NFPA®

204

Standard for
Smoke and Heat Venting

2021

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2021 Edition

This edition of NFPA 204, *Standard for Smoke and Heat Venting*, was prepared by the Technical Committee on Smoke Management Systems. It was issued by the Standards Council on October 5, 2020, with an effective date of October 25, 2020, and supersedes all previous editions.

This edition of NFPA 204 was approved as an American National Standard on October 25, 2020.

Origin and Development of NFPA 204

This project was initiated in 1956 when the NFPA Board of Directors referred the subject to the Committee on Building Construction. A tentative guide was submitted to NFPA in 1958. Revised and tentatively adopted in 1959 and again in 1960, the guide was officially adopted in 1961. In 1968, a revised edition was adopted that included a new section, Inspection and Maintenance.

In 1975, a reconfirmation action failed as concerns over use of the guide in conjunction with automatic sprinklered buildings surfaced. Because of this controversy, work on a revision to the guide continued at a slow pace.

The Technical Committee and Subcommittee members agreed that the state of the art had progressed sufficiently to develop improved technology-based criteria for design of venting; therefore, the 1982 edition of the document represented a major advance in engineered smoke and heating venting, although reservations over vent and sprinkler applications still existed.

At the time the guide was formulated, the current venting theory was considered unwieldy for this format; consequently, the more adaptable theory as described herein was adopted.

Appreciation must be extended to Dr. Gunnar Heskestad at the Factory Mutual Research Corporation (now FM Global) for his major contribution to the theory applied in this standard, which is detailed in Annex B.

The 1985 edition again revised Chapter 6 on the subject of venting in sprinklered buildings. Test data from work done at the Illinois Institute of Technology Research, which had been submitted to the committee as part of a public proposal, did not permit consensus to be developed on whether sprinkler control was impaired or enhanced by the presence of automatic roof vents of typical spacing and area. The revised wording of Chapter 6 encouraged the designer to use the available tools and data referenced in the document while the use of automatic venting in sprinklered buildings was under review.

The 1991 edition made minor changes to Chapter 6 to acknowledge that a design basis existed for using sprinklers and automatic heat venting together but that such had not received wide recognition.

The 1998 edition represented a complete revision of the guide. The rewrite deleted the previous tables that listed vent areas and incorporated engineering equations and referenced computer models, such as LAVENT and DETACT, to provide the designer with the necessary tools to develop vent designs based on performance objectives. This rewrite was based extensively on state-of-the-art technology published in the references. In many cases, the authors of these references participated in the task group's rewrite efforts.

For the 2002 edition of NFPA 204, the document was converted from a guide to a standard, thus implementing mandatory requirements and updated language. The document was also updated to meet *Manual of Style for NFPA Technical Committee Documents* requirements.

The 2007 edition included a number of technical changes. New provisions on air entrainment into the fire plume, the effect of wind on the location of air vents, sizing of air paths, air velocity limitations, and plugholing were provided.

In addition, information on the use of vents as air inlets and a better description of the smoke layer interface were added. Revisions with regard to how heat release rates, discharge coefficients, exhaust rates, and the number of exhaust inlets are to be determined were incorporated. Reference to international standards on vents, mechanical smoke extract, and draft curtains, as well as updated annex text on recent research efforts, were provided.

The 2012 edition was updated to include additional requirements and annex material for venting in sprinklered buildings.

The 2015 edition included revised provisions on draft curtains. These requirements created consistency with NFPA 92.

The 2018 edition was updated to include a correction to an Annex A image, the addition of a definition for the term *standard*, and updated references.

For the 2021 edition, all references in Chapters 5 and 6 that permit sprinkler waterflow to activate automatic smoke vents have been removed. In addition, SI unit conversions have been added to Annex C, and references have been updated.

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

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the design, installation, testing, operation, and maintenance of systems for the control, removal, or venting of heat or smoke from fires in buildings.

Contents

NFPA 204

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text should be sent to the technical committee responsible for the source document.

Information on referenced and extracted publications can be found in Chapter 2 and Annex G.

Chapter 1 Administration

1.1 Scope.

1.1.1* This standard shall apply to the design of venting systems for the emergency venting of products of combustion from fires in buildings. The provisions of Chapters 4 through 10 shall apply to the design of venting systems for the emergency venting of products of combustion from fires in nonsprinklered, single-story buildings using both hand calculations and computer-based solution methods as provided in Chapter 9. Chapter 11 shall apply to venting in sprinklered buildings.

1.1.2* This standard shall not specify under which conditions venting is to be provided or required.

1.1.3 Where a conflict exists between a general requirement and a specific requirement, the specific requirement shall be applicable.

1.2 Purpose. (Reserved)

1.3 Application.

1.3.1* This standard shall not apply to ventilation within a building designed for regulation of environmental air for personnel comfort, to regulation of commercial cooking operations, to regulation of odor or humidity in toilet and bathing facilities, to regulation of cooling of production equipment, or to venting for explosion pressure relief.

1.3.2 This standard shall apply to building construction of all types.

1.3.3 This standard shall apply to venting fires in building spaces with ceiling heights that permit the design fire plume and smoke layer to develop.

1.3.4* This standard shall apply to situations in which the hot smoke layer does not enhance the burning rate of the fuel array. Vent designs developed with this standard shall not be valid for those time intervals where smoke layer temperatures exceed 600°C (1112°F).

1.3.5* This standard shall not be valid for fires having heat release rates greater than $Q_{feasible}$ as determined in accordance with the following equation:

[1.3.5]

$$Q_{feasible} = 12{,}000\left(z_s\right)^{5/2}$$

where:

$Q_{feasible}$ = feasible fire heat release rate (kW)

z_s = height of the smoke layer boundary above the fire base (m)

1.3.6* The engineering equations or computer-based models incorporated into this standard shall be used to calculate the time duration that the smoke layer boundary is maintained at or above the design elevation in a curtained area, relative to the design interval time.

1.4 Retroactivity.

1.4.1 The provisions of this standard shall not be required to be applied retroactively.

1.4.2 Where a system is being altered, extended, or renovated, the requirements of this standard shall apply only to the work being undertaken.

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

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

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

Δ 1.6 Units and Formulas.

***N* 1.6.1** The units of measure in this document are presented in the International System (SI) of Units.

***N* 1.6.2** The values presented for measurements in this document are expressed with a degree of precision appropriate for practical application and enforcement. It is not intended that

the application or enforcement of these values be more precise than the precision expressed.

N 1.6.3 The following symbols define the variables in the equations used throughout the body of this standard:

A = area (of burning surface)

A_i = inlet area for fresh air, below design level of smoke layer boundary

A_v = total vent area of all vents in a curtained area

α = thermal diffusivity, $k/\rho c$

α_g = fire growth coefficient

γ = exhaust location factor (dimensionless)

c_p = specific heat

$C_{d,v}$ = vent discharge coefficient

$C_{d,i}$ = inlet discharge coefficient

d = smoke layer depth

d_c = depth of draft curtain

D = base diameter of the fire

g = acceleration of gravity

H = ceiling height above base of fire

h_c = heat of combustion

h_g = heat of gasification

K = fraction of adiabatic temperature rise

k = thermal conductivity

$k_e\beta$ = constant used in Equation E.5.1

$k\rho c$ = thermal inertia

l = thickness

L = mean flame height above the base of the fire

L_f = flame length, measured from leading edge of burning region

L_v = length of vent opening in the longer direction

$\dot{m}$ = mass burning rate

$\dot{m}''$ = mass burning rate per unit area

$\dot{m}''_\infty$ = mass burning rate per unit area for an infinite diameter pool

$\dot{m}_v$ = mass flow rate through vent

$\dot{m}_p$ = mass flow rate in the plume

$\dot{m}_{pL}$ = mass flow rate in the plume at mean flame height (L)

$\dot{q}''_i$ = incident heat flux per unit area

Q = total heat release rate

(continues)

Q'' = total heat release rate per unit floor area

Q_c = convective heat release rate = $\chi_c Q$

$Q_{feasible}$ = feasible fire heat release rate (kW)

r = radius from fire axis

RTI = response time index $\tau u^{1/2}$

τ = time constant of heat-responsive element for convective heating

ρ = density

ρ_o = ambient air density

S = center to center spacing of vents

t = time

t_d = time to detector activation

t_g = growth time of fire

t_{ig} = time to ignition

t_r = design interval time

t_{sa} = time to sprinkler activation

t_{vo} = time to vent opening

ΔT = gas temperature rise (from ambient) at detector site

ΔT_a = adiabatic temperature rise

ΔT_e = temperature rise (from ambient) of heat-responsive element

T = smoke layer temperature (K)

T_o = ambient air temperature

T_{ig} = ignition temperature

T_s = surface temperature

u = gas velocity at detector site

W_{min} = lateral fire spread by radiation

W_s = largest horizontal dimension of fire

W_v = width of vent opening in the shorter direction

V = flame spread velocity

χ_c = convective fraction of total heat release rate (fraction carried as heat in plume above flames) where χ_c is a convective-heat fraction between 0.6 and 0.7

χ_r = radiant fraction of total heat release rate

y = elevation of smoke layer boundary

y_{ceil} = elevation of ceiling

y_{curt} = elevation of bottom of draft curtain

y_{fire} = elevation of the base of the fire above the floor

z_s = height of the smoke layer boundary above base of fire

z_{si} = height of the smoke layer interface above the base of the fire

z_o = height of virtual origin above base of fire (below base of fire, if negative)

Chapter 2 Referenced Publications

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

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

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2019 edition.

NFPA 72®, National Fire Alarm and Signaling Code®, 2019 edition.

2.3 Other Publications.

Δ **2.3.1 FM Publications.** FM Global, 270 Central Avenue, P.O. Box 7500, Johnston, RI 02919.

FM 4430, *Approval Standard for Heat and Smoke Vents,* 2012.

2.3.2 NIST Publications. National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070.

DETACT-QS (DETector ACTuation — Quasi Steady) software.

DETACT-T2 (DETector ACTuation — Time Squared) software.

LAVENT (Link-Actuated VENTs) software.

Δ **2.3.3 UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 793, *Standard for Automatically Operated Roof Vents for Smoke and Heat,* 2008, revised 2016.

2.3.4 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 72®, National Fire Alarm and Signaling Code®, 2019 edition.

NFPA 92, *Standard for Smoke Control Systems,* 2021 edition.

NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities,* 2021 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

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

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Ceiling Jet. A flow of smoke under the ceiling, extending radially from the point of fire plume impingement on the ceiling.

3.3.2 Clear (Air) Layer. The zone within a building containing air that has not been contaminated by the smoke produced from a fire in the building, and that is located between the floor and the smoke layer boundary.

3.3.3* Clear Layer Interface. The boundary between a smoke layer and smoke-free air.

3.3.4 Continuously Growing Fires. Fires that, if unchecked, will continue to grow over the design interval time.

3.3.5 Curtained Area. An area of a building that has its perimeter delineated by draft curtains, full height partitions, exterior walls, or any combinations thereof.

3.3.6 Design Depth of the Smoke Layer. The difference between the height of the ceiling and the minimum height of the smoke layer boundary above the finished floor level that meets design objectives.

3.3.7 Design Fire. As used in this standard, the time-rate heat release history selected as the input for the calculations prescribed herein.

3.3.8 Design Interval Time. The duration of time for which a design objective is to be met, measured from the time of detector activation.

3.3.9* Draft Curtain. A fixed or deployable barrier that protrudes downward from the ceiling to channel, contain, or prevent the migration of smoke.

3.3.10* Effective Ignition. The time at which a *t*-squared design fire starts.

3.3.11 Fuel Array. A collection and arrangement of materials that can support combustion.

3.3.12 Heat Detector. A fire detector that detects either abnormally high temperature or rate-of-temperature rise, or both. [**72,** 2019]

3.3.13 Limited-Growth Fires. Fires that are not expected to grow beyond a predictable maximum heat release rate.

3.3.14 Mechanical Smoke Exhaust System. A dedicated or shared-duty fan system designed and suitable for the removal of heat and smoke.

3.3.15 Plastics.

3.3.16 Plugholing. The condition where air from below the smoke layer is pulled through the smoke layer into the smoke exhaust due to a high exhaust rate. [**92,** 2021]

3.3.17 Smoke. The airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the mass. [**318,** 2021]

3.3.18* Smoke Layer. The accumulated thickness of smoke below a physical or thermal barrier. [**92,** 2021]

3.3.19* Smoke Layer Boundary. An effective boundary centered in a transition zone between the dense portion of the smoke layer and the first indication of smoke.

3.3.20 Vent. As used in this standard, a device or construction that, when activated, is an opening directly to the exterior at or near the roof level of a building that relies on the buoyant forces created by a fire to exhaust smoke and heat.

3.3.21 Vent System. A system used for the removal of smoke and heat from a fire that utilizes manually or automatically operated heat and smoke vents at roof level and that exhausts smoke from a reservoir bounded by exterior walls, interior walls, or draft curtains to achieve the design rate of smoke mass flow through the vents, and that includes a provision for makeup air.

Chapter 4 Fundamentals

4.1* Design Objectives. The design objectives to be achieved over the design interval time by a vent system design during a design fire or design fires shall include the following:

(1) The minimum allowable smoke layer boundary height
(2) The maximum allowable smoke layer temperature

4.2* Design Basis. A design for a given building and its combustible contents and their distribution shall comprise selecting a design basis (limited-growth versus continuous-growth fire) and establishing the following parameters:

(1) Layout of curtained areas
(2) A draft curtain depth
(3) Type detector and specific characteristics
(4) Detector spacing
(5) A design interval time, t_r, following detection for maintaining a clear layer (for continuous-growth fires)
(6) Total vent area per curtained area
(7) Distribution of individual vents
(8) An air inlet area

4.3 Determination of Contents Hazard.

4.3.1 The determination of contents hazard shall take into account the fuel loading and the rate of heat release anticipated from the combustible materials or flammable liquids contained within the building.

4.3.2 The heat release rate of the design fire shall be quantified in accordance with Chapter 8.

4.4 Venting.

4.4.1 Design Objectives. In order to satisfy design objectives, a vent system shall be designed to slow, stop, or reverse the descent of a smoke layer produced by fire in a building, by exhausting smoke to the exterior.

4.4.2* Vent System Designs and Smoke Production.

4.4.2.1 Vent systems shall be designed in accordance with this standard by calculating the vent area required to achieve a mass rate of flow through the vents that equals the mass rate of smoke production.

4.4.2.2 Vent system designs shall limit the descent of the smoke layer to the design elevation of the smoke layer boundary.

4.4.2.3 Alternative vent system designs shall be permitted to be developed in accordance with this standard by calculating the vent area required to achieve a mass rate of flow through the vents that is less than the mass rate of smoke production, such that the descent of the smoke layer is slowed to meet the design objectives.

4.4.3* Vent Mass Flow. Vent system designs shall be computed on the basis that the mass flow rate through a vent is determined primarily by buoyancy pressure.

4.5 Smoke Production.

4.5.1* Base of the Fire. For the purposes of the equations in this standard, the base of the fire shall be at the bottom of the burning zone.

4.5.2* Fire Size. Burning and entrainment rates of possible fire scenarios shall be considered before establishing the conditions of the design fire.

4.5.3* Entrainment.

4.5.3.1 The entrainment formulas specified in this standard shall be applied only to a single fire origin.

4.5.3.2* Virtual Origin. Predicted plume mass flow above the top of the flame shall take into account the virtual origin, z_o, of the fire as determined in 9.2.3.2.

4.6 Vent Flows.

4.6.1* Buoyancy and Vent Flow.

4.6.1.1 Flow through a vent shall be calculated on the basis of buoyancy pressure difference, assuming that no pressure is contributed by the expansion of gases.

4.6.1.2* Beneficial wind effects shall not be taken into account when calculating vent areas.

4.6.1.3 Air inlets and vents shall be located to avoid adverse wind effects.

4.6.2* Inlet Air.

4.6.2.1 Predicted vent flows shall take into account the area of inlet air openings.

4.6.2.2 Inlet air shall be introduced below the smoke layer boundary.

4.6.2.3 Wall and ceiling leakage above the smoke layer boundary in the curtained area shall not be included in vent flow calculations. *(See Chapter 6 for information on air inlets.)*

Chapter 5 Vents

Δ **5.1* Listed Vents.** Normally closed vents shall be listed and labeled in accordance with UL 793, *Standard for Automatically Operated Roof Vents for Smoke and Heat*; FM 4430, *Approval Standard for Heat and Smoke Vents*; or other approved, nationally recognized standards.

5.2 Vent Design Constraints.

5.2.1* The means of vent actuation shall be selected with regard to the full range of expected ambient conditions.

Δ **5.2.2*** Vents shall consist of a single unit (vent), in which the entire unit (vent) opens fully with the activation of a single detector, or multiple units (vents) in rows or arrays (ganged vents) in which the units (vents) open simultaneously with the activation of a single heat detector, a fusible link, a smoke detector, or other means of detection to satisfy the venting requirements for a specific hazard.

5.2.3* Where the hazard is localized, vents shall open directly above such hazard.

5.2.4 Vents, and their supporting structure and means of actuation, shall be designed so that they can be inspected visually after installation.

5.3 Methods of Operation.

5.3.1* Normally, closed vents shall be designed to open automatically in a fire to meet design objectives or to comply with performance objectives or requirements.

5.3.2* Vents, other than thermoplastic drop-out vents, shall be designed to fail in the open position such that failure of a vent-operating component results in an open vent.

5.3.3 Vents shall be opened using gravity or other approved opening force.

5.3.4 The opening mechanism shall not be prevented from opening the vent by snow, roof debris, or internal projections.

5.3.5* All vents shall be designed to open by manual means. Means of opening shall be either internal or external, as approved by the authority having jurisdiction.

5.3.6 Vents designed for remote operation shall utilize approved fusible links and shall also be capable of actuation by an electric power source, heat-responsive device, or other approved means.

Δ **5.3.7** Vents designed to activate by smoke detection or other activation methods external to the vent shall be approved in accordance with Section 5.1.

5.4 Dimensions and Spacing of Vents.

5.4.1 The dimensions and spacing of vents shall meet the requirements of 5.4.1.1 and 5.4.1.2 to avoid plugholing.

5.4.1.1 The area of a unit vent shall not exceed $2d^2$, where d is the design depth of the smoke layer.

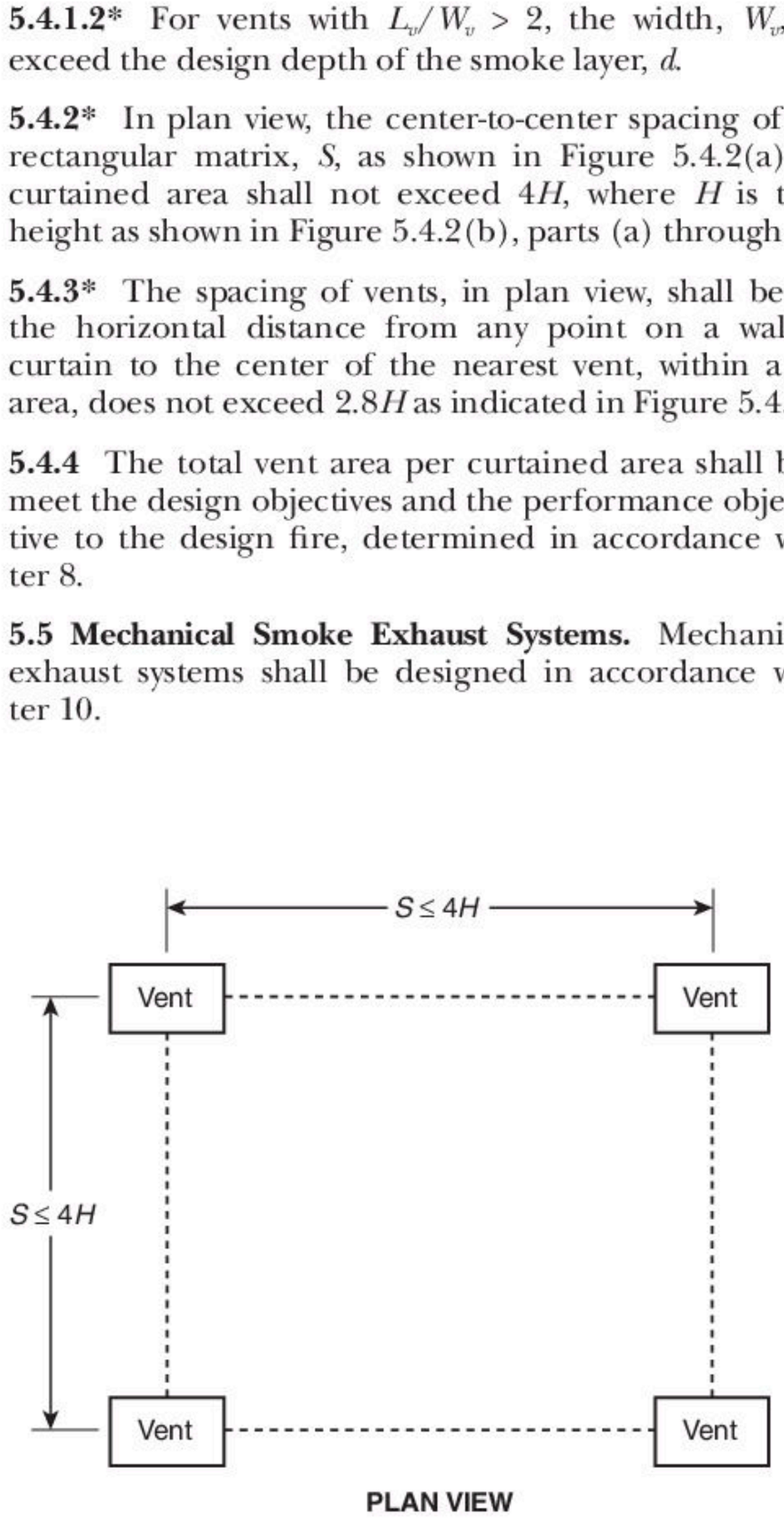
5.4.1.2* For vents with $L_v/W_v > 2$, the width, W_v, shall not exceed the design depth of the smoke layer, d.

5.4.2* In plan view, the center-to-center spacing of vents in a rectangular matrix, S, as shown in Figure 5.4.2(a), within a curtained area shall not exceed $4H$, where H is the ceiling height as shown in Figure 5.4.2(b), parts (a) through (d).

5.4.3* The spacing of vents, in plan view, shall be such that the horizontal distance from any point on a wall or draft curtain to the center of the nearest vent, within a curtained area, does not exceed $2.8H$ as indicated in Figure 5.4.3.

5.4.4 The total vent area per curtained area shall be sized to meet the design objectives and the performance objectives relative to the design fire, determined in accordance with Chapter 8.

5.5 Mechanical Smoke Exhaust Systems. Mechanical smoke exhaust systems shall be designed in accordance with Chapter 10.



Δ **FIGURE 5.4.2(a) Vent Spacing in Rectangular Matrix (plan view).**