROC. Following the completion of the Proposal and Comment periods, there is yet a further opportunity for debate and discussion through the Technical Report Sessions that take place at the NFPA Annual Meeting.

The Technical Report Session provides an opportunity for the final Technical Committee Report (i.e., the ROP and ROC) on each proposed new or revised code or standard to be presented to the NFPA membership for the debate and consideration of motions to amend the Report. The specific rules for the types of motions that can be made and who can make them are set forth in NFPA’s rules which should always be consulted by those wishing to bring an issue before the membership at a Technical Report Session. The following presents some of the main features of how a Report is handled.

What Amending Motions are Allowed. The Technical Committee Reports contain many Proposals and Comments that the Technical Committee has rejected or revised in whole or in part. Actions of the Technical Committee published in the ROP may also eventually be rejected or revised by the Technical Committee during the development of its ROC. The motions allowed by NFPA rules provide the opportunity to propose amendments to the text of a proposed code or standard based on these published Proposals, Comments and Committee actions. Thus, the list of allowable motions include motions to accept Proposals and Comments in whole or in part as submitted or as modified by a Technical Committee action. Motions are also available to reject an accepted Comment in whole or part. In addition, Motions can be made to return an entire Technical Committee Report or a portion of the Report to the Technical Committee for further study.

The NFPA Annual Meeting, also known as the World SafetyConference and Exposition®, takes place in June of each year. A second Fall membership meeting was discontinued in 2004, so the NFPA Technical Report Session now runs once each year at the Annual Meeting in June.

Who Can Make Amending Motions. Those authorized to make these motions is also regulated by NFPA rules. In many cases, the maker of the motion is limited by NFPA rules to the original submitter of the Proposal or Comment or his or her duly authorized representative. In other cases, such as a Motion to Reject an accepted Comment, or to Return a Technical Committee Report or a portion of a Technical Committee Report for Further Study, anyone can make these motions. For a complete explanation, NFPA rules should be consulted.

The filing of a Notice of Intent to Make a Motion. Before making an allowable motion at a Technical Report Session, the intended maker of the motion must file, in advance of the session, and within the published deadline, a Notice of Intent to Make a Motion. A Motions Committee appointed by the Standards Council then reviews all notices and certifies all amending motions that are proper. The Motions Committee can also, in consultation with the makers of the motions, clarify the intent of the motions and, in certain circumstances, combine motions that are dependent on each other together so that they can be made in one single motion. A Motions Committee report is then made available in advance of the meeting listing all certified motions. Only these Certified Amending Motions, together with certain allowable Follow-Up Motions (that is, motions that have become necessary as a result of previous successful amending motions) will be allowed at the Technical Report Session.

Consent Documents. Often there are codes and standards up for consideration by the membership that will be non-controversial and no proper Notices of Intent to Make a Motion will be filed. These “Consent Documents” will bypass the Technical Report Session and head straight to the Standards Council for issuance. The remaining Documents are then forwarded to the Technical Report Session for consideration of the NFPA membership.

Important Note: The filing of a Notice of Intent to Make a Motion is a new requirement that takes effect beginning with those Documents scheduled for the Fall 2005 revision cycle that reports to the June 2006 Annual Meeting Technical Report Session. The filing of a Notice of Intent to Make a Motion will not, therefore, be required in order to make a motion at the June 2005 Annual Meeting Technical Report Session. For updates on the transition to the new Notice requirement and related new rules effective for the Fall 2005 revision cycle and the June 2006 Annual Meeting, check the NFPA website.
**Action on Motions at the Technical Report Session.** In order to actually make a Certified Amending Motion at the Technical Report Session, the maker of the motion must sign in at least an hour before the session begins. In this way a final list of motions can be set in advance of the session. At the session, each proposed Document up for consideration is presented by a motion to adopt the Technical Committee Report on the Document. Following each such motion, the presiding officer in charge of the session opens the floor to motions on the Document from the final list of Certified Amending Motions followed by any permissible Follow-Up Motions. Debate and voting on each motion proceeds in accordance with NFPA rules. NFPA membership is not required in order to make or speak to a motion, but voting is limited to NFPA members who have joined at least 180 days prior to the session and have registered for the meeting. At the close of debate on each motion, voting takes place, and the motion requires a majority vote to carry. In order to amend a Technical Committee Report, successful amending motions must be confirmed by the responsible Technical Committee, which conducts a written ballot on all successful amending motions following the meeting and prior to the Document being forwarded to the Standards Council for issuance.

**Standards Council Issuance**

One of the primary responsibilities of the NFPA Standards Council, as the overseer of the NFPA codes and standards development process, is to act as the official issuer of all NFPA codes and standards. When it convenes to issue NFPA documents it also hears any appeals related to the Document. Appeals are an important part of assuring that all NFPA rules have been followed and that due process and fairness have been upheld throughout the codes and standards development process. The Council considers appeals both in writing and through the conduct of hearings at which all interested parties can participate. It decides appeals based on the entire record of the process as well as all submissions on the appeal. After deciding all appeals related to a Document before it, the Council, if appropriate, proceeds to issue the Document as an official NFPA code or standard. Subject only to limited review by the NFPA Board of Directors, the Decision of the Standards Council is final, and the new NFPA code or standard becomes effective twenty days after Standards Council issuance. The illustration on page 9 provides an overview of the entire process, which takes approximately two full years to complete.