First Revision No. 7-NFPA 2001-2023 [Detail]

A.7.1.7

~~Examples of ventilation systems necessary to ensure safety include cooling of vital equipment required for process safety and ventilation systems required for containment of hazardous materials.~~ Where recirculating ventilation is not shut off, an additional amount of agent could be needed to compensate for room leakage during the hold time.

Submitter Information Verification

Committee: GFE-AAA
Submittal Date: Wed May 10 10:52:23 EDT 2023

Committee Statement

Committee Statement: Annex was revised to align with changes made to 7.1.7, 7.1.7.2 and 7.1.7.3.
Response Message: FR-7-NFPA 2001-2023

First Revision No. 15-NFPA 2001-2023 [Chapter 2]

Chapter 2 Referenced Publications

2.1 General.

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

2.2 NFPA Publications.

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

NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing,* ~~2021~~ 2024 edition.

NFPA 70®, *National Electrical Code®,* ~~2020~~ 2023 edition.

NFPA 72®, *National Fire Alarm and Signaling Code®,* ~~2022~~ 2025 edition.

2.3 Other Publications.

2.3.1 ANSI Publications.

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

ANSI Z535.2, *Standard for Environmental and Facility Safety Signs*, ~~2011~~ 2018 .

2.3.2 ASME Publications.

American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME B1.20.1, *Standard on Pipe Threads, General Purpose, Inch*, 2013.

ASME B31.1, *Power Piping Code*, ~~2020~~ 2022 .

Boiler and Pressure Vessel Code, ~~2019~~ 2023 .

2.3.3 ASTM Publications.

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

ASTM A120-84, *Specification for Pipe, Steel, Black and Hot-Dipped (Galvanized) Welded and Seamless for Ordinary Uses,* 1984 (withdrawn 1987).

IEEE/ ASTM SI10-~~16~~ , *American National Standard for Metric Practice*, 2016.

2.3.4 CGA Publications.

Compressed Gas Association, ~~14501 George Carter Way, Suite 103, Chantilly, VA 20151~~ 8484 Westpark Drive, Suite 220, McLean, VA 22102 .

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, ~~2019~~ 2022 .

2.3.5 IEEE Publications.

~~IEEE Standards Association, 3 Park Avenue, 17th Floor, New York, NY 10016-5997~~ IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141 .

IEEE C2, *National Electrical Safety Code*, ~~2017~~ 2022 .

2.3.6 IMO Publications.

International Maritime Organization, 4, Albert Embankment, London, SE1 7SR, United Kingdom.

IMO MSC/Circ. 848, *Revised Guidelines for the Approval of Equivalent Fixed Gas Fire-Extinguishing Systems as Referred to in SOLAS 74, for Machinery Spaces and Cargo Pump-Rooms*, 1998.

IMO MSC.1/Circ.1267, *Amendments to Revised Guidelines for the Approval of Equivalent Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces and Cargo Pump-Rooms (MSC/Circ.848)*, 2008.

2.3.7 ISO Publications.

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

ISO 7-1*, Pipe Threads Where Pressure-Tight Joints Are Made on the Threads — Part 1: Dimensions, Tolerances and Designation*, 1994 (R2020).

2.3.8 TC Publications.

Transport Canada, ~~Tower C, Place de Ville, 330 Sparks Street, Ottawa, Ontario, K1A 0N5, Canada~~ 330 Sparks Street, Ottawa, ON K1A 0N5, Canada .

TP 127 E, *Ship Safety Electrical Standards*, 2018.

2.3.9 UL Publications.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/CAN/ UL/ULC 2127, *Inert Gas Clean Agent Extinguishing System Units*, ~~2017 (R2020)~~ 2021 .

ANSI/CAN/ UL/ULC 2166, *Halocarbon Clean Agent Extinguishing System Units*, ~~2017 (R2020)~~ 2021 .

2.3.10 U. S. Government Publications.

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

OSHA, Title 29, Code of Federal Regulations, Part 1910, Subpart S.

U.S. Coast Guard, Title 46, Code of Federal Regulations, Part 72.

U.S. Coast Guard, Title 46, Code of Federal Regulations, Subchapter J, “Electrical Engineering.”

DOT Title 49, Code of Federal Regulations, Parts 170–190, “Transportation.”

2.3.11 Other Publications.

Merriam-Webster’s Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, ~~2003~~ 2020 .

2.4 References for Extracts in Mandatory Sections.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* ~~2021~~ 2022 edition.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu May 11 07:21:03 EDT 2023

Committee Statement

Committee Statement: Updated to align with most recent editions of referenced publications

Response Message: FR-15-NFPA 2001-2023

Public Input No. 30-NFPA 2001-2022 [Section No. 2.3.9]

First Revision No. 27-NFPA 2001-2023 [Section No. 3.1]

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.~~

3.1.1

The definitions contained in this chapter shall apply to the terms used in this standard.

3.1.2

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.

3.1.3

Merriam-Webster's Collegiate Dictionary, 11th edition, shall be the source for the ordinarily accepted meaning.

Supplemental Information

File Name	Description	Approved
2001_FR-27_3.1_FINAL.docx	for prod use	

Submitter Information Verification

Committee: GFE-AAA
Submittal Date: Thu May 25 21:15:24 EDT 2023

Committee Statement

Committee Statement: Revised to comply with the MOS.
Response Message: FR-27-NFPA 2001-2023

First Revision No. 22-NFPA 2001-2023 [New Section after 3.3.14]

3.3.15 Extended Discharge.

A continued discharge of clean agent provided in order to maintain the design concentration over a specified period of time after the completion of the initial discharge.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu May 11 13:50:44 EDT 2023

Committee Statement

Committee Statement: Defines a term that is used in the standard.

Response Message: FR-22-NFPA 2001-2023

First Revision No. 21-NFPA 2001-2023 [New Section after 3.3.19]

3.3.21 Initial Discharge.

The discharge of clean agent for the purpose of achieving design concentration.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu May 11 13:49:47 EDT 2023

Committee Statement

Committee Statement: Defines a term that is used in the standard.

Response Message: FR-21-NFPA 2001-2023

First Revision No. 25-NFPA 2001-2023 [Section No. 4.3.2.3]

4.3.2.3

A pre-discharge alarm and time delay shall be provided in accordance with the provisions of Section 9.7 of this standard.

4.3.2.4*

The following additional provisions shall apply:

(1) Halocarbon systems for spaces that are normally occupied and designed to concentrations up to the NOAEL *[see Table 4.3.2.4(a)]* shall be permitted.

(2) Halocarbon systems for spaces that are normally occupied and designed to concentrations above the NOAEL *[see Table 4.3.2.4(a)]* shall be permitted if means are provided to limit exposure to the design concentrations shown in Table 4.3.2.4(b) through Table 4.3.2.4(e) that correspond to an allowable human exposure time of 5 minutes.

(3) Higher design concentrations associated with human exposure times less than 5 minutes as shown in Table 4.3.2.4(b) through Table 4.3.2.4(e) shall not be permitted in normally occupied spaces.

(4) In spaces that are not normally occupied and that are protected by a halocarbon system designed to concentrations above the lowest observable adverse effects level (LOAEL) *[see Table 4.3.2.4(a)]* and where personnel could possibly be exposed, means shall be provided to limit exposure times using Table 4.3.2.4(b) through Table 4.3.2.4(e).

(5) In spaces that are not normally occupied and in the absence of the information needed to fulfill the conditions in 4.3.2.4(4), the following provisions shall apply:

(a) Where egress takes longer than 30 seconds but less than 1 minute, the halocarbon agent shall not be used in a concentration exceeding its LOAEL.

(b) Concentrations exceeding the LOAEL shall be permitted provided that any personnel in the area can escape within 30 seconds.

~~A pre-discharge alarm and time delay shall be provided in accordance with the provisions of Section 9.7 of this standard.~~

Table 4.3.2.4(a) Information for Halocarbon Clean Agents

Agent	NOAEL (vol %)	LOAEL (vol %)
FK-5-1-12	10.0	>10.0
HCFC Blend A	10.0	>10.0
HCFC-124	1.0	2.5
HFC-125	7.5	10.0
HFC-227ea	9.0	10.5
HFC-23	30	>30
HFC-236fa	10	15
HFC Blend B*	5.0*	7.5*
HB-55	8.7%	>8.7%

*These values are for the largest component of the blend (HFC 134A).

Table 4.3.2.4(b) Time for Safe Human Exposure at Stated Concentrations for HFC-125

HFC-125 Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
7.5	75,000	5.00
8.0	80,000	5.00
8.5	85,000	5.00
9.0	90,000	5.00
9.5	95,000	5.00
10.0	100,000	5.00

HFC-125 Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
10.5	105,000	5.00
11.0	110,000	5.00
11.5	115,000	5.00
12.0	120,000	1.67
12.5	125,000	0.59
13.0	130,000	0.54
13.5	135,000	0.49

Notes:

(1) Data derived from the EPA-approved and peer-reviewed physiologically based pharmacokinetic (PBPK) model or its equivalent.

(2) Based on LOAEL of 10.0 percent in dogs.

Table 4.3.2.4(c) Time for Safe Human Exposure at Stated Concentrations for HFC-227ea

HFC-227ea Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
9.0	90,000	5.00
9.5	95,000	5.00
10.0	100,000	5.00
10.5	105,000	5.00
11.0	110,000	1.13
11.5	115,000	0.60
12.0	120,000	0.49

Notes:

(1) Data derived from the EPA-approved and peer-reviewed PBPK model or its equivalent.

(2) Based on LOAEL of 10.5 percent in dogs.

Table 4.3.2.4(d) Time for Safe Human Exposure at Stated Concentrations for HFC-236fa

HFC-236fa Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
10.0	100,000	5.00
10.5	105,000	5.00
11.0	110,000	5.00
11.5	115,000	5.00
12.0	120,000	5.00
12.5	125,000	5.00
13.0	130,000	1.65
13.5	135,000	0.92
14.0	140,000	0.79
14.5	145,000	0.64

HFC-236fa Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
15.0	150,000	0.49

Notes:

(1) Data derived from the EPA-approved and peer-reviewed PBPK model or its equivalent.

(2) Based on LOAEL of 15.0 percent in dogs.

Table 4.3.2.4(e) Time for Safe Human Exposure at Stated Concentrations for FIC-13I1

FIC-13I1 Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
0.20	2000	5.00
0.25	2500	5.00
0.30	3000	5.00
0.35	3500	4.30
0.40	4000	0.85
0.45	4500	0.49
0.50	5000	0.35

Notes:

(1) Data derived from the EPA-approved and peer-reviewed PBPK model or its equivalent.

(2) Based on LOAEL of 0.4 percent in dogs.

Supplemental Information

File Name	Description	Approved
2001_GFE_AAA_F2024_FDM_4.3.2.3.docx	For staff use only	

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 24 10:36:44 EDT 2023

Committee Statement

Committee Statement: Eliminates confusion as to when time delay is required and is consistent with Inert Gas Section 4.3.3.3.

Response Message: FR-25-NFPA 2001-2023

Public Input No. 34-NFPA 2001-2023 [Section No. 4.3.2.3]

First Revision No. 3-NFPA 2001-2023 [Section No. 6.2.2.2]

6.2.2.2

The equivalent length of the container valve shall include the siphon tube, valve, discharge head, and flexible connector, if so equipped .

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 09:19:02 EDT 2023

Committee Statement

Committee Statement: Siphon tubes and flexible connectors are not always present, depending on the design of the system.

Response Message: FR-3-NFPA 2001-2023

Public Input No. 37-NFPA 2001-2023 [Section No. 6.2.2.2]

First Revision No. 6-NFPA 2001-2023 [Section No. 7.1.7 [Excluding any Sub-Sections]]

~~Other than the ventilation systems identified in~~ ~~7.1.7.2~~ ~~, forced~~ Forced -air ventilating systems, including self-contained air recirculation systems, shall be shut down or closed automatically where their continued operation would ~~adversely affect the performance of the fire-extinguishing system~~ prevent the development and maintenance of the required agent concentration in a hazard or result in the propagation of ~~the~~ fire.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 10:18:04 EDT 2023

Committee Statement

Committee Statement: Removed the reference to 7.1.7.2, as existing 7.1.7.2 was deleted. Current 7.1.7 allows for ventilation systems to remain operational under certain circumstances. The term "adversely affect" was removed since it was vague and unenforceable. Existing 7.1.7.3 was moved to 7.1.7.2 and modified to explain when action needs to be taken on whether the ventilation system remains operational.

Response Message: FR-6-NFPA 2001-2023

First Revision No. 4-NFPA 2001-2023 [Section No. 7.1.7.1]

7.1.7.1

~~If not shut down or closed automatically~~ Unless automatically isolated from the hazard prior to discharge of agent , the volume of ~~the self-contained recirculating undampered~~ ventilation system ducts and components ~~mounted below the ceiling height of the protected space~~ shall be considered as part of the total hazard volume when determining the quantity of agent.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 09:31:35 EDT 2023

Committee Statement

Committee Statement: Unless ventilation system ducts are totally isolated from the protected volume, agent will infiltrate the ducts. If, in addition to the agent required to flood the protected volume, sufficient agent to flood any connected ventilation system ducts and components is not provided, the agent concentration in the protected volume will very likely be less than required. Just shutting down the fans would not isolate the environment.

Response Message: FR-4-NFPA 2001-2023

Public Input No. 39-NFPA 2001-2023 [Section No. 7.1.7.1]

Public Input No. 23-NFPA 2001-2022 [Section No. 7.1.7.1]

First Revision No. 5-NFPA 2001-2023 [Sections 7.1.7.2, 7.1.7.3]

~~7.1.7.2~~

~~Ventilation systems necessary to ensure safety shall not be required to be shut down upon activation of the fire suppression system.~~

7.1.7.2

Where a ventilation system is permitted to remain in operation ~~in accordance with 7.1.7.2~~ , an extended agent discharge shall be provided, if required, to maintain the design concentration for the required duration of protection.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 09:52:30 EDT 2023

Committee Statement

Committee Statement: Section 7.1.7.2 was removed since it was redundant with 7.1.7.

7.1.7.3 was modified to reflect the removal of 7.1.7.2. "If required" was added because an extended discharge may not be necessary. For example, if the ventilation system is fully recirculating and adequate hold time is achieved.

Response Message: FR-5-NFPA 2001-2023

Public Input No. 41-NFPA 2001-2023 [Section No. 7.1.7.3]

Public Input No. 40-NFPA 2001-2023 [Section No. 7.1.7.2]

First Revision No. 18-NFPA 2001-2023 [Section No. 7.3.3.3]

7.3.3.3* Design Factor for Enclosure Pressure.

The design quantity of the clean agent shall be adjusted in accordance with Table 7.3.3.3 to compensate for ambient pressures that vary more than 11 percent [equivalent to approximately 3000 ft (915 m) of elevation change] from standard sea level pressures [29.92 in. Hg at ~~70°F~~ 32°F (760 mm Hg at 0°C)].

Table 7.3.3.3 Atmospheric Correction Factors

Equivalent Altitude		Enclosure Pressure (Absolute)		Atmospheric Correction Factor
ft	km	psi	mm Hg	
-3,000	-0.92	16.25	840	1.11
-2,000	-0.61	15.71	812	1.07
-1,000	-0.30	15.23	787	1.04
0	0.00	14.70	760	1.00
1,000	0.30	14.18	733	0.96
2,000	0.61	13.64	705	0.93
3,000	0.91	13.12	678	0.89
4,000	1.22	12.58	650	0.86
5,000	1.52	12.04	622	0.82
6,000	1.83	11.53	596	0.78
7,000	2.13	11.03	570	0.75
8,000	2.45	10.64	550	0.72
9,000	2.74	10.22	528	0.69
10,000	3.05	9.77	505	0.66

Submitter Information Verification

Committee: GFE-AAA
Submittal Date: Thu May 11 12:38:31 EDT 2023

Committee Statement

Committee Statement: Corrected the temperature to the proper value.
Response Message: FR-18-NFPA 2001-2023

First Revision No. 26-NFPA 2001-2023 [Section No. 7.4]

7.4* Duration of Protection.

7.4.1

For flame-extinguishing systems, a minimum concentration of 85 percent of the minimum design concentration shall be held at the highest height of protected content within the hazard for a period of 10 minutes or for a ~~time~~ period sufficient to allow for response by trained personnel.

7.4.2

For inerting systems, a minimum concentration not less than the inerting concentration determined in accordance with 7.2.3.1 shall be held throughout the protected space for a ~~time~~ period sufficient to allow for response by trained personnel.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 24 10:48:06 EDT 2023

Committee Statement

Committee Statement: The word “time” is deleted to make consistent the previous use of “period,” to mean a span of time in two places in the same sentence.

Response Message: FR-26-NFPA 2001-2023

Public Input No. 8-NFPA 2001-2022 [Section No. 7.4.1]

First Revision No. 10-NFPA 2001-2023 [Section No. 7.5.2.2]

7.5.2.2

The performance of the extended discharge system shall be confirmed by a test, or as otherwise required by the authority having jurisdiction .

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 13:09:23 EDT 2023

Committee Statement

Committee Statement: This will allow for emerging techniques to be utilized.

Response Message: FR-10-NFPA 2001-2023

Public Input No. 38-NFPA 2001-2023 [Section No. 7.5.2.2]

First Revision No. 11-NFPA 2001-2023 [Section No. 7.6.3]

7.6.3

The type of nozzles selected, their number, and their placement shall be such that the design concentration will be established in all parts of the hazard enclosure and such that the discharge will not unduly splash flammable liquids or create dust clouds that could extend the fire, create an explosion, or otherwise adversely affect the contents or integrity of the enclosure, or personnel .

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 13:11:00 EDT 2023

Committee Statement

Committee Statement: It is important to consider nozzle placement for personnel safety and egress.

Response Message: FR-11-NFPA 2001-2023

Public Input No. 43-NFPA 2001-2023 [Section No. 7.6.3]

First Revision No. 17-NFPA 2001-2023 [Section No. 8.1.3]

8.1.3* Safety Requirements.

The safety requirements of Section 4.3 shall apply~~. During agent discharge, locally high concentrations of the agent will be developed; therefore the requirements of Section~~ 4.3 ~~shall be followed~~ to prevent exposure of personnel to high concentrations of agent.

A.8.1.3

Local concentrations of agent in the vicinity of the discharge often will exceed the maximum permitted exposure limits described in Section 4.3.

Consideration for exposure to agent discharge from local application systems varies greatly and ~~may~~ can be more complicated than that for total flooding systems, depending on the following:

(1) Quantity of agent released

(2) Time needed to extinguish the fire

(3) Size of the room or enclosure in which the fire occurs

(4) Size of the fire

(5) Proximity of the person to the point of discharge of the agent

(6) Rate at which fresh air infiltrates the space

(7) Air exchange rate near the fire

One approach to assess consumer exposure is to employ a “box model,” which has been widely used for many years to estimate probable exposures of workers to hazardous airborne materials, and has been described in detail by the National Institute for Occupational Safety and Health (NIOSH). The box model takes into consideration assumptions on the volume of the space in which the extinguishant is used, the rate at which fresh air infiltrates the space, the quantity and rate of agent release, the area of the fire, the location of the worker, and the air exchange rate in the vicinity of the fire. Values obtained through the box model, compared to cardiotoxic NOAEL/LOAEL values, provide a screen for assessing risk.

It should be noted that because the model can overstate the actual exposure to an agent, it might be necessary to conduct personal monitoring tests in actual-use scenarios in order to complete the assessment.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu May 11 12:36:02 EDT 2023

Committee Statement

Committee Statement: Revised to clarify the requirements and comply with the manual of style.

Response Message: FR-17-NFPA 2001-2023

First Revision No. 12-NFPA 2001-2023 [Section No. 11.3.7]

11.3.7

The following information shall be recorded on a tag attached to the container:

(1) Date of inspection

(2) Person and organization performing the inspection

(3) Type of agent

(4) Gross weight of the container and net weight of agent *(halocarbon clean agents only)*

(5) Container pressure and temperature *(halocarbon clean agents with a gauge and inert gas clean agents)*

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Wed May 10 13:59:10 EDT 2023

Committee Statement

Committee Statement: The Inspection record lacks the detail of organization performing the inspection. This should also be recorded.

Response Message: FR-12-NFPA 2001-2023

Public Input No. 45-NFPA 2001-2023 [Section No. 11.3.7]

First Revision No. 23-NFPA 2001-2023 [Section No. A.3.3.10]

A.3.3.10 Deep-Seated Fire.

A characteristic of this type of combustion is the slow rate of heat losses from the reaction zone. Thus, the fuel remains hot enough to exothermically react with oxygen, even though the rate of reaction, which is controlled by diffusion processes, is extremely slow. Deep-seated fires can continue to burn for many weeks, for example, in bales of cotton and jute and heaps of sawdust. A deep-seated fire ceases to burn only when either all the available oxygen or fuel has been consumed or the fuel surface is at too low a temperature to react.

~~A deep-seated fire is not subject to immediate extinguishment.~~ Deep-seated fires usually are extinguished by reducing the fuel temperature, either directly by application of a heat-absorbing medium, such as water, or by blanketing with an inert gas. The medium slows the reaction rate to the point where heat generated by oxidation is less than heat losses to surroundings. This causes the temperature to fall below the level necessary for ~~spontaneous~~ re- ignition after removal of the inert atmosphere.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Tue May 23 09:44:20 EDT 2023

Committee Statement

Committee Statement: Revised A.3.3.10 to use more correct terms and to reflect more accurate information.

Response Message: FR-23-NFPA 2001-2023

First Revision No. 29-NFPA 2001-2023 [Section No. A.7.3.2]

A.7.3.2

The volume of inert gas clean agent required to develop a given concentration will be greater than the final volume remaining in the same enclosure. In most cases, the inert gas clean agent must be applied in a manner that promotes progressive mixing of the atmosphere. As the clean agent is injected, the displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents. Some inert gas clean agent is therefore lost with the vented atmosphere. This loss becomes greater at high concentrations. This method of application is called “free efflux” flooding.

Under these conditions, the volume of inert gas clean agent required to develop a given concentration in the atmosphere is expressed by one of the following equations:

$$e^x = \frac{100}{100 - \%\ \mathrm{IG}} \qquad \textbf{[A.7.3.2a]}$$

or

$$X = 2.303 \log_{10} \frac{100}{100 - \%\ \mathrm{IG}} \qquad \textbf{[A.7.3.2b]}$$

where:

% IG = volume percent of inert gas

X = volume of inert gas added per volume of space

Table A.7.3.2(a) through Table A.7.3.2(h) provide the quantity of clean agent needed to achieve design concentration.

Table A.7.3.2(a) IG-01 Total Flooding Quantity (U. S. Units)

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
−40	7.774	0.5243	0.5830	0.6445	0.6873	0.8011	0.8496	1.0946	1.2209
−30	7.959	0.5121	0.5694	0.6296	0.6713	0.7825	0.8299	1.0691	1.1925
−20	8.144	0.5005	0.5565	0.6153	0.6561	0.7647	0.8110	1.0449	1.1654
−10	8.329	0.4893	0.5441	0.6016	0.6415	0.7477	0.7930	1.0216	1.1395
0	8.514	0.4787	0.5323	0.5885	0.6276	0.7314	0.7758	0.9994	1.1148
10	8.699	0.4685	0.5210	0.5760	0.6142	0.7159	0.7593	0.9782	1.0910
20	8.884	0.4588	0.5101	0.5640	0.6014	0.7010	0.7435	0.9578	1.0683
30	9.069	0.4494	0.4997	0.5525	0.5892	0.6867	0.7283	0.9383	1.0465
40	9.254	0.4404	0.4897	0.5415	0.5774	0.6730	0.7137	0.9195	1.0256
50	9.439	0.4318	0.4801	0.5308	0.5661	0.6598	0.6997	0.9015	1.0055
60	9.624	0.4235	0.4709	0.5206	0.5552	0.6471	0.6863	0.8842	0.9862
70	9.809	0.4155	0.4620	0.5108	0.5447	0.6349	0.6733	0.8675	0.9676
80	9.994	0.4078	0.4535	0.5014	0.5346	0.6231	0.6609	0.8514	0.9497
90	10.179	0.4004	0.4452	0.4923	0.5249	0.6118	0.6489	0.8360	0.9324
100	10.364	0.3933	0.4373	0.4835	0.5156	0.6009	0.6373	0.8210	0.9158
110	10.549	0.3864	0.4296	0.4750	0.5065	0.5903	0.6261	0.8066	0.8997
120	10.734	0.3797	0.4222	0.4668	0.4978	0.5802	0.6153	0.7927	0.8842
130	10.919	0.3733	0.4151	0.4589	0.4894	0.5703	0.6049	0.7793	0.8692

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
140	11.104	0.3671	0.4082	0.4513	0.4812	0.5608	0.5948	0.7663	0.8547
150	11.289	0.3610	0.4015	0.4439	0.4733	0.5516	0.5851	0.7538	0.8407
160	11.474	0.3552	0.3950	0.4367	0.4657	0.5428	0.5756	0.7416	0.8272
170	11.659	0.3496	0.3887	0.4298	0.4583	0.5341	0.5665	0.7298	0.8141
180	11.844	0.3441	0.3826	0.4231	0.4511	0.5258	0.5577	0.7184	0.8013
190	12.029	0.3388	0.3768	0.4166	0.4442	0.5177	0.5491	0.7074	0.7890
200	12.214	0.3337	0.3711	0.4102	0.4375	0.5099	0.5408	0.6967	0.7771

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°F)] = design temperature in the hazard area.

[b] s [specific volume (ft^3/lb)] = specific volume of IG-01 vapor can be approximated by $s = 8.514 + 0.0185t$, where t = temperature (°F).

[c] X [agent volume requirements (ft^3/ft^3)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (ft^3/lb)] = specific volume of inert gas agent at 70°F and 14.7 psi absolute

[d] C [concentration (%)] = volumetric concentration of IG-01 in air at the temperature indicated.

Table A.7.3.2(b) IG-01 Total Flooding Quantity (SI Units)

Temp (t) (°C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
−40	0.4853	0.5242	0.5828	0.6444	0.6871	0.8009	0.8494	1.0943	1.2206
−30	0.5061	0.5026	0.5589	0.6179	0.6589	0.7680	0.8145	1.0493	1.1704
−20	0.5269	0.4828	0.5368	0.5935	0.6329	0.7376	0.7823	1.0079	1.1242
−10	0.5477	0.4644	0.5164	0.5710	0.6089	0.7096	0.7526	0.9696	1.0815
0	0.5685	0.4474	0.4975	0.5501	0.5866	0.6837	0.7251	0.9342	1.0419
10	0.5893	0.4316	0.4800	0.5307	0.5659	0.6595	0.6995	0.9012	1.0052
20	0.6101	0.4169	0.4636	0.5126	0.5466	0.6370	0.6756	0.8705	0.9709
30	0.6309	0.4032	0.4483	0.4957	0.5286	0.616	0.6534	0.8418	0.9389
40	0.6517	0.3903	0.4340	0.4798	0.5117	0.5964	0.6325	0.8149	0.9089
50	0.6725	0.3782	0.4206	0.4650	0.4959	0.5779	0.6129	0.7897	0.8808
60	0.6933	0.3669	0.4080	0.4511	0.4810	0.5606	0.5946	0.7660	0.8544
70	0.7141	0.3562	0.3961	0.4379	0.4670	0.5443	0.5772	0.7437	0.8295

Temp (t) (°C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
80	0.7349	0.3461	0.3849	0.4255	0.4538	0.5289	0.5609	0.7226	0.8060
90	0.7557	0.3366	0.3743	0.4138	0.4413	0.5143	0.5455	0.7027	0.7838
100	0.7765	0.3276	0.3643	0.4027	0.4295	0.5005	0.5309	0.6839	0.7628
110	0.7973	0.3190	0.3548	0.3922	0.4183	0.4875	0.5170	0.6661	0.7429
120	0.8181	0.3109	0.3457	0.3822	0.4076	0.4751	0.5039	0.6491	0.7240

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°C)] = design temperature in the hazard area.

[b] s [specific volume (m^3/kg)] = specific volume of IG-01 vapor can be approximated by $s = 0.5685 + 0.00208t$, where t = temperature (°C).

[c] X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (m^3/kg)] = specific volume of inert gas agent at 21°C and 1.013 bar absolute

[d] C [concentration (%)] = volumetric concentration of IG-01 in air at the temperature indicated.

Table A.7.3.2(c) IG-100 Total Flooding Quantity (U.S. Units)

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
−40	10.93	0.5245	0.5832	0.6448	0.6875	0.8013	0.8499	1.0949	1.2213
−30	11.19	0.5122	0.5696	0.6297	0.6715	0.7827	0.8301	1.0695	1.1928
−20	11.45	0.5006	0.5566	0.6154	0.6563	0.7649	0.8112	1.0451	1.1657
−10	11.72	0.4895	0.5443	0.6017	0.6417	0.7479	0.7932	1.0219	1.1398
0	11.98	0.4788	0.5324	0.5886	0.6277	0.7316	0.7759	0.9996	1.1150
10	12.24	0.4686	0.5211	0.5761	0.6143	0.7160	0.7594	0.9784	1.0912
20	12.50	0.4588	0.5102	0.5641	0.6015	0.7011	0.7435	0.9579	1.0685
30	12.76	0.4495	0.4998	0.5526	0.5892	0.6868	0.7284	0.9384	1.0466
40	13.02	0.4405	0.4898	0.5415	0.5774	0.6730	0.7138	0.9196	1.0257
50	13.28	0.4318	0.4802	0.5309	0.5661	0.6598	0.6998	0.9015	1.0056
60	13.54	0.4235	0.4709	0.5207	0.5552	0.6471	0.6471	0.8842	0.9862
70	13.80	0.4155	0.4620	0.5108	0.5447	0.6349	0.6733	0.8675	0.9676

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
80	14.06	0.4078	0.4535	0.5014	0.5346	0.6231	0.6609	0.8514	0.9497
90	14.32	0.4004	0.4452	0.4922	0.5249	0.6118	0.6488	0.8359	0.9324
100	14.58	0.3932	0.4373	0.4834	0.5155	0.6008	0.6372	0.8210	0.9157
110	14.84	0.3863	0.4296	0.4750	0.5065	0.5903	0.6261	0.8066	0.8996
120	15.10	0.3863	0.4296	0.4750	0.5065	0.5903	0.6261	0.8066	0.8996
130	15.36	0.3732	0.4150	0.4588	0.4893	0.5703	0.6048	0.7792	0.8691
140	15.62	0.3670	0.4081	0.4512	0.4811	0.5608	0.5947	0.7662	0.8546
150	15.89	0.3610	0.4014	0.4438	0.4732	0.5516	0.5850	0.7536	0.8406
160	16.15	0.3552	0.3949	0.4366	0.4656	0.5427	0.5755	0.7415	0.8270
170	16.41	0.3495	0.3886	0.4297	0.4582	0.5340	0.5664	0.7297	0.8139
180	16.67	0.3440	0.3826	0.4230	0.4510	0.5257	0.5575	0.7183	0.8012
190	16.93	0.3388	0.3767	0.4165	0.4441	0.5176	0.5489	0.7072	0.7888
200	17.19	0.3336	0.3710	0.4101	0.4374	0.5097	0.5406	0.6965	0.7769

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°F)] = design temperature in the hazard area.

[b] s [specific volume (ft^3/lb)] = specific volume of IG-100 vapor can be approximated by $s = 11.976 + 0.02606t$, where t = temperature (°F).

[c] X [agent volume requirements (ft^3/ft^3)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (ft^3/lb)] = specific volume of inert gas agent at 70°F and 14.7 psi absolute

[d] C [concentration (%)] = volumetric concentration of IG-100 in air at the temperature indicated.

Table A.7.3.2(d) IG-100 Total Flooding Quantity (SI Units)

Temp (t) (°C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
−40	0.6825	0.5243	0.5830	0.6446	0.6874	0.8011	0.8497	1.0947	1.2210
−30	0.7118	0.5027	0.5590	0.6181	0.6591	0.7682	0.8147	1.0496	1.1707
−20	0.7411	0.4829	0.536	0.5936	0.6330	0.7378	0.7825	1.0081	1.1244
−10	0.7704	0.4645	0.5165	0.5711	0.6090	0.7097	0.7527	0.9698	1.0817
0	0.7997	0.4475	0.4976	0.5501	0.5866	0.6837	0.7252	0.9342	1.0420
10	0.8290	0.4317	0.4800	0.5307	0.5659	0.6596	0.6995	0.9012	1.0052

Temp (t) ($^\circ$C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	37	40	42	47	49	58	62
20	0.8583	0.4169	0.4636	0.5126	0.5466	0.6370	0.6756	0.8705	0.9709
30	0.8876	0.4032	0.4483	0.4956	0.5285	0.6160	0.6533	0.8417	0.9388
40	0.9169	0.3903	0.4340	0.4798	0.5117	0.5963	0.6325	0.8148	0.9088
50	0.9462	0.3782	0.3782	0.4650	0.4958	0.5779	0.6129	0.7896	0.8807
60	0.9755	0.3668	0.4079	0.4510	0.4809	0.5605	0.5945	0.7659	0.8542
70	1.0048	0.3561	0.3960	0.4378	0.4669	0.5442	0.5771	0.7435	0.8293
80	1.0341	0.3461	0.3848	0.4254	0.4537	0.5287	0.5608	0.7225	0.8058
90	1.0634	0.3365	0.3742	0.4137	0.4412	0.5142	0.5453	0.7026	0.7836
100	1.0927	0.3275	0.3642	0.4026	0.4293	0.5004	0.5307	0.6837	0.7626

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature ($^\circ$C)] = design temperature in the hazard area.

[b] s [specific volume (m^3/kg)] = specific volume of IG-100 vapor can be approximated by $s = 0.7997 + 0.00293t$, where t = temperature ($^\circ$C).

[c] X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (m^3/kg)] = specific volume of inert gas agent at 21°C and 1.013 bar absolute

[d] C [concentration (%)] = volumetric concentration of IG-100 in air at the temperature indicated.

Table A.7.3.2(e) IG-541 Total Flooding Quantity (U.S. Units)

Temp (t) ($^\circ$F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
−40	9.00	0.5243	0.603	0.6874	0.7776	0.8747	0.9799	1.0947	1.2210
−30	9.22	0.5121	0.5892	0.6714	0.7595	0.8543	0.9571	1.0692	1.1926
−20	9.43	0.5005	0.5758	0.6561	0.7422	0.8349	0.9354	1.0449	1.1655
−10	9.64	0.4894	0.5630	0.6416	0.7257	0.8164	0.9146	1.0217	1.1396
0	9.86	0.4787	0.5508	0.6276	0.7100	0.7986	0.8947	0.9995	1.1148
10	10.07	0.4686	0.5391	0.6143	0.6948	0.7816	0.8757	0.9782	1.0911
20	10.29	0.4588	0.5278	0.6015	0.6804	0.7653	0.8574	0.9579	1.0684
30	10.50	0.4494	0.5171	0.5892	0.6665	0.7497	0.8399	0.9383	1.0466
40	10.72	0.4404	0.5067	0.5774	0.6532	0.7347	0.8231	0.9196	1.0256
50	10.93	0.4318	0.4968	0.5661	0.6404	0.7203	0.8070	0.9015	1.0055

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
60	11.14	0.4235	0.4872	0.5552	0.6280	0.7065	0.7915	0.8842	0.9862
70	11.36	0.4155	0.4780	0.5447	0.6162	0.6931	0.7765	0.8675	0.9676
80	11.57	0.4078	0.4692	0.5346	0.6048	0.6803	0.7621	0.8514	0.9497
90	11.79	0.4004	0.4607	0.5249	0.5938	0.6679	0.7483	0.8360	0.9324
100	12.00	0.3933	0.4524	0.5155	0.5832	0.6560	0.7349	0.8210	0.9157
110	12.22	0.3864	0.4445	0.5065	0.5729	0.6445	0.7220	0.8066	0.8997
120	12.43	0.3797	0.4368	0.4978	0.5631	0.6334	0.7096	0.7927	0.8842
130	12.64	0.3733	0.4294	0.4893	0.5535	0.6227	0.6976	0.7793	0.8692
140	12.86	0.3670	0.4223	0.4812	0.5443	0.6123	0.6859	0.7663	0.8547
150	13.07	0.3610	0.4153	0.4733	0.5354	0.6022	0.6747	0.7537	0.8407
160	13.29	0.3552	0.4086	0.4657	0.5267	0.5925	0.6638	0.7416	0.8271
170	13.50	0.3496	0.4022	0.4583	0.5184	0.5831	0.6533	0.7298	0.8140
180	13.72	0.3441	0.3959	0.4511	0.5103	0.5740	0.6431	0.7184	0.8013
190	13.93	0.3388	0.3898	0.4442	0.5024	0.5652	0.6332	0.7073	0.7890
200	14.14	0.3337	0.3839	0.4374	0.4948	0.5566	0.6236	0.6966	0.7770

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°F)] = design temperature in the hazard area.

[b] s [specific volume (ft^3/lb)] = specific volume of IG-541 vapor can be approximated by $s = 9.8579 + 0.02143t$, where t = temperature (°F).

[c] X [agent volume requirements (ft^3/ft^3)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (ft^3/lb)] = specific volume of inert gas agent at 70°F and 14.7 psi absolute

[d] C [concentration (%)] = volumetric concentration of IG-541 in air at the temperature indicated.

Table A.7.3.2(f) IG-541 Total Flooding Quantity (SI Units)

Temp (t) (°C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
−40	0.5624	0.5232	0.6020	0.6859	0.7759	0.8728	0.9778	1.0924	1.2184
−30	0.5863	0.5019	0.5774	0.6580	0.7443	0.8373	0.9380	1.0479	1.1687
−20	0.6102	0.4822	0.5548	0.6322	0.7151	0.8045	0.9012	1.0068	1.1230
−10	0.6341	0.4641	0.5339	0.6084	0.6882	0.7741	0.8673	0.9689	1.0806

Temp (t) ($^\circ$C)[a]	Specific Vapor Volume (s) (m^3/kg)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
0	0.6580	0.4472	0.5145	0.5863	0.6632	0.7460	0.8358	0.9337	1.0414
10	0.6819	0.4315	0.4965	0.5657	0.6399	0.7199	0.8065	0.9009	1.0049
20	0.7058	0.4169	0.4797	0.5466	0.6183	0.6955	0.7792	0.8704	0.9709
30	0.7297	0.4033	0.4639	0.5287	0.5980	0.6727	0.7536	0.8419	0.9391
40	0.7536	0.3905	0.4492	0.5119	0.5791	0.6514	0.7297	0.8152	0.9093
50	0.7775	0.3785	0.4354	0.4962	0.5613	0.6314	0.7073	0.7902	0.8813
60	0.8014	0.3672	0.4224	0.4814	0.5445	0.6125	0.6862	0.7666	0.8550
70	0.8253	0.3566	0.4102	0.4674	0.5287	0.5948	0.6663	0.7444	0.8303
80	0.8492	0.3465	0.3987	0.4543	0.5139	0.5780	0.6476	0.7235	0.8069
90	0.8731	0.3370	0.3877	0.4418	0.4998	0.5622	0.6299	0.7036	0.7848
100	0.8970	0.3281	0.3774	0.4301	0.4865	0.5472	0.6131	0.6849	0.7639

Note: The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°C)] = design temperature in the hazard area.

[b] s [specific volume (m^3/kg)] = specific volume of IG-541 vapor can be approximated by $s = 0.65799 + 0.00239t$, where t = temperature (°C).

[c] X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (m^3/kg)] = specific volume of inert gas agent at 21°C and 1.013 bar absolute

[d] C [concentration (%)] = volumetric concentration of IG-541 in air at the temperature indicated.

Table A.7.3.2(g) IG-55 Total Flooding Quantity (U.S. Units)

Temp (t) ($^\circ$F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c] Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
−40	9.02	0.5245	0.6034	0.6875	0.7777	0.8749	0.9801	1.0949	1.2213
−30	9.24	0.5122	0.5893	0.6715	0.7596	0.8545	0.9573	1.0694	1.1928
−20	9.45	0.5006	0.5759	0.6563	0.7423	0.8351	0.9355	1.0451	1.1657
−10	9.67	0.4895	0.5631	0.6417	0.7258	0.8165	0.9147	1.0219	1.1398
0	9.88	0.4788	0.5508	0.6277	0.7100	0.7987	0.8948	0.9996	1.1150
10	10.10	0.4686	0.5391	0.6143	0.6949	0.7817	0.8757	0.9783	1.0912
20	10.31	0.4588	0.5279	0.6015	0.6804	0.7654	0.8575	0.9579	1.0685
30	10.53	0.4495	0.5171	0.5892	0.6665	0.7498	0.8400	0.9384	1.0466

Temp (t) (°F)[a]	Specific Vapor Volume (s) (ft^3/lb)[b]	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]							
		Design Concentration (% by Volume)[d]							
		34	38	42	46	50	54	58	62
40	10.74	0.4405	0.5067	0.5774	0.6532	0.7348	0.8232	0.9196	1.0257
50	10.96	0.4318	0.4968	0.5661	0.6404	0.7204	0.8070	0.9015	1.0056
60	11.17	0.4235	0.4872	0.5552	0.6280	0.7065	0.7915	0.8842	0.9862
70	11.39	0.4155	0.4780	0.5447	0.6162	0.6931	0.7765	0.8675	0.9676
80	11.60	0.4078	0.4692	0.5346	0.6048	0.6803	0.7621	0.8514	0.9497
90	11.82	0.4004	0.4606	0.5249	0.5938	0.6679	0.7483	0.8359	0.9324
100	12.03	0.3932	0.4524	0.5155	0.5832	0.6560	0.7349	0.8210	0.9157
110	12.25	0.3863	0.4445	0.5065	0.5729	0.6445	0.7220	0.8066	0.8996
120	12.46	0.3797	0.4368	0.4977	0.5630	0.6333	0.7095	0.7927	0.8841
130	12.68	0.3732	0.4294	0.4893	0.5535	0.6226	0.6975	0.7792	0.8691
140	12.89	0.3670	0.4222	0.4811	0.5442	0.6122	0.6859	0.7662	0.8546
150	13.11	0.3610	0.4153	0.4732	0.5353	0.6022	0.6746	0.7537	0.8406
160	13.32	0.3552	0.4086	0.4656	0.5267	0.5925	0.6637	0.7415	0.8270
170	13.54	0.3495	0.4021	0.4582	0.5183	0.5830	0.6532	0.7297	0.8139
180	13.75	0.3441	0.3958	0.4510	0.5102	0.5739	0.6430	0.7183	0.8012
190	13.97	0.3388	0.3897	0.4441	0.5024	0.5651	0.6331	0.7072	0.7888
200	14.18	0.3336	0.3838	0.4374	0.4947	0.5565	0.6235	0.6965	0.7769

Notes:

~~(1) V_s = the term X = ln [100/(100 −C)] gives the volume at a rated concentration (%) and temperature to reach an air-agent mixture at the end of flooding time in a volume of 1 ft^3 .~~

(~~2~~ 1) The manufacturer's listing specifies the temperature range for operation.

[a] t [temperature (°F)] = design temperature in the hazard area.

[b] s [specific volume (ft^3/lb)] = specific volume of IG-55 vapor can be approximated by $s = 9.8809 + 0.0215t$, where t = temperature (°F).

[c] X [agent volume requirements (lb/ft^3)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (ft^3/lb)] = specific volume of inert gas agent at 70°F and 14.7 psi absolute

[d] C [concentration (%)] = volumetric concentration of IG-55 in air at the temperature indicated.

Table A.7.3.2(h) IG-55 Total Flooding Quantity (SI Units)

Temp (t) (°C)[a]	Specific Vapor Volume (s)	Volume Requirements of Agent per Unit Volume of Hazard ($V_{agent}/V_{enclosure}$)[c]
		Design Concentration (% by Volume)[d]

	(m^3/kg)[b]	34	38	42	46	50	54	58	62
−40	0.5630	0.5245	0.6034	0.6876	0.7778	0.8749	0.9801	1.0950	1.2213
−35	0.5751	0.5134	0.5907	0.6731	0.7614	0.8565	0.9595	1.0719	1.1956
−30	0.5872	0.5029	0.5785	0.6592	0.7457	0.8388	0.9397	1.0498	1.1710
−25	0.5993	0.4927	0.5668	0.6459	0.7306	0.8219	0.9208	1.0286	1.1473
−20	0.6114	0.4829	0.5556	0.6331	0.7162	0.8056	0.9025	1.0083	1.1246
−15	0.6235	0.4736	0.5448	0.6208	0.7023	0.7900	0.8850	0.9887	1.1028
−10	0.6356	0.4646	0.5345	0.6090	0.6889	0.7750	0.8682	0.9699	1.0818
−5	0.6477	0.4559	0.5245	0.5976	0.6760	0.7605	0.8520	0.9518	1.0616
0	0.6598	0.4475	0.5149	0.5867	0.6636	0.7465	0.8363	0.9343	1.0421
5	0.6719	0.4395	0.5056	0.5761	0.6517	0.7331	0.8213	0.9175	1.0233
10	0.6840	0.4317	0.4966	0.5659	0.6402	0.7201	0.8067	0.9013	1.0052
15	0.6961	0.4242	0.4880	0.5561	0.6290	0.7076	0.7927	0.8856	0.9878
20	0.7082	0.4169	0.4797	0.5466	0.6183	0.6955	0.7792	0.8705	0.9709
25	0.7203	0.4099	0.4716	0.5374	0.6079	0.6838	0.7661	0.8558	0.9546
30	0.7324	0.4032	0.4638	0.5285	0.5979	0.6725	0.7534	0.8417	0.9388
35	0.7445	0.3966	0.4563	0.5199	0.5881	0.6616	0.7412	0.8280	0.9236
40	0.7566	0.3903	0.4490	0.5116	0.5787	0.6510	0.7293	0.8148	0.9088
45	0.7687	0.3841	0.4419	0.5036	0.5696	0.6408	0.7179	0.8020	0.8945
50	0.7808	0.3782	0.4351	0.4958	0.5608	0.6308	0.7067	0.7895	0.8806
55	0.7929	0.3724	0.4284	0.4882	0.5522	0.6212	0.6959	0.7775	0.8672
60	0.8050	0.3668	0.4220	0.4809	0.5439	0.6119	0.6855	0.7658	0.8541
65	0.8171	0.3614	0.4157	0.4737	0.5359	0.6028	0.6753	0.7545	0.8415
70	0.8292	0.3561	0.4097	0.4668	0.5281	0.5940	0.6655	0.7434	0.8292
75	0.8413	0.3510	0.4038	0.4601	0.5205	0.5855	0.6559	0.7328	0.8173
80	0.8534	0.3460	0.3981	0.4536	0.5131	0.5772	0.6466	0.7224	0.8057
85	0.8655	0.3412	0.3925	0.4472	0.5059	0.5691	0.6376	0.7123	0.7944
90	0.8776	0.3365	0.3871	0.4411	0.4989	0.5613	0.6288	0.7024	0.7835
95	0.8897	0.3319	0.3818	0.4351	0.4922	0.5536	0.6202	0.6929	0.7728
100	0.9018	0.3274	0.3767	0.4292	0.4856	0.5462	0.6119	0.6836	0.7625

Note: The manufacturer's listing specifies the temperature range for operation.

[a] *t* [temperature (°C)] = design temperature in the hazard area.

[b] *s* [specific volume (m^3/kg)] = specific volume of IG-55 vapor can be approximated by $s = 0.6598 + 0.00242t$, where t = temperature (°C).

[c] *X* [agent volume requirements (m^3 /m^3) = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{s_0}{s}\right) \times \log_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{s_0}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

where:

s_0 [specific volume (m^3/kg)] = specific volume of inert gas agent at 21°C and 1.013 bar absolute

[d] *C* [concentration (%)] = volumetric concentration of IG-55 in air at the temperature indicated.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu Jun 29 15:31:47 EDT 2023

Committee Statement

Committee Statement: Deleted note (1) from Table A.7.3.2(g), as the associated variable is not used anywhere in the section.

Response Message: FR-29-NFPA 2001-2023

First Revision No. 16-NFPA 2001-2023 [Section No. B.1.1]

B.1.1 Toxicological Effects of Halocarbon Agents.

Table B.1.1 provides information on the toxicological effects of halocarbon agents covered by this standard. The no observable adverse effect level (NOAEL) is the highest concentration at which no adverse physiological or toxicological effect has been observed. The lowest observable adverse effect level (LOAEL) is the lowest concentration at which an adverse physiological or toxicological effect has been observed.

An appropriate protocol measures the effect in a stepwise manner such that the interval between the LOAEL and NOAEL is sufficiently small to be acceptable to the competent regulatory authority. The EPA includes in its Significant New Alternatives Policy (SNAP) evaluation this aspect (of the rigor) of the test protocol.

The EPA considers cardiac sensitization during SNAP evaluation, as well as a variety of other escape impairing effects, such as central nervous system effects.

Table B.1.1 Toxicity Information for Halocarbon Clean Agents

Agent	LC_{50} or ALC (%)	NOAEL (%)	LOAEL (%)
FIC-13I1	>12.8	0.2	0.4
FK-5-1-12	>10.0	10	>10.0
HCFC Blend A	64	10	>10.0
HCFC-124	23–29	1	2.5
HFC-125	>70	7.5	10
HFC-227ea	>80	9	10.5
HFC-23	>65	30	>30
HFC-236fa	>45.7	10	15
HFC Blend B	56.7*	5.0*	7.5*
HB-55	>11	8.7	>8.7

Notes:

(1) LC_{50} is the concentration lethal to 50 percent of a rat population during a 4-hour exposure. The ALC is the approximate lethal concentration.

(2) The cardiac sensitization levels are based on the observance or nonobservance of serious heart arrhythmias in a dog. The usual protocol is a 5-minute exposure followed by a challenge with epinephrine.

(3) High concentration values are determined with the addition of oxygen to prevent asphyxiation.

*These values are for the largest component of the blend (HFCB 134A).

~~For halocarbons covered in this standard, the NOAEL and LOAEL are based on the toxicological effect known as cardiac sensitization.~~ *Cardiac Sensitization.* Cardiac sensitization occurs when a chemical causes an increased sensitivity of the heart to adrenaline, a naturally occurring substance produced by the body during times of stress, leading to the sudden onset of irregular heartbeats and possibly heart attack. Cardiac sensitization is measured in dogs after they have been exposed to a halocarbon agent for 5 minutes. At the 5-minute time period, an external dose of adrenaline (i.e., epinephrine) is administered and an effect is recorded if the dog experiences cardiac sensitization. The cardiac sensitization potential as measured in dogs is a highly conservative indicator of the potential in humans. The conservative nature of the cardiac sensitization test stems from several factors; the two most pertinent are as follows:

(1) Very high doses of adrenaline are given to the dogs during the testing procedure (doses are more than 10 times higher than the highest levels secreted by humans under maximum stress).

(2) Four to ten times more halocarbon is required to cause cardiac sensitization in the absence of externally administered adrenaline, even in artificially created situations of

stress or fright in the dog test.

Because the cardiac sensitization potential is measured in dogs, a means of providing human relevance to the concentration at which this cardiac sensitization occurs (LOAEL) has been established through the use of physiologically based pharmacokinetic (PBPK) modeling.

A PBPK model is a computerized tool that describes time-related aspects of a chemical's distribution in a biological system. The PBPK model mathematically describes the uptake of the halocarbon into the body and the subsequent distribution of the halocarbon to the areas of the body where adverse effects can occur. For example, the model describes the breathing rate and uptake of the halocarbon from the exposure atmosphere into the lungs. From there, the model uses the blood flow bathing the lungs to describe the movement of the halocarbon from the lung space into the arterial blood that directly feeds the heart and vital organs of the body.

It is the ability of the model to describe the halocarbon concentration in human arterial blood that provides its primary utility in relating the dog cardiac sensitization test results to a human who is unintentionally exposed to the halocarbon. The concentration of halocarbon in the dog arterial blood at the time the cardiac sensitization event occurs (5-minute exposure) is the critical arterial blood concentration, and this blood parameter is the link to the human system. Once this critical arterial blood concentration has been measured in dogs, the EPA-approved PBPK model simulates how long it will take the human arterial blood concentration to reach the critical arterial blood concentration (as determined in the dog test) during human inhalation of any particular concentration of the halocarbon agent. As long as the simulated human arterial concentration remains below the critical arterial blood concentration, the exposure is considered safe. Inhaled halocarbon concentrations that produce human arterial blood concentrations equal to or greater than the critical arterial blood concentration are considered unsafe because they represent inhaled concentrations that potentially yield arterial blood concentrations where cardiac sensitization events occur in the dog test. Using these critical arterial blood concentrations of halocarbons as the ceiling for allowable human arterial concentrations, any number of halocarbon exposure scenarios can be evaluated using this modeling approach.

For example, in the dog cardiac sensitization test on Halon 1301, a measured dog arterial blood concentration of 25.7 mg/L is measured at the effect concentration (LOAEL) of 7.5 percent after a 5-minute exposure to Halon 1301 and an external intravenous adrenaline injection. The PBPK model predicts the time at which the human arterial blood concentration reaches 25.7 mg/L for given inhaled Halon 1301 concentrations. Using this approach, the model also predicts that at some inhaled halocarbon concentrations, the critical arterial blood concentration is never reached; thus, cardiac sensitization will not occur. Accordingly, in the tables in 4.3.2.4, the time is arbitrarily truncated at 5 minutes, because the dogs were exposed for 5 minutes in the original cardiac sensitization testing protocols.

The time value, estimated by the EPA-approved and peer-reviewed PBPK model or its equivalent, is that required for the human arterial blood level for a given halocarbon to equal the arterial blood level of a dog exposed to the LOAEL for 5 minutes.

For example, if a system is designed to achieve a maximum concentration of 12.0 percent HFC-125, means should be provided such that personnel are exposed for no longer than 1.67 minutes. Examples of suitable exposure-limiting mechanisms include self-contained breathing apparatuses and planned and rehearsed evacuation routes.

The requirement for pre-discharge alarms and time delays is intended to prevent human exposure to agents during firefighting. However, in the unlikely circumstance that an accidental discharge occurs, restrictions on the use of certain halocarbon agents covered in this standard are based on the availability of PBPK modeling information. For those halocarbon agents in which modeling information is available, means should be provided to limit the exposure to those concentrations and times specified in the tables in 4.3.2.4. The concentrations and times given in the tables are those that have been predicted to limit the human arterial blood concentration to below the critical arterial blood concentration associated with cardiac sensitization. For halocarbon agents where the needed data are unavailable, the agents are restricted based on whether the protected space is normally occupied or unoccupied and how quickly egress from the area can be effected. Normally occupied areas are those intended for human occupancy. Normally unoccupied areas are those in which personnel can be present

from time to time. Therefore, a comparison of the cardiac sensitization values to the intended design concentration would determine the suitability of a halocarbon for use in normally occupied or unoccupied areas.

In specialized applications that require a very high rate of discharge, where agent concentration is measured at a much faster rate than human respiration periods, brief pulses of high concentration levels can be observed. In these cases, a time-weighted average of the concentration level with a period of one second can be used to compare to the safe levels given in the tables in 4.3.2.4.

Toxicity of Blends. When test data using the actual blend is available, that data should be used. If test data using the actual blend is not available, a calculated value of the NOAEL and LOAEL can be considered. See ANSI/ASHRAE 34, *Designation and Safety Classification of Refrigerants* , for additional information.

Submitter Information Verification

Committee: GFE-AAA

Submittal Date: Thu May 11 09:04:36 EDT 2023

Committee Statement

Committee Statement: Proposed changes provide further clarification of EPA SNAP evaluation. Provides additional information on toxicological considerations for halocarbon agents. Additional information was provided on the evaluation of blends.

Response Message: FR-16-NFPA 2001-2023

Public Input No. 4-NFPA 2001-2022 [Section No. B.1.1]

First Revision No. 28-NFPA 2001-2023 [Section No. B.1.2]

B.1.2 Toxicological Effects of Hydrogen Fluoride.

Clearly, longer exposure of the agent to high temperatures would produce greater concentrations of these gases. The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the agent to the elevated temperature if the concentration of the breakdown products must be minimized. In most cases the area would be untenable for human occupancy due to the heat and breakdown products of the fire itself.

These decomposition products have a sharp, acrid odor, even in minute concentrations of only a few parts per million. This characteristic provides a built-in warning system for the agent but at the same time creates a noxious, irritating atmosphere for those who must enter the hazard following a fire.

Background and toxicology of hydrogen fluoride. Hydrogen fluoride (HF) vapor can be produced in fires as a breakdown product of fluorocarbon fire-extinguishing agents and in the combustion of fluoropolymers.

The significant toxicological effects of HF exposure occur at the site of contact. By the inhalation route, significant deposition is predicted to occur in the most anterior (i.e., front part) region of the nose and extending back to the lower respiratory tract (i.e., airways and lungs) if sufficient exposure concentrations are achieved. The damage induced at the site of contact with HF is characterized by extensive tissue damage and cell death (i.e., necrosis) with inflammation. One day after a single, 1-hour exposure of rats to HF concentrations of 950 ppm to 2600 ppm, tissue injury was limited exclusively to the anterior section of the nose (DuPont, 1990). No effects were seen in the trachea or lungs.

At high concentrations of HF (about 200 ppm), human breathing patterns would be expected to change primarily from nose breathing to primarily mouth breathing. This change in breathing pattern determines the deposition pattern of HF into the respiratory tract, either upper respiratory tract (i.e., nose breathing) or lower respiratory tract (i.e., mouth breathing). In studies conducted by Dalby (1996), rats were exposed by nose-only or mouth-only breathing. In the mouth-only breathing model, rats were exposed to various concentrations of HF through a tube placed in the trachea, thereby bypassing the upper respiratory tract. This exposure method is considered to be a conservative approach for estimating a “worst-case” exposure in which a person would not breathe through the nose but inhale through the mouth, thereby maximizing the deposition of HF into the lower respiratory tract.

In the nose-only breathing model, 2-minute or 10-minute exposures of rats to about 6400 or 1700 ppm, respectively, produced similar effects; that is, no mortality resulted but significant cell damage in the nose was observed. In contrast, marked differences in toxicity were evident in the mouth-only breathing model. Indeed, mortality was evident following a 10-minute exposure to a concentration of about 1800 ppm and a 2-minute exposure to about 8600 ppm. Significant inflammation of the lower respiratory tract was also evident. Similarly, a 2-minute exposure to about 4900 ppm produced mortality and significant nasal damage. However, at lower concentrations (950 ppm) following a 10-minute exposure or 1600 ppm following a 2-minute exposure, no mortality and only minimal irritation were observed.

Numerous other toxicology studies have been conducted in experimental animals for longer durations, such as 15, 30, or 60 minutes. In nearly all of these studies, the effects of HF were generally similar across all species; that is, severe irritation of the respiratory tract was observed as the concentration of HF was increased.

In humans, an irritation threshold appears to be at about 3 ppm, where irritation of the upper airways and eyes occurs. In prolonged exposure at about 5 ppm, redness of the skin has also resulted. In controlled human exposure studies, humans are reported to have tolerated mild nasal irritation (subjective response) at 32 ppm for several minutes (Machle et al., 1934). Exposure of humans to about 3 ppm for an hour produced slight eye and upper respiratory tract irritation. Even with an increase in exposure concentration (up to 122 ppm) and a decrease in exposure duration to about 1 minute, skin, eye, and respiratory tract irritation occurs (Machle and Kitzmiller, 1935).

Meldrum (1993) proposed the concept of the dangerous toxic load (DTL) as a means of predicting the effects of, for example, HF in humans. Meldrum developed the argument that the toxic effects of certain chemicals tend to follow Haber’s law:

$$C \times t = k \quad \text{[B.1.2]}$$

where:

C = concentration

t = time

k = constant

The available data on the human response to inhalation of HF were considered insufficient to provide a basis for establishing a DTL. Therefore, it was necessary to use the available animal lethality data to establish a model for the response in humans. The DTL is based on an estimate of 1 percent lethality in an exposed population of animals. Based on the analysis of animal lethality data, the author determined that the DTL for HF is 12,000 ppm-min. Although this approach appears reasonable and consistent with mortality data in experimental animals, the predictive nature of this relationship for nonlethal effects in humans has not been demonstrated.

Potential human health effects and risk analysis in fire scenarios. It is important for a risk analysis to distinguish between normally healthy individuals, such as firefighters, and those with compromised health. Exposure to higher concentrations of HF would be expected to be tolerated more in healthy individuals, whereas equal concentrations can have escape-impairing effects in those with compromised health. The following discussion assumes that the effects described at the various concentrations and durations are for the healthy individual.

Inflammation (i.e., irritation) of tissues represents a continuum from “no irritation” to “severe, deep penetrating” irritation. Use of the terms *slight*, *mild*, *moderate*, and *severe* in conjunction with irritation represents an attempt to quantify this effect. However, given the large variability and sensitivity of the human population, differences in the degree of irritation from exposure to HF are expected to occur. For example, some individuals can experience mild irritation to a concentration that results in moderate irritation in another individual.

At concentrations of <50 ppm for up to 10 minutes, irritation of upper respiratory tract and the eyes would be expected to occur. At these low concentrations, escape-impairing effects would not be expected in the healthy individual. As HF concentrations increase to 50 ppm to 100 ppm, an increase in irritation is expected. For short duration (10 to 30 minutes), irritation of the skin, eyes, and respiratory tract would occur. At 100 ppm for 30 to 60 minutes, escape-impairing effects would begin to occur, and continued exposure at 200 ppm and greater for an hour could be lethal in the absence of medical intervention. As the concentration of HF increases, the severity of irritation increases, and the potential for delayed systemic effects also increases. At about 100 to 200 ppm of HF, humans would also be expected to shift their breathing pattern to mouth breathing. Therefore, deeper lung irritation is expected. At greater concentrations (>200 ppm), respiratory discomfort, pulmonary (i.e., deep lung) irritation, and systemic effects are possible. Continued exposure at these higher concentrations can be lethal in the absence of medical treatment.

Generation of HF from fluorocarbon fire-extinguishing agents represents a potential hazard. In the foregoing discussion, the duration of exposure was indicated for 10 to 60 minutes. In fire conditions in which HF would be generated, the actual exposure duration would be expected to be less than 10 minutes and in most cases less than 5 minutes. As Dalby (1996) showed, exposing mouth-breathing rats to HF concentrations of about 600 ppm for 2 minutes was without effect. Similarly, exposing mouth-breathing rats to a HF concentration of about 300 ppm for 10 minutes did not result in any mortality or respiratory effects. Therefore, one could surmise that humans exposed to similar concentrations for less than 10 minutes would be able to survive such concentrations. However, caution needs to be employed in interpreting these data. Although the toxicity data would suggest that humans could survive these large concentrations for less than 10 minutes, those individuals with compromised lung function or those with cardiopulmonary disease can be more susceptible to the effects of HF. Furthermore, even in the healthy individual, irritation of the upper respiratory tract and eyes would be expected, and escape could be impaired.

Table B.1.2 provides potential human health effects of hydrogen fluoride in healthy individuals.

Occupational exposure limits have been established for HF. The limit set by the American Conference of Governmental Industrial Hygienists (ACGIH)~~, the Threshold Limit Value~~

~~(TLV®),~~ represents exposure of normally healthy workers for an 8-hour workday or a 40-hour workweek. For HF, the limit established is 3 ppm, which represents a ceiling limit; that is, the airborne concentration that should not be exceeded at any time during the workday. This limit is intended to prevent irritation and possible systemic effects with repeated, long-term exposure. This and similar time-weighted average limits are not considered relevant for fire-extinguishing use of fluorocarbons during emergency situations. However, these limits might need to be considered in clean-up procedures where high levels of HF were generated.

Table B.1.2 Potential Human Health Effects of Hydrogen Fluoride in Healthy Individuals

Exposure Time	Concentration of Hydrogen Fluoride (ppm)	Reaction
2 minutes	<50	Slight eye and nasal irritation
	50–100	Mild eye and upper respiratory tract irritation
	100–200	Moderate eye and upper respiratory tract irritation; slight skin irritation
	>200	Moderate irritation of all body surfaces; increasing concentration may be escape impairing
5 minutes	<50	Mild eye and nasal irritation
	50–100	Increasing eye and nasal irritation; slight skin irritation
	100–200	Moderate irritation of skin, eyes, and respiratory tract
	>200	Definite irritation of tissue surfaces; will cause escape-impairing effects at increasing concentrations
10 minutes	<50	Definite eye, skin, and upper respiratory tract irritation
	50–100	Moderate irritation of all body surfaces
	100–200	Moderate irritation of all body surfaces; escape-impairing effects likely
	>200	Escape-impairing effects will occur; increasing concentrations can be lethal without medical intervention

In contrast to the limit set by ACGIH ~~TLV~~ , the American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline (ERPG) represents limits established for emergency release of chemicals. The *ERPG/WEEL Handbook* provides a quick reference for these limits, which are established to also account for sensitive populations, such as those with compromised health. The ERPG limits are designed to assist emergency response personnel in planning for catastrophic releases of chemicals. These limits are not developed to be used as “safe” limits for routine operations. However, in the case of fire-extinguishing use and generation of HF, these limits are more relevant than other time-weighted average limits ~~such as the TLV~~ . The ERPG limits consist of three levels for use in emergency planning and are typically 1-hour values; 10-minute values have also been established for HF. For the 1-hour limits, the ERPG 1 (2 ppm) is based on odor perception and is below the concentration at which mild sensory irritation has been reported (3 ppm). ERPG 2 (20 ppm) is the most important guideline value set and is the concentration at which mitigating steps should be taken, such as evacuation, sheltering, and donning masks. This level should not impede escape or cause irreversible health effects and is based mainly on the human irritation data obtained by Machle et al. (1934) and Largent (1960). ERPG 3 (50 ppm) is based on animal data and is the maximum nonlethal level for nearly all individuals. This level could be lethal to some susceptible people. The 10-minute values established for HF and used in emergency planning in fires where HF vapor is generated are ERPG 3 = 170 ppm, ERPG 2 = 50 ppm, and ERPG 1 = 2 ppm.

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First Revision No. 13-NFPA 2001-2023 [Chapter G]

Annex G Informational References

G.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.

G.1.1 NFPA Publications.

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NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, ~~2020~~ 2023 edition.

NFPA 70®, *National Electrical Code®*, ~~2020~~ 2023 edition.

NFPA 72®, *National Fire Alarm and Signaling Code®*, ~~2022~~ 2025 edition.

NFPA 75, *Standard for the Fire Protection of Information Technology Equipment*, ~~2020~~ 2024 edition.

NFPA 77, *Recommended Practice on Static Electricity*, ~~2019~~ 2024 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, ~~2021~~ 2024 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*, ~~2021~~ 2024 edition.

G.1.2 Other Publications.

G.1.2.1 ACGIH Publications.

American Conference of Governmental Industrial Hygienists, ~~1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634~~ 3640 Park 42 Drive, Cincinnati, OH 45241 .

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G.1.2.2 AIHA Publications.

American Industrial Hygiene Association, 3141 Fairview Park Drive, Suite 777, Falls Church, VA 22042.

ERPG/WEEL Handbook, ~~2019~~ 2020 .

G.1.2.3 ASHRAE Publications.

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G.1.2.6 CAN/ CGSB Publications.

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CAN/CGSB-149.10-M86, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*, 2019.

G.1.2.7 CGA Publications.

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HARC Code of Practice for Use of Recycled Halogenated Clean Agents, 2015.

G.1.2.10 IMO Publications.

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G.1.2.11 ISO Publications.

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G.1.2.13 SFPE Publications.

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G.1.2.14 UL Publications.

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

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