NFPA®

92

Standard for Smoke Control Systems

2021

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Smoke Control Systems

2021 Edition

This edition of NFPA 92, *Standard for Smoke Control Systems,* 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 document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See "Codes & Standards" at www.nfpa.org for more information.

This edition of NFPA 92 was approved as an American National Standard on October 25, 2020.

Origin and Development of NFPA 92

The NFPA Standards Council established the Technical Committee on Smoke Management Systems in 1985 and charged it with addressing the need for guidelines and materials on smoke management in buildings. The Committee's first document, NFPA 92A, *Recommended Practice for Smoke-Control Systems*, was published in 1988 and addressed smoke control utilizing barriers, airflows, and pressure differentials so as to confine the smoke of a fire to the zone of fire origin to maintain a tenable environment in other zones. The complex problem of maintaining tenable conditions within large zones of fire origin such as atria and shopping malls represented a more difficult issue in terms of the physics involved and thus was reserved for another document, NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas*, first published in 1991.

Between 1991 and 2009, NFPA 92A and NFPA 92B were separately maintained. In 2006, NFPA 92A was rewritten as a standard with mandatory provisions regarding design, installation, and testing of smoke-control systems and was renamed *Smoke-Control Systems Utilizing Barriers and Pressure Differences.* In 2005 and 2006, both documents were reorganized to comply with the *Manual of Style for NFPA Technical Committee Documents.* Both documents eventually contained many of the same requirements for design objectives, activation, and installation.

In the Annual 2011 revision cycle, NFPA 92A and NFPA 92B were withdrawn and replaced with a new document, NFPA 92, *Standard for Smoke Control Systems.* NFPA 92 was created using requirements from both of the original documents, removing duplicate provisions and making numerous editorial changes. The new document used the term *smoke control systems* to address both containment and management systems. With the consolidation effort, the new standard covered the following topics: design of smoke management systems and calculations, design of smoke containment systems, design of stairwell pressurization systems, and testing requirements.

The 2015 edition included editorial revisions and new requirements addressing draft curtain materials.

The 2018 edition added requirements regarding the verification of dedicated smoke control equipment through use of the weekly self-test function. A new annex on tenability was added to provide guidelines for designers to assess tenable conditions in spaces protected by smoke control systems, in connected spaces, and of means of egress elements during the operation of a smoke control system.

The 2021 edition of NFPA 92 has revised the requirements for the design number in Chapter 4 and the number of doors required to be open during testing in Chapter 8 for smoke containment and stairwell pressurization systems to only doors that are automatically opened during the smoke control strategy. New Annex A material has been added to provide guidance on systems with makeup air velocities exceeding 200 ft/min (1.02 m/s). Equations and values throughout the document have been updated to provide both I-P and SI values.

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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.

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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 shall 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 N.

Chapter 1 Administration

1.1* Scope. This standard shall apply to the design, installation, acceptance testing, operation, and ongoing periodic testing of smoke control systems.

1.2 Purpose.

1.2.1 The purpose of this standard shall be to establish requirements for smoke control systems to accomplish one or more of the following:

(1) Inhibit smoke from entering stairwells, means of egress, smoke refuge areas, elevator shafts, or similar areas
(2) Maintain a tenable environment in smoke refuge areas and means of egress during the time required for evacuation
(3) Inhibit the migration of smoke from the smoke zone
(4) Provide conditions outside the smoke zone that enable emergency response personnel to conduct search and rescue operations and to locate and control the fire
(5) Contribute to the protection of life and to the reduction of property loss

1.2.2 The requirements specifying the conditions under which a smoke control system shall be provided are addressed by other codes and standards.

1.2.3 Specific design objectives are established in other codes and standards.

1.3 Retroactivity.

1.3.1 Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

1.3.2 In those cases where the authority having jurisdiction determines that the existing situation involves a distinct hazard to life or property, retroactive application of the provisions of this document shall be permitted.

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

1.3.4 Verification is required to ensure that new or modified systems do not adversely affect the performance of existing smoke control systems.

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 Units and Formulas. (Reserved)

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 70®, National Electrical Code®, 2020 edition.

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

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 2021 edition.

NFPA *101®, Life Safety Code®*, 2021 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 2019 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2021 edition.

2.3 Other Publications.

Δ 2.3.1 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 555, *Standard for Fire Dampers*, 2006, revised 2016.

UL 555S, *Standard for Smoke Dampers*, 2014.

UL 864, *Standard for Control Units and Accessories for Fire Alarm Systems*, 2018.

2.3.2 Other Publications.

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

Δ 2.4 References for Extracts in Mandatory Sections.

NFPA 1, *Fire Code*, 2021 edition.

NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems*, 2021 edition.

NFPA *101®*, *Life Safety Code®*, 2021 edition.

NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities*, 2022 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 Atrium. A large-volume space created by a floor opening or series of floor openings connecting two or more stories that is covered at the top of the series of openings and is used for purposes other than an enclosed stairway; an elevator hoistway; an escalator opening; or as a utility shaft used for plumbing, electrical, air-conditioning, or communications facilities. [***101***, 2021]

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

3.3.3* Design Pressure Difference. The desired pressure difference between the protected space and an adjacent space measured at the boundary of the protected space under a specified set of conditions with the smoke control system operating.

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

3.3.5 Fire.

3.3.5.1 ***Fuel-Limited Fire.*** A fire that has a heat release rate that is controlled by the material burning.

3.3.5.2 ***Steady Fire.*** A fire that has a constant heat release rate.

3.3.5.3 ***t-squared (t^2) Fire.*** A fire that has a heat release rate that grows proportionally to the square of time from ignition. *[See Annex B for further information on t-squared (t^2) profile fires.]*

3.3.5.4 ***Unsteady Fire.*** A fire that has a heat release rate that varies with respect to time.

3.3.5.5 ***Ventilation Limited Fire.*** A fire where every object in the fire compartment is fully involved in fire and the heat release rate depends on the airflow through the openings to the fire compartment.

3.3.6* Fire Fighters' Smoke Control Station (FSCS). A system that provides graphical monitoring and manual overriding capability over smoke control systems and equipment at designated location(s) within the building for use by the fire department.

3.3.7 Growth Time (t_g). The time interval from the time of effective ignition until the heat release rate of the fire is 1000 Btu/sec (1055 kW).

3.3.8 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.

3.3.9* Plume. A column of smoke that rises above a fire.

3.3.9.1* ***Axisymmetric Plume.*** A plume that rises above a fire, does not come into contact with walls or other obstacles, and is not disrupted or deflected by airflow.

3.3.9.2* ***Balcony Spill Plume.*** A smoke plume that originates from a compartment fire, flows out the doorway, flows under a balcony, and flows upward after passing the balcony edge.

3.3.9.3* ***Window Plume.*** A plume that flows out of an opening to a room or other compartment that is involved in a ventilation limited fire.

3.3.10 Pressurized Stairwells. A type of containment smoke control system in which stair shafts are mechanically pressurized, with respect to the fire area, with outdoor air to keep smoke from contaminating them during a fire incident.

3.3.11 Registered Design Professional (RDP). An individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of the jurisdiction in which the project is to be constructed, or other professional with qualifications or credentials acceptable to the jurisdiction in which the project is to be constructed. [**3,** 2021]

Δ **3.3.12 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,** 2022]

3.3.12.1* ***First Indication of Smoke.*** The boundary between the transition zone and the smoke free air.

3.3.13* Smoke Barrier. For the purposes of this standard, a continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke in conjunction with a smoke control system.

3.3.14* Smoke Containment. A smoke control method that uses mechanical equipment to produce pressure differences across smoke barriers.

3.3.15 Smoke Control Mode. A predefined operational configuration of a system or device for the purpose of smoke control.

3.3.16 Smoke Damper. A device within the air distribution system to control the movement of smoke.

3.3.17* Smoke Layer. The accumulated thickness of smoke below a physical or thermal barrier.

3.3.18* Smoke Layer Interface. The theoretical boundary between a smoke layer and the smoke-free air.

3.3.19 Smoke Management. A smoke control method that utilizes natural or mechanical systems to maintain a tenable environment in the means of egress from a large-volume space or to control and reduce the migration of smoke between the fire area and communicating spaces.

3.3.20 Smoke Refuge Area. An area of the building separated from other spaces by fire-resistance-rated smoke barriers in which a tenable environment is maintained for the period of time that such areas might need to be occupied at the time of fire.

3.3.21 Space.

3.3.21.1* ***Communicating Space.*** A space within a building that has an open pathway to a large-volume space such that smoke from a fire either in the communicating space or in a large-volume space can move from one to another without restriction.

3.3.21.2 ***Large-Volume Space.*** An uncompartmented space, generally two or more stories in height, within which smoke from a fire either in the space or in a communicating space can move and accumulate without restriction.

3.3.21.3 ***Separated Spaces.*** Spaces within a building that are isolated from large-volume spaces by smoke barriers.

3.3.22 Stack Effect. The vertical airflow within buildings caused by the temperature-created density differences between the building interior and exterior or between two interior spaces.

3.3.23 System.

3.3.23.1 ***Compensated System.*** A system that adjusts for changing conditions either by modulating supply airflows or by relieving excess pressure.

3.3.23.2* ***Dedicated Smoke Control System.*** Smoke control systems and components that are installed for the sole purpose of providing smoke control and that upon activation of the systems operate specifically to perform the smoke control function.

3.3.23.3* ***Nondedicated Smoke Control Systems.*** A smoke-control system that shares components with some other system(s), such as the building HVAC system, which changes its mode of operation to achieve the smoke-control objective. [**1,** 2021]

3.3.23.4 ***Pressurization System.***

3.3.23.4.1 ***Multiple-Injection Pressurization System.*** A type of smoke control system that has pressurization air supplied from multiple locations.

3.3.23.4.2 ***Single-Injection Pressurization System.*** A type of containment smoke control system that has pressurization air supplied from only one location.

3.3.23.5 ***Smoke Control System.*** An engineered system that includes all methods that can be used singly or in combination to modify smoke movement.

3.3.23.6* ***Smoke Exhaust System.*** A mechanical or gravity system intended to move smoke from the smoke zone to the exterior of the building, including smoke removal, purging, and venting systems, as well as the function of exhaust fans utilized to reduce the pressure in a smoke zone.

3.3.23.7 ***Zoned Smoke Control System.*** A smoke control system that includes a combination of smoke containment and smoke management methods for smoke exhaust for the smoke zone and pressurization for all contiguous smoke control zones.

3.3.24* Tenable Environment. An environment in which smoke and heat are limited or otherwise restricted to maintain the impact on occupants to a level that is not life threatening.

3.3.25 Zone.

3.3.25.1 ***Smoke Control Zone.*** A space within a building enclosed by smoke barriers, including the top and bottom, that is part of a zoned smoke control system.

3.3.25.2 ***Smoke Zone.*** The smoke control zone in which the fire is located.

3.3.25.3* ***Transition Zone.*** The layer between the smoke layer interface and the first indication of smoke in which the smoke layer temperature decreases to ambient.

Chapter 4 Design Fundamentals

4.1 Design Objectives.

4.1.1* The methods for accomplishing smoke control shall include one or more of the following:

(1) The containment of smoke to the zone of origin by establishment and maintenance of pressure differences across smoke zone boundaries
(2) The management of smoke within a large-volume space and any unseparated spaces that communicate with the large-volume space

4.1.2* The specific objectives to be achieved over the design interval time shall include one or more of the following:

(1) Containing the smoke to the zone of fire origin
(2) Maintaining a tenable environment within exit stairwells for the time necessary to allow occupants to exit the building
(3) Maintaining a tenable environment within all exit access and smoke refuge area access paths for the time necessary to allow occupants to reach an exit or smoke refuge area
(4) Maintaining the smoke layer interface to a predetermined elevation in large volume spaces

4.2 Design Basis.

4.2.1* Smoke Containment Systems. A smoke control system in a given building shall be designed to contain smoke to a given zone or keep smoke from entering another zone.

4.2.1.1 The design pressure difference shall be based on the following:

(1) Whether the smoke zone is sprinklered
(2) The height of the ceiling in the smoke zone
(3) Maximum and minimum pressure differentials

4.2.2 Smoke Management Systems. The design basis for smoke management within a given large-volume space and any unseparated spaces shall include the determination of the following parameters:

(1) The design basis fires used to calculate smoke production (i.e., type, location, and quantity of fuel for each design basis fire, extent of coverage and reliability of automatic suppression, and extent and type of ventilation)
(2) Height, cross-sectional area, and plan area of the large-volume space to be protected
(3) Height, cross-sectional area, and plan area of each unseparated space that communicates with the large-volume space
(4) Type and location of occupancies within and communicating with the large-volume space
(5) Barriers, if any, that separate the communicating space from the large-volume space
(6) Egress routes from the large-volume space and any communicating space
(7) Any areas of refuge

4.2.3 Temperature Ratings.

4.2.3.1 The temperature ratings for the equipment used for smoke control systems shall be based on the expected temperature experienced by the equipment while the equipment is intended to be operational.

4.2.3.2 Temperature ratings shall be based on the following:

(1) Proximity to the fire
(2) Effects of dilution of the smoke and hot gases by entrained air

4.3 Design Approaches.

4.3.1 Smoke Containment Systems. The design approach for smoke containment systems shall be one of or a combination of the following:

(1) Stairwell pressurization
(2) Zoned smoke control
(3) Elevator pressurization
(4) Vestibule pressurization
(5) Smoke refuge area pressurization

4.3.2* Smoke Management Systems. The design approach for smoke management within large-volume spaces and communicating spaces shall be one of or a combination of the following:

(1) Natural smoke filling of an unoccupied volume or smoke reservoir and calculating or modeling of smoke layer descent to determine whether the smoke layer interface will reach a height at which occupants will be exposed to smoke prior to their ability to egress from the space
(2)* Mechanical smoke exhaust capacity to remove smoke from a space to maintain the smoke layer interface at a predefined height in the space for the design interval time
(3) Mechanical smoke exhaust capacity to remove smoke from a space to slow the rate of smoke layer descent for a period that allows occupants to safely egress from the space
(4) Gravity smoke venting to maintain the smoke layer interface at a predefined height in the space for the design interval time
(5) Gravity smoke venting to slow the rate of smoke layer descent for a period that allows occupants to egress from the space
(6)* Opposed airflow to prevent smoke movement between a large-volume space and a communicating space

4.4 Design Criteria.

4.4.1* Weather Data. Designs shall incorporate the effect of outdoor temperature and wind on the performance of systems.

4.4.2 Pressure Differences. The maximum and minimum allowable pressure differences across the boundaries of smoke control zones shall be established for containment systems.

4.4.2.1 Pressure Differences Across Spaces.

4.4.2.1.1* Except as specified by 4.4.2.1.2, the pressure differences in Table 4.4.2.1.1 shall be used for designs that are based on maintaining minimum pressure differences between specified spaces.

Δ Table 4.4.2.1.1 Minimum Design Pressure Differences Across Smoke Barriers

Building Type	Ceiling Height [ft (m)]	Design Pressure Difference* [in. w.g. (Pa)]
AS	Any	0.05 (12.5)
NS	9 (2.7)	0.10 (25)
NS	15 (4.6)	0.14 (35)
NS	21 (6.4)	0.18 (45)

AS: Sprinklered. NS: Nonsprinklered.
Notes:
(1) The table presents minimum design pressure differences developed for a gas temperature of 1700°F (927°C) next to the smoke barrier.
(2) For design purposes, a smoke control system must maintain these minimum pressure differences under specified design conditions of stack effect or wind.
*For zoned smoke control systems, the pressure difference is required to be measured between the smoke zone and adjacent spaces while the affected areas are in the smoke control mode.

4.4.2.1.2 Where the system designer has determined that a higher minimum pressure difference is necessary to achieve the smoke control system objectives, the higher minimum pressure difference shall be used.

4.4.2.1.3 The minimum allowable pressure difference shall restrict smoke leakage during building evacuation to a level that maintains a tenable environment in areas outside the smoke zone.

4.4.2.1.4 The minimum pressure difference for smoke control systems shall be established at a level that is high enough that it will not be overcome by the forces of wind, stack effect, or buoyancy of hot smoke.

4.4.2.1.5* The calculations shall take into account the design number of doors to be opened simultaneously via automatic opening devices controlled open as part of the smoke control strategy.

4.4.2.2* Pressure Differences Across Doors. The pressure differences across doors shall not cause the maximum force permitted to begin opening the door to exceed the value stipulated in NFPA *101* or state or local codes and regulations.

4.4.3 Fire Location. The source of the smoke from the design basis fires shall consider fire locations within the large-volume space and within unseparated communicating spaces.

4.4.4 Smoke Movement and Airflow.

4.4.4.1* Makeup Air. Makeup air for smoke management systems shall be provided by fans or by openings to the outside.

4.4.4.1.1 The supply points for the makeup air shall be located beneath the smoke layer interface.

4.4.4.1.2 Mechanical makeup air shall be less than the mass flow rate of the mechanical smoke exhaust.

4.4.4.1.3 The makeup air shall not cause door-opening force to exceed allowable limits.

4.4.4.1.4* The makeup air velocity shall not exceed 200 ft/min (1.02 m/sec) where the makeup air could come into contact with the plume unless a higher makeup air velocity is supported by engineering analysis.

4.4.4.2 Communicating Spaces.

4.4.4.2.1 Managing Smoke Spread to Communicating Spaces.

4.4.4.2.1.1 Managing smoke spread to communicating spaces shall be accomplished by one of the following methods:

(1) Maintaining the smoke layer interface at a level higher than that of the highest opening to the communicating space
(2) Providing a smoke barrier to limit smoke spread into the communicating space
(3) Providing an opposed airflow through the opening to prohibit smoke spread into the communicating space

4.4.4.2.1.2 When smoke barriers are used to limit smoke spread into the communicating space, engineering calculations shall be provided to verify whether a pressure difference applied across the smoke barrier will be needed to prevent smoke migration.

4.4.4.2.1.3 When the airflow method is used to prevent smoke movement from the large-volume space into communicating spaces for large openings, the flow shall be nearly perpendicular to the plane of the opening.

4.4.4.2.2* Managing Smoke from Communicating Spaces.

4.4.4.2.2.1 When communicating spaces are designed to allow the smoke to spill into the large-volume space, the smoke spilling into the large-volume space shall be handled by the smoke management system to maintain the design smoke layer interface height.

4.4.4.2.2.2 When the smoke control systems are designed to use airflow to prevent the movement of smoke into the large-volume space, sufficient exhaust from the communicating space shall be provided to establish a minimum flow between the communicating space and the large-volume space. *(See 5.10.1.)*

4.4.4.3* Openings and Leakage Areas. Designs shall incorporate the effect of openings and leakage areas in smoke barriers on the performance of smoke control systems.

4.4.4.4 Special Considerations Related to Natural Venting. Smoke management system designs that use a mix of natural and mechanical ventilation shall have supporting engineering analysis or physical (scale) modeling to verify the design functions as intended.

4.4.5* Gaseous Fire Suppression Systems. The operation of the smoke control system shall not compromise the performance of gaseous agent fire protection systems.

4.5* System Operation.

4.5.1 Limitations.

4.5.1.1* Tenability. Where the design of the smoke control system is based on the potential for occupants being exposed to smoke, the tenability conditions shall be assessed.

4.5.1.2* Egress Analysis. Where the design of the smoke control system is based on occupants exiting a space before being exposed to smoke or before tenability thresholds are reached, there shall be sufficient time for the movement of the occupant as determined by a timed egress analysis.

4.5.1.3* Minimum Design Smoke Layer Depth. The minimum design depth of the smoke layer for a smoke management system shall be either of the following:

(1) Twenty percent of the floor-to-ceiling height
(2) Based on an engineering analysis

4.5.2 Activation. Activation of smoke control systems shall be accomplished by an approved automatic means.

4.5.3 System Startup.

4.5.3.1 The smoke control system shall achieve full operation prior to conditions in the space reaching the design smoke conditions.

4.5.3.2 The determination of the time it takes for the system to become operational shall consider the following events (as appropriate to the specific design objectives):

(1) Time for detection of the fire incident
(2) HVAC system activation time, including shutdown and startup of air-handling equipment, opening and closing of dampers, and opening and closing of natural ventilation devices

4.5.4 Duration.

4.5.4.1 When the design of the smoke management system is based on occupants exiting a space before being exposed to smoke or before tenability thresholds are reached, the following shall be met:

(1) A timed egress analysis shall be conducted.
(2) The system shall remain operational for the duration required.

4.5.4.2 Smoke management systems designed to maintain tenable conditions shall not be required to prevent the descent of a smoke layer in spaces where tenable conditions are demonstrated.

4.6 Stairwell Pressurization Systems.

Δ 4.6.1* General.

N **4.6.1.1** Where stairwell pressurization systems are provided, the pressure difference between the smoke zone and the stairwell, with zero and the design number of doors open, shall be as follows:

(1) Not less than the minimum pressure difference specified in 4.4.2
(2) Not greater than the maximum pressure difference specified in 4.4.2.2

N **4.6.1.2** Design pressures shall be achieved with all doors closed, with the exception of doors to be opened simultaneously via automatic opening devices controlled open as part of the smoke control strategy.

4.6.2* Location of Supply Air Source. To limit smoke from entering the stairwell through the supply air intake, the supply air intake shall be separated from all building exhausts, outlets from smoke shafts and roof smoke and heat vents, open vents from elevator shafts, and other building openings that might expel smoke from the building in a fire.

4.6.3 Supply Air Fans.

4.6.3.1* Propeller Fans. Roof or exterior wall-mounted propeller fans shall be permitted to be used in single-injection systems, provided that wind shields are provided for the fan.

4.6.3.2 Other Types of Fans. Centrifugal or in-line axial fans shall be permitted to be used in single- or multiple-injection systems.

4.6.4* Single- and Multiple-Injection Systems.

4.6.4.1 Single-Injection Systems.

4.6.4.1.1* The air injection point for a single-injection system shall be permitted to be located at any location within the stairwell.

4.6.4.1.2* Design analysis shall be performed for all single-bottom-injection systems and for all other single-injection systems for stairwells in excess of 100 ft (30.5 m) in height.

4.6.4.2* Multiple-Injection Systems. For system designs with injection points more than three stories apart, a design analysis shall be performed to ensure that loss of pressurization air through open doors does not lead to stairwell pressurization below the minimum design pressure.

4.7* Elevator Pressurization Systems. Where elevator pressurization is provided, elevator hoistways shall be pressurized to maintain a minimum positive pressure in accordance with 4.4.2. The minimum pressure shall be maintained with the elevator car at the recall floor and elevator doors and the hoistway vents open.

4.8* Zoned Smoke Control.

4.8.1 Smoke Control Zones.

4.8.1.1 When zoned smoke control is to be used to provide containment, the building shall be divided into smoke control zones, with each zone separated from the others by smoke barriers.

4.8.1.1.1* A smoke control zone shall be permitted to consist of one or more floors.

4.8.1.1.2 A floor shall be permitted to consist of one or more smoke control zones.

4.8.1.2 The zoned smoke control system shall be designed such that when zoned smoke control is active, the pressure differences between the adjacent non–smoke zones and the smoke zone meet or exceed the minimum design pressure differences given in 4.4.2, and at locations with doors, the pressure difference shall not exceed the values given in 4.4.2.2.

4.8.2 Smoke Zone Exhaust.

4.8.2.1 The smoke zone exhaust shall discharge to the outside of the building.

4.8.2.2 The smoke zone exhaust shall be permitted to be either mechanical or natural ventilation.

4.8.3* Smoke Refuge Areas.

4.8.3.1 A non–smoke zone of a zoned smoke control system shall be permitted to be used as an area intended to protect

occupants for the period of time needed for evacuation or to provide a smoke refuge area.

4.8.3.2 For areas of refuge adjacent to stairwells or elevators, provisions shall be made to prevent the loss of pressure or excessive pressures due to the interaction between the smoke refuge area smoke control and the shaft smoke control.

4.9* Combination of Systems. Smoke control systems shall be designed such that where multiple smoke control systems operate simultaneously, each system will meet its individual design objectives.

4.10 Vestibules.

4.10.1* Vestibules shall not be required but shall be permitted as part of the building smoke control system.

4.10.2* Where vestibules are provided, either pressurized or nonpressurized vestibules shall be permitted.

Δ **4.11 Doors.** Doors located in smoke barriers shall be either self-closing or arranged to close automatically upon activation of the smoke control system.

Chapter 5 Smoke Management Calculation Procedures

5.1* Introduction. The method of analysis used for design of a smoke management system shall be one of the methods given in 5.1.1 through 5.1.3.

5.1.1* Algebraic Equations. The algebraic equations in Chapter 5 shall be permitted to be used to provide a means of calculating individual factors that collectively can be used to establish the design requirements of a smoke management system.

5.1.2* Scale Modeling.

5.1.2.1 In a scale model, the model shall be proportional in all dimensions to the actual building.

5.1.2.2 The size of the fire and the interpretation of the results shall be governed by the scaling laws, as given in Section 5.11.

5.1.3* Compartment Fire Models. Compartment fire models shall be zone fire models or computational fluid dynamics (CFD) models. *(For information about zone fire models and CFD models, see Annex C.)*

5.2 Design Fire.

5.2.1* General. This section presents the equations that shall be used to calculate the heat release rates for design fires. *(For information about the heat release rates of fires, see Annex B.)*

5.2.2 Design Fire Types. Design fires shall be one of the following:

(1) Steady fire with a constant heat release rate
(2) Unsteady fire with a heat release rate that varies with time

5.2.3 Steady Design Fires.

5.2.3.1 The heat release rate of steady design fires shall be based on available or developed test data.

Δ **5.2.3.2** Where the available fuel mass is used to limit the duration of a steady design fire, the duration of the fire shall be calculated using Equation 5.2.3.2 as follows:

[5.2.3.2]

$$\Delta t = \frac{mH_c}{Q}$$

where:
Δt = duration of fire (sec)
m = total fuel mass consumed (lb or kg)
H_c = heat of combustion of fuel (Btu/lb or kJ/kg)
Q = heat release rate (Btu/sec or kW)

5.2.4 Unsteady Design Fires. Unsteady design fires shall include a growth phase and shall include a steady phase or a decay phase, as depicted in Figure 5.2.4(a) and Figure 5.2.4(b), where steady or decay phases are justified based on test data, fuel configuration, or proposed protection systems.

5.2.4.1 Growth Phase. The growth phase of the fire shall be described using one of the following:

(1) Fire test data
(2) *t*-squared fire growth model
(3) Other fire growth models acceptable to the authority having jurisdiction

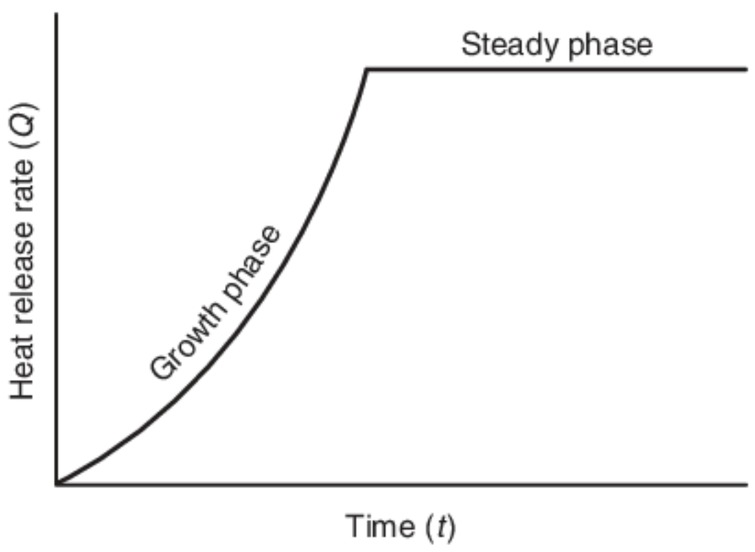

FIGURE 5.2.4(a) Unsteady Design Fire with Steady Phase.

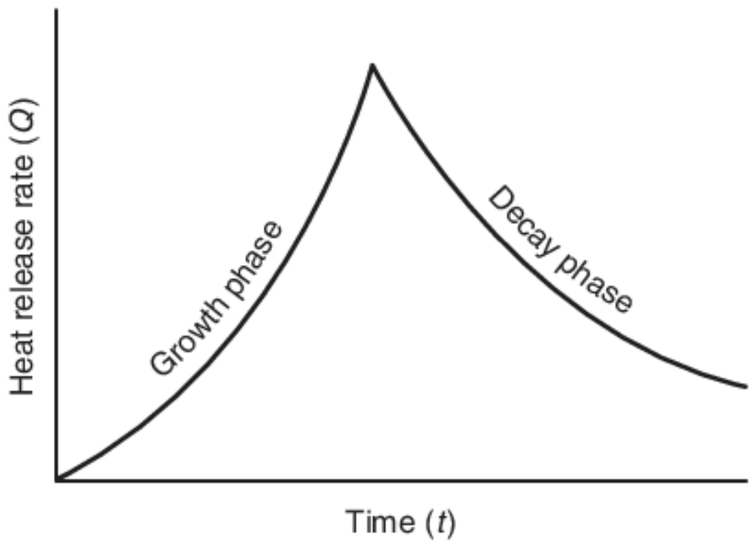

FIGURE 5.2.4(b) Unsteady Design Fire with Decay Phase.