

Second Revision No. 5-NFPA 92-2017 [Global Comment]

New Annex After Annex N

The Technical Committee would like to add an entire new annex. Please see the attached word document for proposed annex.

Supplemental Information

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
ANNEX_M_NFPA_92_Tenability_Section_Final.docx	This is the new Annex that the committee would like to add to the standard.	

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Submittal Date: Tue Feb 07 14:47:09 EST 2017

Committee Statement

Committee Statement: The Technical Committee added a new annex to the document to provide needed guidance on tenability criteria as it relates to smoke management systems. Section 4.5.1.1 recognized tenability smoke control systems since the 2005 edition of NFPA 92 and until now, no guidance has been provided on acceptable tenability criteria.

Response Message:

See page 11 for Attachment

Second Revision No. 3-NFPA 92-2017 [Section No. A.4.5.1.1]

A.4.5.1.1



~~Tenability analysis is outside the scope of this document~~Suggested tenability criteria are discussed in Annex M. However, other references are available that present analytical methods for use in tenability analysis. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* describes a process of establishing tenability limits. Additional guidance is given in ~~NFPA 130 and in the~~ ASHRAE/ICC/NFPA/SFPE Handbook of Smoke Control Engineering.

The SFPE guide references D. A. Purser, "Combustion Toxicity," Chapter 62, of the *SFPE Handbook of Fire Protection Engineering*, which describes a fractional effective dose (FED) calculation approach, which is also contained in NFPA 269. The FED addresses the effects of carbon monoxide, hydrogen cyanide, carbon dioxide, hydrogen chloride, hydrogen bromide, and anoxia. It is possible to use the test data, combined with laboratory experience, to estimate the FED value that leads to the survival of virtually all people. This value is about 0.8.

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Committee Statement

Committee Statement: SFPE Document title was edited to provide correct title of document

ASHRAE Document title was edited to be consistent with way document is referenced throughout the standard

Reference to new Annex M was added to help guide users in recommended tenability criteria.
Reference to NFPA 130 was removed because the new annex M is very similar to the NFPA 130 material and a user would not have to go to both places for the same information.

Response Message:

Public Comment No. 2-NFPA 92-2016 [Section No. A.4.5.1.1]

Second Revision No. 6-NFPA 92-2017 [Section No. M.1.1]

N.1.1 NFPA Publications.

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2016 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*, 2016 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, 2016 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 2015~~2018~~ edition.

NFPA 101®, *Life Safety Code*®, 2018 edition.

~~NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*, 2017 edition.~~

NFPA 204, *Standard for Smoke and Heat Venting*, 2015~~2018~~ edition.

NFPA 269, *Standard Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling*, 2017 edition.

NFPA 909, *Code for the Protection of Cultural Resource Properties — Museums, Libraries, and Places of Worship*, 2017 edition.

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

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Committee Statement

Committee Statement: Updated NFPA 204 reference to most current edition.

Response Message:

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N.1.2.3 ASTM Publications.

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

ASTM E1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*, 2013.

ASTM E1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2015A2016a.

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Committee Statement

Committee Statement: Referenced standard has been updated to most recent edition.

Response Message:

[Public Comment No. 5-NFPA 92-2016 \[Section No. M.1.2.3\]](#)

Second Revision No. 1-NFPA 92-2017 [Section No. M.1.2.6]

N.1.2.6 SFPE Publications.

Society of Fire Protection Engineers, 9711 Washington Blvd, Suite 380, Gaithersburg, MD 20878.

SFPE Engineering Guide to Performance-Based Fire Protection, 2007, 2nd edition, 2007.

SFPE Handbook of Fire Protection Engineering, 2015, 4th edition, 2016.

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Committee Statement

Committee Statement: The Technical Committee edited this section to provide the latest edition of the SFPE Handbook.

Response Message:

[Public Comment No. 3-NFPA 92-2016 \[Section No. M.1.2.6\]](#)

Second Revision No. 2-NFPA 92-2017 [Section No. M.1.2.8]

N.1.2.8 Other Publications.

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2. Beyler, C., "Fire Plumes and Ceiling Jets," *Fire Safety Journal*, 11, pp. 63–65, 1986.

3. CIBSE. "Relationships for smoke control calculations," Technical Memoranda TM19, Chartered Institution of Building Services Engineers. London, UK, 1995.

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Committee Statement

Committee Statement: The Technical Committee updated the information to the latest edition of the SFPE Handbook.

Response Message:

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Second Revision No. 7-NFPA 92-2017 [Section No. M.3]

N.3 References for Extracts in Informational Sections.

NFPA 204, *Standard for Smoke and Heat Venting*, ~~2015~~2018 edition.

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Committee Statement

Committee Statement: Updating referenced documents to most current edition.

Response Message:

Annex M_Tenability

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

M.1 General. The purpose of this annex is to provide guidelines for designers to assess tenable conditions in spaces protected by smoke control systems, connected spaces and means of egress elements during the operation of a smoke control system.

M.2 Tenable Environments.

M.2.1 The conditions in a space should be maintained tenable for occupants to evacuate. For this reason, the context in which the analysis will be performed is the first factor that should be used to develop the tenability criteria. The following analysis conditions/context should be considered when applying the tenability criteria that follow in this section to determine if alternate criteria should be applied:

- (1) The geometry of the space, including but not limited to exit or exit access doorways, ceiling heights, travel distances within the space, exit signage, and means of egress illumination.
- (2) Occupant characteristics, including but not limited to age, physical capabilities, disabilities (e.g. audible, respiratory), use of drugs or alcohol or other cognitive impairment.
- (3) Products of fuel decomposition and combustion, including but not limited to carbon monoxide, heat, soot, hydrogen cyanide, hydrogen chloride, ammonia, nitrogen oxides, and hydrocarbons.

The following section explores several of these factors in more detail, specifically as the development of tenability criteria. The context in which these factors are addressed are large open spaces such as malls and atria. This is because tenability criteria (i.e., maintaining tenability in a space) are typically applied in conjunction with smoke exhaust systems, which are most commonly used in large open spaces such as malls and atria. It should be noted that additional tenability criteria may be appropriate for specific applications and that additional research outside of this document may be necessary to identify and quantify those tenability criteria.

M.3 Tenability Criteria.

M.3.1 A tenable environment is one in which the products of combustion, including heat, smoke, and toxic gasses, are at levels that are not life threatening or adversely impact the ability to egress.

M.3.2 A tenability analysis should include evaluation of heat, toxic gasses, thermal radiation, and visibility.

M.3.3 For most materials, if the products of combustion are sufficiently diluted to satisfy the visibility criteria, heat, toxic gasses, and thermal radiation levels will also be at non-life threatening levels.

M.3.4 The application of tenability criteria at the perimeter of a fire is impractical. The zone of tenability should be defined to apply outside a boundary away from the perimeter of the fire. This distance will be dependent on the fire heat release rate, the fire smoke release rate, local geometry, and ventilation and could be as much as 30 m (100 ft). A critical consideration in determining this distance will be how the resultant radiation exposures and smoke layer temperatures affect egress.

M.3.5 Some factors that should be considered in maintaining a tenable environment for periods of short duration are defined in M.3.6 through M.3.8.

M.3.6 Heat Effects. Exposure to heat can lead to life threat in three basic ways:

- (1) Hyperthermia
- (2) Body surface burns

(3) Respiratory tract burns

For use in the modeling of life threat due to heat exposure in fires, it is necessary to consider only two criteria: the threshold of burning of the skin and the exposure at which hyperthermia is sufficient to cause mental deterioration and thereby threaten survival.

Note that thermal burns to the respiratory tract from inhalation of air containing less than 10 percent by volume of water vapor do not occur in the absence of burns to the skin or the face; thus, tenability limits with regard to skin burns normally are lower than for burns to the respiratory tract. However, thermal burns to the respiratory tract can occur upon inhalation of air above 60°C (140°F) that is saturated with water vapor.

M.3.6.1 Radiant Heat Exposure

The tenability limit for exposure of skin to radiant heat is approximately 1.7 kW·m⁻². Below this incident heat flux level, exposure can be tolerated for 30 minutes or longer without significantly affecting the time available for escape. Above this threshold value, the time to burning of skin due to radiant heat decreases rapidly according to Equation M.3.6.1a.

$$t_{Irad} = 106q^{-1.35} \quad (\text{M.3.6.1a})$$

where:

t_{Irad} = time in minutes

q = radiant heat flux (kW/m²)

As with toxic gases, an exposed occupant can be considered to accumulate a dose of radiant heat over a period of time. The fraction equivalent dose (FED) of radiant heat accumulated per minute is the reciprocal of t_{Irad} .

Radiant heat tends to be directional, producing localized heating of particular areas of skin even though the air temperature in contact with other parts of the body might be relatively low. Skin temperature depends on the balance between the rate of heat applied to the skin surface and the removal of heat subcutaneously by the blood. Thus, there is a threshold radiant flux below which significant heating of the skin is prevented but above which rapid heating occurs.

Based on the preceding information, it is estimated that the uncertainty associated with the use of Equation M.3.6.1a is ±25 percent. moreover, an irradiance of 2.5 kW·m⁻² would correspond to a source surface temperature of approximately 200°C, which is most likely to be exceeded near the fire, where conditions are changing rapidly.

M.3.6.2 Convected Heat Exposure.

Calculation of the time to incapacitation under conditions of exposure to convected heat from air containing less than 10 percent by volume of water vapor can be made using either Equation M.3.6.2a or Equation M.3.6.2b.

As with toxic gases, an exposed occupant can be considered to accumulate a dose of convected heat over a period of time. The fraction equivalent dose (FED) of radiant heat accumulated per minute is the reciprocal of t_{Iconv} .

Convected heat accumulated per minute depends on the extent to which an exposed occupant is clothed and the nature of the clothing. For fully clothed subjects, Equation M.3.6.2a is suggested:

$$t_{Iconv} = (4.1 \times 10^8) T^{-3.61} \quad (\text{M.3.6.2a})$$

where:

t_{conv} = time in minutes
 T = temperature (°C)

For unclothed or lightly clothed subjects, it might be more appropriate to use Equation M.3.6.2b:

$$t_{conv} = (5 \times 10^7) T^{-3.4} \quad (\text{M.3.6.2b})$$

where:

t_{conv} = time in minutes
 T = temperature (°C)

Equations M.3.6.2a and M.3.6.2b are empirical fits to human data. It is estimated that the uncertainty is ± 25 percent.

Thermal tolerance data for unprotected human skin suggest a limit of about 120°C (248°F) for convected heat, above which there is, within minutes, onset of considerable pain along with the production of burns. Depending on the length of exposure, convective heat below this temperature can also cause hyperthermia.

The body of an exposed occupant can be regarded as acquiring a "dose" of heat over a period of time. A short exposure to a high radiant heat flux or temperature generally is less tolerable than a longer exposure to a lower temperature or heat flux. A methodology based on additive FEDs similar to that used with toxic gases can be applied. Provided that the temperature in the fire is stable or increasing, the total fractional effective dose of heat acquired during an exposure can be calculated using Equation M.3.6.2c:

$$FED = \sum_{t_1}^{t_2} \left(\frac{1}{t_{rad}} + \frac{1}{t_{conv}} \right) \Delta t \quad (\text{M.3.6.2c})$$

Note 1: In areas within an occupancy where the radiant flux to the skin is under $2.5 \text{ kW} \cdot \text{m}^{-2}$, the first term in Equation M.3.6.2c is to be set at zero.

Note 2: The uncertainty associated with the use of this last equation would be dependent on the uncertainties with the use of the three earlier equations.

The time at which the FED accumulated sum exceeds an incapacitating threshold value of 0.3 represents the time available for escape for the chosen radiant and convective heat exposures.

As an example, consider the following:

- (1) Evacuees lightly clothed
- (2) Zero radiant heat flux
- (3) Time to FED reduced by 25 percent to allow for uncertainty in Equations M. 3.6.2b and M. 3.6.2c.
- (4) Exposure temperature constant
- (5) FED not to exceed 0.3

Equations M.3.6.2b and M. 3.6.2c can be manipulated to provide:

$$t_{exp} = (1.125 \times 10^7) T^{-3.4} \quad (\text{M.3.6.2d})$$

where:

t_{exp} = time of exposure (min.) to reach a FED of 0.3. This gives the values in Table M.3.6.2.

Table M.3.6.2 Maximum Exposure Time

Exposure Temperature		Without Incapacitation (min.)
°C	°F	
80	176	3.8
75	167	4.7
70	158	6.0
65	149	7.7
60	140	10.1
55	131	13.6
50	122	18.8
45	113	26.9
40	104	40.2

M.3.7 Toxic Gases. A number of potentially toxic gases are created from a fire that need to be considered when evaluating tenability. The predominant toxic gas created from a fire is carbon monoxide (CO), which is readily generated from the combustion of wood and other cellulosic materials. Carbon dioxide (CO₂) is an asphyxiant, which can cause nervous system depression leading to loss of consciousness and potentially death. Another asphyxiant of concern is Hydrogen Cyanide (CN). Other toxic gases classified as irritants have the potential to cause irritation of the eyes, respiratory tract, and lungs. Potential irritants created by fires include halogen acids such as Hydrogen Chloride (HCl), Hydrogen Fluoride (HF), and Hydrogen Bromide (HBr).

Carbon monoxide tenability limits are discussed in Section M.3.7.1. Creation of other toxic gases is largely a function of the fuel being burned. Discussion of tenability limits for these gases is provided elsewhere.

M.3.7.1 Air Carbon Monoxide Content. An exposed occupant can be considered to accumulate a dose of carbon monoxide over a period of time. This exposure to carbon monoxide can be expressed as a fractional effective dose, according to Equation M.3.7.1a; see M.3.7.1.1, reference [1] [page 6, Equation (2)]:

$$FED_{co} = \sum_{t_i} \frac{[CO] \Delta t}{35000} \quad (\text{M.3.7.1a})$$

where:

Δt = time increment in minutes
 $[CO]$ = average concentration of CO (ppm) over the time increment Δt

It has been estimated that the uncertainty associated with the use of Equation M.3.6.1a is ± 35 percent. The time at which the FED accumulated sum exceeds a chosen incapacitating threshold value represents the time available for escape for the chosen carbon monoxide exposure. As an example, consider the following:

- (1) Time to FED reduced by 35 percent to allow for the uncertainty in Equation M.3.6.1a
- (2) Exposure concentrations constant

This gives the values in Table M.3.7.1 for a range of threshold values.

Table M. 3.7.1 Maximum Carbon Monoxide Exposure

Time (min)	Tenability Limit		
	AEGL2	0.3	0.5
4	–	1706	2844
6	–	1138	1896
10	420	683	1138
15	–	455	758
30	150	228	379
60	83	114	190
240	33	28	47

A value for the FED threshold limit of 0.5 is typical of healthy adult populations [1], 0.3 is typical in order to provide for escape by the more sensitive population [1] and the AEGL 2 limits are intended to protect the general population, including susceptible individuals, from irreversible or other serious long-lasting health effects [2].

The selection of the FED threshold limit value should be chosen appropriate for the fire safety design objectives. A value of 0.3 is typical. More conservative criteria may be employed for use by especially susceptible populations. Additional information is available in references [1] and [3].

M.3.7.1.1 The following references are cited in M.3.7.1

- (1) "Life threat from fires – Guidance on the estimation of time available for escape using fire data." ISO/DIS 13571, International Standard: Organization, 2006.
- (2) "Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 8," Committee on Acute Exposure Guideline Levels, Committee on Toxicology, National Research Council. National Academies Press, Washington, DC, 2010.
- (3) Kuligowski, E. D., "Compilation of Data on the Sublethal Effects of Fire Effluent," Technical Note 1644, National Institute of Standards and Technology, 2009.

M.3.8 Visibility. Visibility through smoke should be maintained above the point which a sign internally illuminated at 80 lx (7.5-ft candles) is discernible at 30 m (100 ft) and doors and walls are discernible at 10 m (33 ft). These distances can be reduced if demonstrated by an engineering analysis.

M.3.8.1 Reduction of visibility thresholds (minimum visibility distance) should be avoided where the egress paths themselves create confusion or where occupants need to maneuver around many obstructions during exiting.

M.3.8.2 For confined egress routes containing little to no obstructions and where the exits are readily located in any direction of travel (e.g., small rooms/balconies or hotel corridors with exit stairs at remote ends), the visibility threshold can be reduced to the point at which an exit sign is discernible at no less than 10 m (33 ft) and doors and walls are discernible at no less than 3.75m (12 ft).

M.4 Geometric Considerations.

The application of tenability criteria at the perimeter of a fire is impractical. The zone of tenability should be defined to apply outside a boundary away from the perimeter of the fire. This distance will be dependent on the fire heat release rate, the fire smoke release rate, local geometry, and ventilation and could be as much as 30 m (100 ft). A critical consideration in determining

this distance will be how the resulting radiation exposures and smoke layer temperatures affect egress. This consideration should include the specific geometries of each application and how those factors interact to support or interfere with access to the means of egress.