Technical Committee on Gaseous Fire Extinguishing Systems

M E M O R A N D U M

DATE: February 18, 2016

TO: Principal and Alternate Members of the Technical Committee on Gaseous Fire Extinguishing Systems

FROM: Barry Chase, NFPA Staff Liaison
Office: (617) 984-7259 Email: bchase@nfpa.org

SUBJECT: **AGENDA – NFPA 12, 12A, and 2001 First Draft Meeting (Fall 2017)**
March 17-18, 2016, Four Points by Sheraton French Quarter, New Orleans, LA

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1. Call to Order – March 17, 2016, 8:00 am Central
2. Introductions and Attendance
3. Chair's Comments and Agenda Review
4. NFPA Staff Liaison Presentation
   a. NFPA Standards Development Process
   b. Fall 2017 Revision Cycle Schedule
   c. NFPA Resources
5. Approval of Previous Meeting Minutes
   a. March 26-27, 2014 – NFPA 12, 12A, and 2001 Second Draft Meeting (San Antonio, TX)
6. NFPA 12 First Draft
   a. Address Public Input (17 submittals, ATTACHED)
   b. Committee Revisions
7. NFPA 12A First Draft
   a. Address Public Input (7 submittals, ATTACHED)
   b. Committee Revisions
8. NFPA 2001 First Draft
   a. Address Public Input (38 submittals, ATTACHED)
   b. Committee Revisions
9. Other Business
10. Next Meeting

Please submit requests for additional agenda items to the chair at least seven days prior to the meeting, and notify the chair and staff liaison as soon as possible if you plan to introduce any committee revisions at the meeting.

All NFPA Technical Committee meetings are open to the public. Please contact me for information on attending a meeting as a guest. Read NFPA's Regulations Governing the Development of NFPA Standards (Section 3.3.3.3) for further information.

Additional Meeting Information:
See the Meeting Notice on the Document Information Page (www.nfpa.org/12next, www.nfpa.org/12Anext or www.nfpa.org/2001next) for meeting location details. If you have any questions, please feel free to contact **Diane Matthews**, *Administrator, Technical Projects*, at 617-984-7407 or by email dmatthews@nfpa.org.

C. Standards Administration

Attachment #1

NFPA 12 *Standard on Carbon Dioxide Extinguishing Systems*

- Public Input

Public Input No. 2-NFPA 12-2015 [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 70® , *National Electrical Code®,* 2014 edition.

NFPA 72® , *National Fire Alarm and Signaling Code,* 2013 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 ~~/IEEE C2,~~ ~~*National Electrical Safety Code*~~ ~~, 2012.ANSI Z535~~ Z535 **.2** , *Standard for Environmental and Facility Safety Signs*, 2011.

2.3.2 API Publications.

American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, Pre–July 1, 1961.

2.3.3 ASME Publications.

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

ASME B31.1, *Power Piping* ~~*Code*~~ , ~~2012~~ **2014** .

2.3.4 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C 700, West Conshohocken, PA 19428-2959.

ASTM A53**/A53M** , *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2012.

ASTM A106**/A106M** , *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, ~~2011~~ **2014** .

ASTM A120, *Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses*, 1984 (~~withdrawn 1987~~ **Superseded by ASTM A53/A53M**).

ASTM A182**/A182M** , *Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*, ~~2012~~ **2015** .

2.3.5 CGA Publications.

Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA ~~G6~~ **G-6** **.2** , *Commodity Specification for Carbon Dioxide*, 2011.

2.3.6 CSA Publications.

Canadian Standards Association, 5060 Spectrum Way, Mississauga **CSA Group, 178 Rexdale Blvd., Toronto , ON,** L4W 5N6 **Canada ,** Canada **M9W 1R3** .

CSA C22.1, *Canadian Electrical Code*, **2015** .

2.3.7 IEEE Publications.

IEEE, 445 and 501 Hoes Lanes, Piscataway, NJ 08854-4141.

IEEE C2, National Electrical Safety Code (NESC), 2012.

2.3. 7 8 U.S. Government Publications.

U.S. Government Printing Government **Publishing** Office, Washington, DC 20402 **732 North Capitol Street, NW, Washinton, DC 20401-0001** .

Title 46, Code of Federal Regulations, Part 58.20.

Title 46, Code of Federal Regulations, Part 72.

Title 49, Code of Federal Regulations, Parts 171–190 (Department of Transportation).

Coward, H. F., and G. W. Jones, *Limits of Flammability of Gases and Vapors*, U.S. Bureau of Mines Bulletin 503,1952.

Zabetakis, Michael G., *Flammability Characteristics of Combustible Gases and Vapors*, U.S. Bureau of Mines Bulletin 627, 1965.

2.3. 8 9 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 1, *Fire Code* , 2015 edition.

NFPA 122, *Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities,* 2015 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* 2012 edition.

Statement of Problem and Substantiation for Public Input

Referenced current SDO names, addresses, standard names, numbers, and editions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3-NFPA 12-2015 [Chapter H]	

Submitter Information Verification

Submitter Full Name: Aaron Adamczyk
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 19 16:06:06 EDT 2015

Public Input No. 23-NFPA 12-2016 [Section No. 2.2]

2.2 NFPA Publications.

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

NFPA 4, Standar for Integrated Fire Protection and Life Safety System Testing, 2015 edition.

NFPA 70® , *National Electrical Code®,* 2014 edition.

NFPA 72® , *National Fire Alarm and Signaling Code,* 2013 edition.

Statement of Problem and Substantiation for Public Input

Adding to support Public input #22, if accepted.

Submitter Information Verification

Submitter Full Name:	Kimberly Gruner
Organization:	Fike Corporation
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Jan 06 14:58:51 EST 2016

Public Input No. 8-NFPA 12-2015 [Section No. 3.3.3]

3.3.3 Inspection.

A ~~visible~~ visual examination of a system or portion thereof to verify that it appears to be in operating condition and is free of physical damage. [**820,** 2012]

Statement of Problem and Substantiation for Public Input

This text is extracted from NFPA 820, but does not match what is in NFPA 820. Section 3.3.34 of NFPA 820 uses the term visual, which is more appropriate.

Submitter Information Verification

Submitter Full Name: Jim Muir
Organization: Building Safety Division, Clark County, WA
Affilliation: NFPAs Building Code Development Committee (BCDC)
Street Address:
City:
State:
Zip:
Submittal Date: Mon Nov 09 20:40:04 EST 2015

Public Input No. 9-NFPA 12-2015 [Section No. 4.4.1.1]

4.4.1.1

Specifications for carbon dioxide fire-extinguishing systems shall be prepared under the supervision of a person fully experienced and qualified in the design of carbon dioxide extinguishing systems and with the ~~advice~~ approval of the authority having jurisdiction.

Statement of Problem and Substantiation for Public Input

This Public Input offers a change that would more closely relate to the traditional role of the AHJ and avoid the implication of participation in the system design by providing design advice. The term "advice" does not impart or indicate authority, and it opens the door to concerns about liability in the wake of an incident involving an extinguishing system about which an AHJ has "advised." This is similar to a Public Input submitted to NFPA 12A, section 5.1.1.

Submitter Information Verification

Submitter Full Name: Jim Muir

Organization: Building Safety Division, Clark County, WA

Affilliation: NFPAs Building Code Development Committee (BCDC)

Street Address:

City:

State:

Zip:

Submittal Date: Mon Nov 09 20:42:31 EST 2015

Public Input No. 22-NFPA 12-2016 [New Section after 4.4.1.2]

4.4.1.3

Individual Systems that are integrated with the Carbon Dioxide Extinguishing Sytem shall be identified in the specification for plannned testing, documentation, and maintenance in accordance wtih NFPA 4 Standard for Integrated Fire Protection and Life Safety System Testing.

Statement of Problem and Substantiation for Public Input

Many installations utilize various individual systems (Carbon Dioxide, Fire Alarm or signaling system, emergency communication system, fire doors, dampers, elevators, smoke control, HVAC, supervising station, etc.) for fire protection and life safety where each may utilize their own code, standard, or acceptance criteria. NFPA 4 is a new standard that provides requirements for testing integrated systems together so that the entire fire protection and life safety system objective is accomplished.

Submitter Information Verification

Submitter Full Name: Kimberly Gruner

Organization: Fike Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jan 06 14:51:31 EST 2016

Public Input No. 20-NFPA 12-2016 [Section No. 4.7.1.5.1.3]

4.7.1.5.1.3

Flanged joints downstream of stop valves or in systems with no stop valves shall be permitted to be Class 300.

4.7.1.5.1.4

Threaded unions shall, as a minimum, be equivalent to Class 2000 forged steel.

Statement of Problem and Substantiation for Public Input

Currently there are two requirements under this one section. There have been reports that installations utilizing threaded unions are following the fitting requirements in Section 4.7.1.5.1.1 when actually the unions fall under a threaded flange. Separating the requirement pertaining to threaded unions will hopefully call more attention to it and stop confusion in the field.

Submitter Information Verification

Submitter Full Name: Katherine Adrian

Organization: Tyco Fire Protection Products

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jan 04 14:36:22 EST 2016

Public Input No. 21-NFPA 12-2016 [Section No. 4.7.1.5.1.4]

4.7.1.5.1. ~~4~~ 5

Stainless steel fittings shall be Type 304 or 316, wrought or forged in accordance with ASTM A182, threaded or socket weld, for all sizes, ⅛ in. (3 mm) through 4 in. (100 mm).

Statement of Problem and Substantiation for Public Input

changing section due to public input 20

Submitter Information Verification

Submitter Full Name: Katherine Adrian

Organization: Tyco Fire Suppression & Buildi

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jan 04 14:43:18 EST 2016

Public Input No. 16-NFPA 12-2015 [Section No. 4.7.2 [Excluding any Sub-Sections]]

> The piping system shall ~~be securely supported with due allowance for agent thrust forces and thermal expansion and contraction and shall~~ not be subject to mechanical, chemical, or other damage.

Statement of Problem and Substantiation for Public Input

Removes unenforceable language.

Submitter Information Verification

Submitter Full Name:	David Hague
Organization:	Liberty Mutual Insurance
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Dec 23 10:09:59 EST 2015

Public Input No. 17-NFPA 12-2015 [Section No. 4.7.2.1]

4.7.2.1

~~Where explosions are possible, the piping system shall be hung from supports that are least likely to be displaced.~~

Statement of Problem and Substantiation for Public Input

Removes unenforceable language.

Submitter Information Verification

Submitter Full Name: David Hague

Organization: Liberty Mutual Insurance

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 23 10:12:30 EST 2015

Public Input No. 18-NFPA 12-2015 [New Section after 4.7.5.3.2]

TITLE OF NEW CONTENT

Type your content here ...

4.7.6 Pipe Hangers and Supports . All pipe hangers and supports shall be in accordance with ANSI B31.1

4.7.6.1 All pipe hangers and supports shall be attached directly to the building structure.

4.7.6.2 Rigid hangers are required wherever a change in direction or elevation occurs. **4.7.6.3** On long straight runs in excess of 20ft., every other hanger shall be rigid.

4.7.6.4 All hangers and components shall be ferrous.

4.7.6.5 All piping shall be attached to rigid hangers by means of u-bolts fastened with double nuts.

4.7.6.5.1 The pipe shall be free to move longitudinally within the u-bolt unless the piping design requires it to be anchored.

A.4.7.6.5.1 Hangers and pipe should be designed to allow longitudinal movement due to agent thrust forces and thermal expansion.

4.7.6.5.6 All pipe supports shall be designed and installed to prevent movement of supported pipe during system discharge.

4.7.6.5.7 Where explosions are possible, the piping system shall be supported to prevent displacement.

4.7.6.5.8 The maximum distance between hangers shall not exceed that specified in Table 4.7.6.5.8.

4.7.6.5.9 Where required, seismic bracing shall be in accordance with NFPA 13.

Table 4.7.6.5.8 Maximum Spacing Between Supports
For Threaded or Welded Pipe

Nominal Pipe Size		Maximum Span	
in.	**mm**	**ft**	**m**
1/4	6	5	1.5
1/2	15	5	1.5
3/4	20	6	1.8
1	25	7	2.1
1 1/4	32	8	2.4
1 1/2	40	9	2.7
2	50	10	3.0
2 1/2	65	11	3.4
3	80	12	3.7
4	100	14	4.3
5	125	16	4.9
6	150	17	5.2
8	200	19	5.8

Statement of Problem and Substantiation for Public Input

Presently there is little guidance on the proper support of CO_2 system piping (low pressure systems only – see Section 4.7.2) and no guidance for support of high pressure systems at all. Due to the potential for pipe movement and dislodgement due to agent forces and thermal expansion/contraction, there is a need to specify rigid pipe supports at critical points of the system and dead weight support for the remainder of the system piping. There are no requirements presently for seismic bracing of system piping.

Submitter Information Verification

Submitter Full Name: David Hague

Organization: Liberty Mutual Insurance

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 23 10:13:59 EST 2015

Public Input No. 11-NFPA 12-2015 [Section No. 5.3.2.2]

5.3.2.2 *

Table 5.3.2.2 shall be used to determine the minimum carbon dioxide concentrations for the liquids and gases shown in the table.

In Table 5.3.2.2 revise as follows:

(1) Revise "Higher paraffin" line in Table 5.3.2.2 by replacing "Higher paraffin hydrocarbons $C_n H_{2m}$ 2m-5" with "Higher paraffin hydrocarbons, $C_n H_{2n\ 2}$, n ≥ 5"

(2) Delete "Hexane" line.

Table 5.3.2.2 Minimum Carbon Dioxide Concentrations for Extinguishment

Material	Theoretical Minimum CO_2 Concentration (%)	Minimum Design CO_2 Concentration (%)
Acetylene	55	66
Acetone	27*	34
Aviation gas grades 115/145	30	36
Benzol, benzene	31	37
Butadiene	34	41
Butane	28	34
Butane-I	31	37
Carbon disulfide	60	72
Carbon monoxide	53	64
Coal or natural gas	31*	37
Cyclopropane	31	37
Diethyl ether	33	40
Dimethyl ether	33	40
Dowtherm	38*	46
Ethane	33	40
Ethyl alcohol	36	43
Ethyl ether	38*	46
Ethylene	41	49
Ethylene dichloride	21	34
Ethylene oxide	44	53
Gasoline	28	34
Hexane	29	35
Higher paraffin hydrocarbons $C_n H_{2m}$		
+		
2m - 5	28	34
Hydrogen	62	75
Hydrogen sulfide	30	36
Isobutane	30*	36
Isobutylene	26	34
Isobutyl formate	26	34
JP-4	30	36

Kerosene	28	34
Methane	25	34
Methyl acetate	29	35
Methyl alcohol	33	40
Methyl butene-I	30	36
Methyl ethyl ketone	33	40
Methyl formate	32	39
Pentane	29	35
Propane	30	36
Propylene	30	36
Quench, lube oils	28	34

Note: The theoretical minimum extinguishing concentrations in air for the materials in the table were obtained from a compilation of Bureau of Mines, Bulletins 503 and 627.

*Calculated from accepted residual oxygen values.

Additional Proposed Changes

File Name	Description	Approved
NFPA_12_Table_5.3.2.2.docx	Proposed revisions to Table 5.3.2.2	

Statement of Problem and Substantiation for Public Input

Substantiation:

1. The intended “Higher paraffin” text is from the caption of Figure 35 of U.S. Bureau of Mines Bulletin 627.
2. The “Higher paraffin” line, with n = 6 (hexane), has a column #2 value = 28 % (and MDC = 34 %), while directly above is “Hexane” with a column #2 value = 29 % (and MDC = 35 %). Thus, the “Hexane” line and the “Higher paraffin” line are in conflict. Close examination of the hexane flammability data in both U.S. Bureau of Mines Bulletins 503 and 627 clearly indicates that the 28 % for hexane “Minimum Theoretical Concentration” is correct.

Submitter Information Verification

Submitter Full Name: Joseph Senecal
Organization: Kidde-Fenwal, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 09 08:03:11 EST 2015

NFPA 12, Table 5.3.2.2

Proposal:

1. Revise "Higher paraffin" line in Table 5.3.2.2 by replacing "Higher paraffin hydrocarbons C_nH_{2m} + 2m-5" with "Higher paraffin hydrocarbons, C_nH_{2n+2}, n ≥ 5"
2. Delete "Hexane" line.

Ethylene oxide	44	53
Gasoline	28	34
Hexane	29	35
Higher paraffin hydrocarbons $C_n H_{2m}$ + 2m - 5	28	34
Hydrogen	62	75
Hydrogen sulfide	30	36

Substantiation:

1. The intended "Higher paraffin" text is from the caption of Figure 35 of U.S. Bureau of Mines Bulletin 627.
2. The "Higher paraffin" line, with n = 6 (hexane), has a column #2 value = 28 % (and MDC = 34 %), while directly above is "Hexane" with a column #2 value = 29 % (and MDC = 35 %). Thus, the "Hexane" line and the "Higher paraffin" line are in conflict. Close examination of the hexane flammability data in both U.S. Bureau of Mines Bulletins 503 and 627 clearly indicates that the 28 % for hexane "Minimum Theoretical Concentration" is correct.

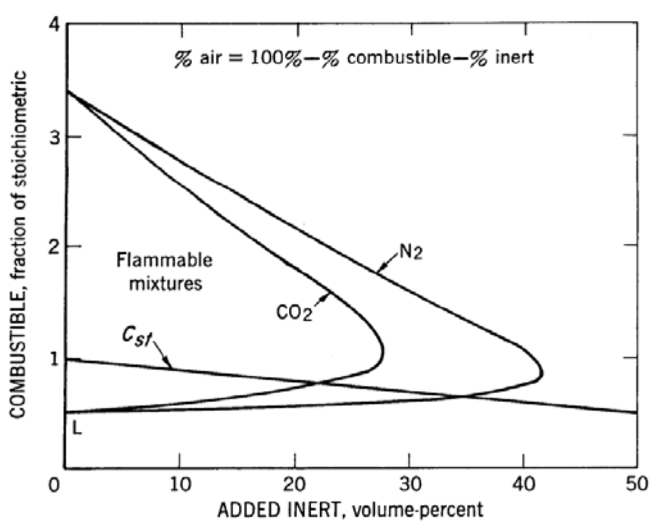

FIGURE 35.—Approximate Limits of Flammability of Higher Paraffin Hydrocarbons (C_nH_{2n+2}, $n \geq 5$) in Carbon Dioxide-Air and Nitrogen-Air Mixtures at 25° C and Atmospheric Pressure.

Public Input No. 12-NFPA 12-2015 [Section No. 5.5.2.1]

5.5.2.1 * _

5.5.2.1* For surface fires, the design concentration shall be achieved within

~~1 minute~~

1 minute from start of liquid _ discharge.

5.5.2.1.1 The duration of pre-liquid vapor discharge shall not exceed 60 s.

Statement of Problem and Substantiation for Public Input

Substantiation: There is some ambiguity as to what is meant by "start of discharge." Some liquid CO2 is vaporized in the pipe system. The duration of the pre-liquid vapor discharge can vary widely. The portion of discharge that is most effective for firefighting purposes is the liquid discharge. The proposal acknowledges the variable-duration pre-liquid vapor discharge, and emphasizes that the design concentration is to be achieved within 60 s of the onset of liquid discharge. Both the duration of pre-liquid vapor discharge and liquid discharge are calculable. The proposal harmonizes NFPA 12 with similar language in ISO 6183.

Submitter Information Verification

Submitter Full Name: Joseph Senecal

Organization: Kidde-Fenwal, Inc.

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 09 08:07:59 EST 2015

Public Input No. 14-NFPA 12-2015 [Section No. 5.5.2.3]

5.5.2.3

For deep-seated fires, the design concentration shall be achieved within 7 minutes ~~, but the rate~~ of the start of liquid discharge .

5.5.2.3.1 Notwithstanding the requirements of 5.5.2.3, the rate liquid discharge shall be not less than that required to develop a carbon dioxide concentration of ~~30 percent in 2 minutes~~ 30 percent within 2 minutes of the start of liquid discharge .

Statement of Problem and Substantiation for Public Input

1. The requirements of the current 5.5.2.3 contains two separate requirements that need to be separated;
2. The duration of pre-liquid vapor discharge can be lengthy, tens of seconds, and that portion of the discharge raises CO2 concentration relatively slowly. The onset of the liquid portion of CO2 discharge begins the rapid rise in CO2 concentration and should be the starting point for development of the required concentrations.

Submitter Information Verification

Submitter Full Name: Joseph Senecal

Organization: Kidde-Fenwal, Inc.

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 09 10:15:45 EST 2015

Public Input No. 19-NFPA 12-2015 [Section No. A.4.7.2]

~~A.4.7.2 —~~

~~ASME B31.1 should be consulted for guidance on this matter.~~

Statement of Problem and Substantiation for Public Input

Added mandatory reference to ANSI B31.1 in new proposed section 4.7.6 "Pipe Hangers and Supports".

Submitter Information Verification

Submitter Full Name:	David Hague
Organization:	Liberty Mutual Insurance
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Dec 23 10:18:43 EST 2015

Public Input No. 13-NFPA 12-2015 [Section No. A.5.5.2.1]

A.5.5.2.1

~~Normally~~ Generally , the ~~measured discharge time~~ effective start of discharge, for fire extinguishing purposes, is considered to ~~be the time when the measuring device starts to record the presence of carbon dioxide until the design concentration is achieved~~ occur when liquid discharge begins .

Statement of Problem and Substantiation for Public Input

The criterion of "…when the measuring device starts to record the presence of carbon dioxide…" is subject to wide variation and interpretation.

1. A measuring device may be slow to respond to the presence of CO_2 gas;
2. It may use a long sample tube with substantial transit time to the measuring sensor;
3. The sensor may be placed anywhere in a protected space;
4. A sensor may respond to low concentrations of CO_2 during the slow initial discharge of CO_2 vapor that is created in the pipe system (the duration of "initial vapor time" can vary from less than 1 s to 30 s, or more, depending on the type of CO_2 supply, high-pressure or low-pressure, and the length and mass of the pipe system).
5. Where initial vapor time is long, say 20 s, and where the initial presence of CO_2 gas is detected promptly, the current language suggests to the AHJ that the liquid discharge time is to be at most 60 s – 20 s = 40 s. This would impose flow limit challenges requiring larger nozzles, and, in some cases, larger diameter pipe systems.
6. The parallel ISO CO_2 systems standard, ISO 6183 / 7.7.1 Discharge time, requires, in total flood applications, a maximum liquid discharge time of 60 s and up to 60 s of "pre-liquid vapour flow time" for a total pre-liquid plus liquid discharge time of up to 120 s.

Submitter Information Verification

Submitter Full Name: Joseph Senecal

Organization: Kidde-Fenwal, Inc.

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 09 08:10:47 EST 2015

Public Input No. 15-NFPA 12-2015 [Section No. C.1]

C.1

Computing pipe sizes for carbon dioxide systems is complicated by the fact that the pressure drop is nonlinear with respect to the pipeline. Carbon dioxide leaves the storage vessel as a liquid at saturation pressure. As the pressure drops due to pipeline friction, the liquid boils and produces a mixture of liquid and vapor. Consequently, the volume of the flowing mixture increases and the velocity of flow must also increase. Thus, the pressure drop per unit length of pipe is greater near the end of the pipeline than it is at the beginning.

Pressure drop information for designing piping systems can best be obtained from curves of pressure versus equivalent length for various flow rates and pipe sizes. Such curves can be plotted using the theoretical equation given in 4.7.5.1. The *Y* and *Z* factors in the equation in that paragraph depend on storage pressure and line pressure. In the following equations, *Z* is a dimensionless ratio, and the *Y* factor has units of pressure times density and will therefore change the system of units. The *Y* and *Z* factors can be evaluated as follows:

$$Y = -\int_{P_1}^{P} \rho \, dP$$

$$Z = -\int_{\rho_1}^{\rho} \frac{d\rho}{\rho} = \ln \frac{\rho_1}{\rho} \qquad \textbf{[C.1a]}$$

where:

P = pressure at end of pipeline [psi (kPa)]

P_1 = storage pressure [psi (kPa)]

ρ = density at pressure P [lb/ft^3 (kg/m^3)]

ρ_1 = density at pressure P_1 [lb/ft^3 (kg/m^3)]

ln = natural logarithm

The storage pressure is an important factor in carbon dioxide flow. In low-pressure storage, the starting pressure in the storage vessel will recede to a lower level, depending on whether all or only part of the supply is discharged. Because of this, the average pressure during discharge will be about 285 psi (1965 kPa). The flow equation is based on absolute pressure; therefore, 300 psi (2068 kPa) is used for calculations involving low-pressure systems.

In high-pressure systems, the storage pressure depends on the ambient temperature. Normal ambient temperature is assumed to be 70°F (21°C). For this condition, the average pressure in the cylinder during discharge of the liquid portion will be about 750 psi (5171 kPa). This pressure has therefore been selected for calculations involving high-pressure systems.

Using the base pressures of 300 psi (2068 kPa) and 750 psi (5171 kPa), values have been determined for the *Y* and *Z* factors in the flow equation. These values are listed in Table C.1(a) and Table C.1(b).

Table C.1(a) Values of Y and Z for 300 psi Initial Storage Pressure

Pressure		*Y*									
(psi)	*Z*	0	1	2	3	4	5	6	7	8	9
300	0.000	0	0	0	0	0	0	0	0	0	0
290	0.135	596	540	483	426	367	308	248	187	126	63
280	0.264	1119	1070	1020	969	918	866	814	760	706	652
270	0.387	1580	1536	1492	1448	1402	1357	1310	1263	1216	1168
260	0.505	1989	1950	1911	1871	1831	1790	1749	1708	1666	1623
250	0.620	2352	2318	2283	2248	2212	2176	2139	2102	2065	2027
240	0.732	2677	2646	2615	2583	2552	2519	2487	2454	2420	2386
230	0.841	2968	2940	2912	2884	2855	2826	2797	2768	2738	2708
220	0.950	3228	3204	3179	3153	3128	3102	3075	3049	3022	2995
210	1.057	3462	3440	3418	3395	3372	3349	3325	3301	3277	3253

Pressure		Y									
(psi)	Z	0	1	2	3	4	5	6	7	8	9
200	1.165	3673	3653	3632	3612	3591	3570	3549	3528	3506	3485
190	1.274	3861	3843	3825	3807	3788	3769	3750	3731	3712	3692
180	1.384	4030	4014	3998	3981	3965	3948	3931	3914	3896	3879
170	1.497	4181	4167	4152	4138	4123	4108	4093	4077	4062	4046
160	1.612	4316	4303	4291	4277	4264	4251	4237	4223	4210	4196
150	1.731	4436	4425	4413	4402	4390	4378	4366	4354	4341	4329

Table C.1(b) Values of Y and Z for 750 psi Initial Storage Pressure

Pressure		Y									
(psi)	Z	0	1	2	3	4	5	6	7	8	9
750	0.000	0	0	0	0	0	0	0	0	0	0
740	0.038	497	448	399	350	300	251	201	151	101	51
730	0.075	975	928	881	833	786	738	690	642	594	545
720	0.110	1436	1391	1345	1299	1254	1208	1161	1115	1068	1022
710	0.143	1882	1838	1794	1750	1706	1661	1616	1572	1527	1481
700	0.174	2314	2271	2229	2186	2143	2100	2057	2013	1970	1926
690	0.205	2733	2691	2650	2608	2567	2525	2483	2441	2399	2357
680	0.235	3139	3099	3059	3018	2978	2937	2897	2856	2815	2774
670	0.265	3533	3494	3455	3416	3377	3338	3298	3259	3219	3179
660	0.296	3916	3878	3840	3802	3764	3726	3688	3649	3611	3572
650	0.327	4286	4250	4213	4176	4139	4102	4065	4028	3991	3953
640	0.360	4645	4610	4575	4539	4503	4467	4431	4395	4359	4323
630	0.393	4993	4959	4924	4890	4855	4821	4786	4751	4716	4681
620	0.427	5329	5296	5263	5229	5196	5162	5129	5095	5061	5027
610	0.462	5653	5621	5589	5557	5525	5493	5460	5427	5395	5362
600	0.498	5967	5936	5905	5874	5843	5811	5780	5749	5717	5685
590	0.535	6268	6239	6209	6179	6149	6119	6089	6058	6028	5997
580	0.572	6560	6531	6502	6473	6444	6415	6386	6357	6328	6298
570	0.609	6840	6812	6785	6757	6729	6701	6673	6645	6616	6588
560	0.646	7110	7084	7057	7030	7003	6976	6949	6922	6895	6868
550	0.683	7371	7345	7320	7294	7268	7242	7216	7190	7163	7137
540	0.719	7622	7597	7572	7548	7523	7498	7472	7447	7422	7396
530	0.756	7864	7840	7816	7792	7768	7744	7720	7696	7671	7647
520	0.792	8098	8075	8052	8028	8005	7982	7958	7935	7911	7888
510	0.827	8323	8301	8278	8256	8234	8211	8189	8166	8143	8120
500	0.863	8540	8519	8497	8476	8454	8433	8411	8389	8367	8345
490	0.898	8750	8730	8709	8688	8667	8646	8625	8604	8583	8562
480	0.933	8953	8933	8913	8893	8873	8852	8832	8812	8791	8771
470	0.967	9149	9129	9110	9091	9071	9052	9032	9012	8993	8973
460	1.002	9338	9319	9301	9282	9263	9244	9225	9206	9187	9168
450	1.038	9520	9502	9484	9466	9448	9430	9412	9393	9375	9356
440	1.073	9697	9680	9662	9644	9627	9609	9592	9574	9556	9538
430	1.109	9866	9850	9833	9816	9799	9782	9765	9748	9731	9714

Pressure		Y									
(psi)	Z	0	1	2	3	4	5	6	7	8	9
420	1.146	10030	10014	9998	9982	9966	9949	9933	9916	9900	9883
410	1.184	10188	10173	10157	10141	10126	10110	10094	10078	10062	10046
400	1.222	10340	10325	10310	10295	10280	10265	10250	10234	10219	10204
390	1.262	10486	10472	10458	10443	10429	10414	10399	10385	10370	10355
380	1.302	10627	10613	10599	10585	10571	10557	10543	10529	10515	10501
370	1.344	10762	10749	10735	10722	10708	10695	10681	10668	10654	10641
360	1.386	10891	10878	10866	10853	10840	10827	10814	10801	10788	10775
350	1.429	11015	11003	10991	10978	10966	10954	10941	10929	10916	10904
340	1.473	11134	11122	11110	11099	11087	11075	11063	11051	11039	11027
330	1.518	11247	11236	11225	11214	11202	11191	11180	11168	11157	11145
320	1.564	11356	11345	11334	11323	11313	11302	11291	11280	11269	11258
310	1.610	11459	11449	11439	11428	11418	11408	11398	11387	11377	11366
300	1.657	11558	11548	11539	11529	11519	11509	11499	11489	11479	11469

For practical application, it is desirable to plot curves for each pipe size that can be used. However, the flow equation can be rearranged as shown in the following equation:

$$\frac{L}{D^{1.25}} = \frac{3647Y}{\left(\frac{Q}{D^2}\right)^2} - 8.08Z \qquad \textbf{[C.1b]}$$

Thus, by plotting values of $L/D^{1.25}$ and Q/D^2, it is possible to use one family of curves for any pipe size. Figure C.1(a) gives flow information for 0°F (−18°C) storage temperature on this basis. Figure C.1(b) gives similar information for high-pressure storage at 70°F (21°C). For an inside pipe diameter of exactly 1 in., D^2 and $D^{1.25}$ reduce to unity and cancel out. For other pipe sizes, it is necessary to convert the flow rate and equivalent length by dividing or multiplying by these factors. Table C.1(c) gives values for *D*.

Figure C.1(a) Pressure Drop in Pipeline for 300 psi (2068 kPa) Storage Pressure.

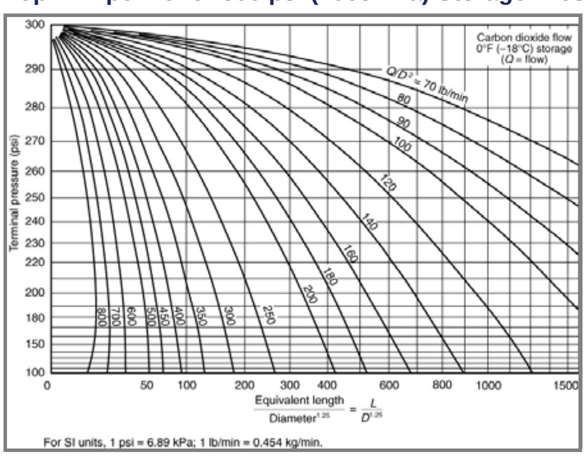

Figure C.1(b) Pressure Drop in Pipeline for 750 psi (5171 kPa) Storage Pressure.

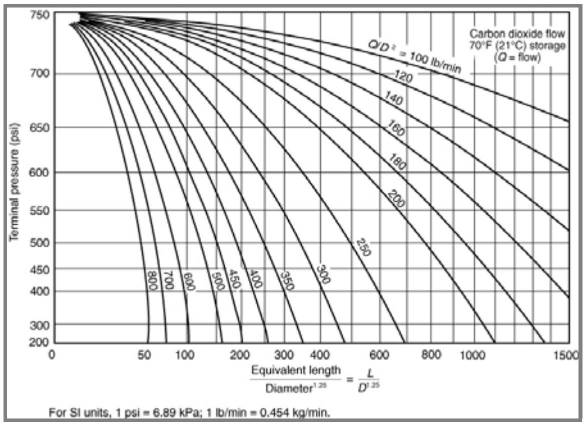

Table C.1(c) Values of $D^{1.25}$ and D^{2} for Various Pipe Sizes

Pipe Size and Type	**Inside Diameter (in.)**	$D^{1.25}$	D^{2}
1/2 Std.	0.622	0.5521	0.3869
1/4 Std.	0.824	0.785	0.679
1 Std.	1.049	1.0615	1.100
1 XH	0.957	0.9465	0.9158
1 1/4 Std.	1.380	1.496	1.904
1 1/4 XH	1.278	1.359	1.633
1 1/2 Std.	1.610	1.813	2.592
1 1/2 XH	1.500	1.660	2.250
2 Std.	2.067	2.475	4.272
2 XH	1.939	2.288	3.760
2 1/2 Std.	2.469	3.09	6.096
2 1/2 XH	2.323	2.865	5.396
3 Std.	3.068	4.06	9.413
3 XH	2.900	3.79	8.410
4 Std.	4.026	5.71	16.21
4 XH	3.826	5.34	14.64
5 Std.	5.047	7.54	25.47
5 XH	4.813	7.14	23.16
6 Std.	6.065	9.50	36.78
6 XH	5.761	8.92	33.19

These curves can be used for designing systems or for checking possible flow rates. For example, assume the problem is to determine the terminal pressure for a low-pressure system consisting of a single 2 in. Schedule 40 pipeline with an equivalent length of 500 ft and a flow rate of 1000 lb/min. The flow rate and the equivalent length must be converted to terms of Figure C.1(a) as follows:

Revise equations C.1c

From: Q/D^{2} = 1000/4.28 = 234 lb/min-D^{2} To: Q/D^{2} = 1000/4.28 = 234 lb/min-in^{2}

From: $L/D^{1.25}$ = 500/2.48 = 201 ft-$D^{1.25}$ To: $L/D^{1.25}$ = 500/2.48 = 201 ft-$in^{1.25}$

$$\frac{Q}{D^2} = \frac{1000}{4.28} = 234 \text{ lb/min} \cdot D^2$$

[C.1c]

$$\frac{L}{D^{1.25}} = \frac{500}{2.48} = 201 \text{ ft} \cdot D^{1.25}$$

From Figure C.1(a), the terminal pressure is found to be about 228 psi at the point where the interpolated flow rate of 234 lb/min intersects the equivalent length scale at 201 ft.

If this line terminates in a single nozzle, the equivalent orifice area must be matched to the terminal pressure in order to control the flow rate at the desired level of 1000 lb/min. Referring to Table 4.7.5.2.1, it will be noted that the discharge rate will be 1410 lb/min·in.^{2} of equivalent orifice area when the orifice pressure is 230 psi. The required equivalent orifice area of the nozzle is thus equal to the total flow rate divided by the rate per square inch, as shown in the following equation:

$$\text{Equivalent orifice area} = \frac{1000 \text{ lb/min}}{1410 \text{ lb/min} \cdot \text{in.}^2} = 0.709 \text{ in.}^2$$ **[C.1d]**

From a practical viewpoint, the designer would select a standard nozzle having an equivalent area nearest to the computed area. If the orifice area happened to be a little larger, the actual flow rate would be slightly higher and the terminal pressure would be somewhat lower than the estimated 228 psi (1572 kPa).

If, in the previous example, instead of terminating with one large nozzle, the pipeline branched into two smaller pipelines, it would be necessary to determine the pressure at the end of each branch line. To illustrate this procedure, assume that the branch lines are equal and consist of 1 ½ in. Schedule 40 pipe with equivalent lengths of 200 ft (61 m) and that the flow in each branch line is to be 500 lb/min (227 kg/min). Converting to terms used in Figure C.1(a), the following equations result:

Revise equations C.1e

From: Q/D^2 = 500/2.592 = 193 lb/min-D^2 To: Q/D^2 = 500/2.592 = 193 lb/min-in^2

From: L/D$^{1.25}$ = 200/1.813 = 110 ft-D$^{1.25}$ To: L/D$^{1.25}$ = 200/1.813 = 110 ft/in$^{1.25}$

$$\frac{Q}{D^2} = \frac{500}{2.592} = 193 \text{ lb/min} \cdot D^2$$

[C.1e]

$$\frac{L}{D^{1.25}} = \frac{200}{1.813} = 110 \text{ ft} \cdot D^{1.25}$$

From Figure C.1(a), the starting pressure of 228 psi (1572 kPa) (terminal pressure of main line) intersects the flow rate line [193 lb/min (87.6 kg/min)] at an equivalent length of about 300 ft (91.4 m). In other words, if the branch line started at the storage vessel, the liquid carbon dioxide would have to flow through 300 ft (91.4 m) of pipeline before the pressure dropped to 228 psi (1572 kPa). This length thus becomes the starting point for the equivalent length of the branch line. The terminal pressure of the branch line is then found to be 165 psi (1138 kPa) at the point where the 193 lb/min (87.6 kg/min) flow rate line intersects the total equivalent length line of 410 ft (125 m), or 300 ft + 110 ft (91 m + 34 m). With this new terminal pressure [165 psi (1138 kPa)] and flow rate [500 lb/min (227 kg/min)], the required equivalent nozzle area at the end of each branch line will be approximately 0.567 in.^{2} (366 mm^2). This is about the same as the single large nozzle example, except that the discharge rate is cut in half due to the reduced pressure.

The design of the piping distribution system is based on the flow rate desired at each nozzle. This in turn determines the required flow rate in the branch lines and the main pipeline. From practical experience, it is possible to estimate the approximate pipe sizes required. The pressure at each nozzle can be determined from suitable flow curves. The nozzle orifice sizes are then selected on the basis of nozzle pressure from the data given in 4.7.5.2.

In high-pressure systems, the main header is supplied by a number of separate cylinders. The total flow is thus divided by the number of cylinders to obtain the flow rate from each cylinder. The flow capacity of the cylinder valve and the connector to the header vary with each manufacturer, depending on design and size. For any particular valve, dip tube, and connector assembly, the equivalent length can be determined in terms of feet of standard pipe size. With this information, the flow equation can be used to prepare a curve of flow rate versus pressure drop. This curve provides a convenient method of determining header pressure for a specific valve and connector combination.

Table C.1(d) and Table C.1(e) list the equivalent lengths of pipe fittings for determining the equivalent length of piping systems. Table C.1(d) is for threaded joints, and Table C.1(e) is for welded joints. Both tables were computed for Schedule 40 pipe sizes; however, for all practical purposes, the same figures can also be used for Schedule 80 pipe sizes.

Table C.1(d) Equivalent Lengths in Feet of Threaded Pipe Fitting

Pipe Size (in.)	Elbow Std. 45 Degrees	Elbow Std. 90 Degrees	Elbow 90 Degrees Long Radius and Tee Thru Flow	Tee Side	Union Coupling or Gate Valve
3/8	0.6	1.3	0.8	2.7	0.3
1/2	0.8	1.7	1.0	3.4	0.4
3/4	1.0	2.2	1.4	4.5	0.5
1	1.3	2.8	1.8	5.7	0.6
1 1/4	1.7	3.7	2.3	7.5	0.8
1 1/2	2.0	4.3	2.7	8.7	0.9
2	2.6	5.5	3.5	11.2	1.2
2 1/2	3.1	6.6	4.1	13.4	1.4
3	3.8	8.2	5.1	16.6	1.8
4	5.0	10.7	6.7	21.8	2.4
5	6.3	13.4	8.4	27.4	3.0
6	7.6	16.2	10.1	32.8	3.5

For SI units, 1 ft = 0.3048 m.

Table C.1(e) Equivalent Lengths in Feet of Welded Pipe Fitting

Pipe Size (in.)	Elbow Std. 45 Degrees	Elbow Std. 90 Degrees	Elbow 90 Degrees Long Radius and Tee Thru Flow	Tee Side	Gate Valve
3/8	0.2	0.7	0.5	1.6	0.3
1/2	0.3	0.8	0.7	2.1	0.4
3/4	0.4	1.1	0.9	2.8	0.5
1	0.5	1.4	1.1	3.5	0.6
1 1/4	0.7	1.8	1.5	4.6	0.8
1 1/2	0.8	2.1	1.7	5.4	0.9
2	1.0	2.8	2.2	6.9	1.2
2 1/2	1.2	3.3	2.7	8.2	1.4
3	1.8	4.1	3.3	10.2	1.8
4	2.0	5.4	4.4	13.4	2.4
5	2.5	6.7	5.5	16.8	3.0
6	3.0	8.1	6.6	20.2	3.5

For SI units, 1 ft = 0.3048 m.

For nominal changes in elevation of piping, the change in head pressure is negligible. However, if there is a substantial change in elevation, this factor should be taken into account. The head pressure correction per foot of elevation depends on the average line pressure where the elevation takes place because the density changes with pressure. Correction factors are given in Table C.1(f) and Table C.1(g) for low-pressure and high-pressure systems, respectively. The correction is subtracted from the terminal pressure when the flow is upward and is added to the terminal pressure when the flow is downward.

Table C.1(f) Elevation Correction Factors for Low-Pressure System

Average Line Pressure		Elevation Correction	
psi	kPa	psi/ft	kPa/m
300	2068	0.443	10.00
280	1930	0.343	7.76
260	1792	0.265	5.99
240	1655	0.207	4.68
220	1517	0.167	3.78
200	1379	0.134	3.03
180	1241	0.107	2.42
160	1103	0.085	1.92
140	965	0.067	1.52

Table C.1(g) Elevation Correction Factors for High-Pressure System

Average Line Pressure		Elevation Correction	
psi	kPa	psi/ft	kPa/m
750	5171	0.352	7.96
700	4826	0.300	6.79
650	4482	0.255	5.77
600	4137	0.215	4.86
550	3792	0.177	4.00
500	3447	0.150	3.39
450	3103	0.125	2.83
400	2758	0.105	2.38
350	2413	0.085	1.92
300	2068	0.070	1.58

Statement of Problem and Substantiation for Public Input

The original equations incorrectly uses “D2” (pipe diameter) in the units rather than “in” (inch), which is the correct unit of pipe diameter.

Submitter Information Verification

Submitter Full Name: Joseph Senecal
Organization: Kidde-Fenwal, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 09 10:25:14 EST 2015

Public Input No. 3-NFPA 12-2015 [Chapter H]

Annex H Informational References

H.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.

H.1.1 NFPA Publications.

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 72 ®, *National Fire Alarm and Signaling Code*, 2013 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2014 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations*, 2014 edition.

NFPA *101* ®, *Life Safety Code* ®, 2015 edition.

H.1.2 Other Publications.

H.1.2.1 ASME Publications.

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

ASME B31.1, *Power Piping ~~Code~~* ~~-~~ **,** ~~2012~~ **2014** .

H.1.2.2 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C 700, West Conshohocken, PA 19428-2959.

ASTM SI10, *American National Standard for Metric Practice*, 2010.

H.1.2.3 DHHS Publications.

Department of Health and Human Services, National Institute of Safety and Health, Robert A. Taft Laboratory, 4676 Columbia Parkway, Cincinnati, OH 45226.

DHHS (NIOSH) Publication 76-194, *Criteria for a Recommended Standard: Occupational Exposure to Carbon Dioxide.*

H.1.2.4 EPA Publications.

Environmental Protection Agency, William Jefferson Clinton East Bldg., 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

EPA 430-R-00-002, “Carbon Dioxide as a Fire Suppressant: Examining the Risks,” February 2000.

H.1.2.5 FM Global Publications.

FM Global, ~~1175 Boston-Providence Turnpike~~ **270 Central Avenue** , P.O. Box ~~9102~~ **7500** , ~~Norwood, MA, 02062~~ **Johnston, RI 02919-4923** .

FM ~~Approvals~~ Approval 5420, *~~Approval Standard for~~ Carbon Dioxide Extinguishing Systems*, ~~April~~ 2007.

H.1.2.6 FSSA Publications.

Fire Suppression Systems Association, ~~5024-R Campbell Boulevard~~ **3601 East Joppa Road** , Baltimore, MD 21234.

Application Guide Detection & Control for Fire Suppression Systems, November 2010.

Design Guide for Use with Carbon Dioxide Total Flooding Applications, 1st edition, February 2011.

Design Guidelines for Carbon Dioxide Local Application Rate by Area, January 2010.

Design Guidelines for Carbon Dioxide Local Application Rate by Volume, December 2005.

Fire Protection Systems Inspection Form Guidelines, January 2012.

Pipe Design Handbook for Use with Special Hazard Fire Suppression Systems, 2nd edition, 2011.

Test Guide for Use with Special Hazard Fire Suppression Systems Containers, 3rd edition, January 2012.

H.1.2.7 U.S. Government Publications.

U.S. ~~Government Printing~~ Government **Publishing** Office, Washington, DC 20402.

Title 46, Code of Federal Regulations, Part 119, “Machinery Installations.”

Title 49, Code of Federal Regulations, Parts 171–190 (Department of Transportation).

H.2 Informational References. (Reserved)

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

Statement of Problem and Substantiation for Public Input

Referenced current SDO names, addresses, standard names, numbers, and editions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2-NFPA 12-2015 [Chapter 2]	Referenced current SDO names, addresses, standard names, numbers, and editions.

Submitter Information Verification

Submitter Full Name: Aaron Adamczyk
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 19 16:53:48 EDT 2015

Attachment #2

NFPA 12A *Standard on Halon 1301 Fire Extinguishing Systems*

- Public Input

Public Input No. 1-NFPA 12A-2015 [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 70® , *National Electrical Code®,* 2014 edition.

NFPA 72, *National Fire Alarm and Signaling Code,* 2013 edition.

2.3 Other Publications.

2.3.1 ~~ANSI~~ ASME Publications.

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

~~ANSI B1.20.1, *Standard for Pipe Threads, General Purpose* , 1983, reaffirmed 2006.~~

~~ANSI/IEEE C2, *National Electrical Safety Code,* 2012.~~

~~2.3.2 ASME Publications.~~

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

ASME *Boiler and Pressure Vessel Code,* Section VIII**, Division i, Rules for Construction of Pressure Vessels, 2015.** .

ASME Boiler and Pressure Vessel Code, Section IX, Welding, Brazing, and Fusing Qualifications, 2015.

ASME B1.20.1, Pipe Threads, General Purpose (inch), 2013.

ASME B31.1, *Power Piping ~~Code~~* ,~~2012~~ **2014** .

2.3. ~~3~~ 2 ASTM Publications.

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

ASTM A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless, 2012.

ASTM A120, *Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses,* 1984 (~~withdrawn 1987~~ **Superseded by ASTM A53/A53M**).

ASTM D5632, *Standard Specification for Halon 1301, Bromotrifluoromethane (CF_3 Br),* 2012.

2.3. 4 3 CGA Publications.

Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders,*~~2007~~ **2013** .

2.3. 4 IEEE Publications.

IEEE, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141.

IEEE C2, National Electrical Safety Code (NESC), 2012.

2.3.5 ULC Publications.

Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON, Canada ~~M1R#3A9~~ M1R 3A9 .

ULC CAN ~~/ULC S524~~ S524 -06, *Standard for the Installation of Fire Alarm Systems,* 2011.

~~CAN/~~ **ULC** - ~~S529~~ S529 -09, *Standard for Smoke Detectors for Fire Alarm Systems,* 2009.

2.3.6 U.S. Government Publications.

U.S. ~~Government Printing~~ Government **Publishing** Office, Washington, DC 20402.

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

Title 49, Code of Federal Regulations.

2.3.7 Other Publications.

Coll, John P., "Inerting Characteristics of Halon 1301 and 1211 with Various Combustibles," Fenwal Inc., Report PSR 661, July 16, 1976.

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

2.4 References for Extracts in Mandatory Sections.

(Reserved)

Statement of Problem and Substantiation for Public Input

Referenced current SDO names, addresses, standard names, numbers, and editions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2-NFPA 12A-2015 [Chapter M]	

Submitter Information Verification

Submitter Full Name: Aaron Adamczyk
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 19 17:05:42 EDT 2015

Public Input No. 8-NFPA 12A-2016 [Section No. 2.3.5]

2.3.5 ULC Publications.

Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON, Canada M1R#3A9.

CAN/ULC S524-~~06~~ 14 , *Standard for the Installation of Fire Alarm Systems,*~~2011~~ 2014 .

CAN/ULC S529-09, *Standard for Smoke Detectors for Fire Alarm Systems,* 2009.

Statement of Problem and Substantiation for Public Input

ULC references standard has been revised/updated to a newer edition.

Submitter Information Verification

Submitter Full Name:	Ronald Farr
Organization:	Ul Llc
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jan 07 09:13:20 EST 2016

Public Input No. 5-NFPA 12A-2015 [Section No. 5.1.1]

5.1.1 Specifications.

Specifications for Halon 1301 fire-extinguishing systems shall be prepared under the supervision of a person fully experienced and qualified in the design of Halon 1301 extinguishing systems and with the ~~advice~~ approval of the authority having jurisdiction. The specifications shall include all pertinent items necessary for the proper design of the system such as the designation of the authority having jurisdiction, variances from the standard to be permitted by the authority having jurisdiction, and the type and extent of the approval testing to be performed after installation of the system.

Statement of Problem and Substantiation for Public Input

This Public Input suggests a change that would more closely relate to the traditional role of the AHJ and avoid the implication of participation in the system design by providing design advice. The term “advice” does not impart or indicate authority, and it opens the door to concerns about liability in the wake of an incident involving an extinguishing system about which an AHJ has “advised.” This is similar to a Public Input submitted to NFPA 12, section 4.4.1.1.

Submitter Information Verification

Submitter Full Name: Jim Muir
Organization: Building Safety Division, Clark County, WA
Affilliation: NFPAs Building Code Development Committee (BCDC)
Street Address:
City:
State:
Zip:
Submittal Date: Mon Nov 09 20:45:34 EST 2015

Public Input No. 4-NFPA 12A-2015 [Section No. 5.5.1 [Excluding any Sub-Sections]]

The amount of Halon 1301 required to achieve the design concentration shall be calculated from the following formula:

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right) \quad [5.5.1a]$$

where:

W = weight of Halon 1301 required to achieve design concentration (~~kg~~ lb)

s = 2.2062 ~~+ 0~~ 0 .005046t

t = minimum anticipated temperature of the protected volume (°F)

V = net volume of hazard ft^3 (enclosed volume minus fixed structures impervious to halon)

C = Halon 1301 concentration, percent by volume

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right) \quad [5.5.1b]$$

where:

W = weight of Halon 1301 required to achieve design concentration (kg)

s = 0.14781 ~~+ 0~~ 0 .000567t

t = minimum anticipated temperature of the protected volume (°C)

V = net volume of hazard (m^3) (enclosed volume minus fixed structures impervious to halon)

C = Halon 1301 concentration, percent by volume

Statement of Problem and Substantiation for Public Input

Equation 5.5.1a is intended to apply to English Units. Reference NFPA 12A 2004 Edition for the same equation. The 2009 edition of NFAP 12A transitioned the units for weigh from lbs (2004) to kgs (2009), which was maintained in 2015. Based on the units for specific volume (cu.ft./lb) and net volume of hazard (cu.ft.), the intended units for this equation are lbs, not kgs. Also reference NFPA FP Handbook 20 Edition Section 17-113 equation 1 and Table 17.6.16, which confirms that lbs is the intended unit for this equation.

Note: the NFPA public input form removed the addition symbol for specific volume in equations 5.5.1a/b. No modification is proposed to either specific volume equations (s) in either Equation 5.5.1a/b.

Submitter Information Verification

Submitter Full Name: BRENDAN KARCHERE

Organization: CONOCOPHILLIPS

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 10 20:44:48 EDT 2015

Public Input No. 6-NFPA 12A-2015 [Section No. 5.5.1 [Excluding any Sub-Sections]]

The amount of Halon 1301 required to achieve the design concentration shall be calculated from the following formula:

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$ **[5.5.1a]**

where:

W = weight of Halon 1301 required to achieve design concentration (~~kg~~ lbs)

s = 2.2062 ~~+~~ – 0.005046t

t = minimum anticipated temperature of the protected volume (°F)

V = net volume of hazard ft^3 (enclosed volume minus fixed structures impervious to halon)

C = Halon 1301 concentration, percent by volume

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$ **[5.5.1b]**

where:

W = weight of Halon 1301 required to achieve design concentration (~~kg~~ lbs)

s = 0.14781 ~~+~~ – 0.000567t

t = minimum anticipated temperature of the protected volume (°C)

V = net volume of hazard (m^3) (enclosed volume minus fixed structures impervious to halon)

C = Halon 1301 concentration, percent by volume

Statement of Problem and Substantiation for Public Input

The weight of Halon calculated here I believe should be lbs, not kg. Numerous references that also use this calculation exclusively use 'lbs'. English units on the right side of the equation followed by metric on the left is poor form anyhow.

Submitter Information Verification

Submitter Full Name: Tim Tull

Organization: Aerojet Rocketdyne

Street Address:

City:

State:

Zip:

Submittal Date: Mon Nov 30 19:26:21 EST 2015

Public Input No. 2-NFPA 12A-2015 [Chapter M]

Annex M Informational References

M.1 Referenced Publications.

The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not part of the requirements of this document unless also listed in Chapter 2.

M.1.1 NFPA Publications.

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 2013 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 72® , *National Fire Alarm and Signaling Code*, 2013 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2014 edition.

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

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*, 2015 edition.

M.1.2 Other Publications.

M.1.2.1 ASME Publications.

~~American Society of Mechanical Engineers~~ **ASME International** , Two Park Avenue, New York, NY 10016-5590.

ASME B31.1, *Power Piping ~~Code~~* **,** ~~2010~~ **2014** .

ASME B31.9, *Building Services Piping,* ~~2011~~ **2014** .

M.1.2.2 ASTM Publications.

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

ASTM A53**/A53M** , *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless,* 2012.

ASTM A106**/106M** , *Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service,* ~~2011~~ **2014** .

ASTM A120, *Specification for Welded and Steel Pipe,* 1986. **(Superseded by ASTM A53/A53M)**

ASTM B88, *Standard Specification for Seamless Copper Water Tube,* ~~2009~~ **2014** .

ASTM E779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization,* 2010.

ASTM SI10, *American National Standard for Metric Practice,* 2010.

M.1.2.3 CGA Publications.

Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA P-1, *Safe Handling of Compressed Gas in Containers*, ~~2008~~ **2015** .

M.1.2.4 CSA Publications.

~~Canadian Standards Association, 5060 Spectrum Way, Mississauga~~ **CSA Group, 178 Rexdale Blvd., Toronto , ON,** ~~L4W 5N6~~ **Canada ,** ~~Canada~~ **M9W 1R3** .

CAN3-Z234.1, *Canadian Metric Practice Guide,* 2000 (R2011). **Withdrawn**

CAN/CGSB-149.10-M86, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method,* 1986.

M.1.2.5 UL Publications.

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

UL 711, *Rating and Fire Testing of Fire Extinguishers,* ~~2002~~ **2004, revised 2013** .

M.1.2.6 Toxicology References.

Clark, D. G., 1970, "The toxicity of bromotrifluoromethane (FE 1301) in animals and man," Ind. Hyg. Res. Lab. Imperial Chemical Industries, Alderley Park, Cheshire, England.

The Hine Laboratories, Inc., 1968, "Clinical toxicologic studies on Freon FE 1301," Report No. 1, San Francisco, CA (unpublished).

Paulet, G., 1962, "Etude toxicologique et physiopathologique du mono-bromo-trifluoromethane (CF3Br)," *Arch. Mal. Prof. Med. Trav. Secur. Soc.* 23:341-348. (*Chem. Abstr. 60:738e*).

Stewart, Richard D., Paul E. Newton, Anthony Wu, Carl L. Hake, and Neil D. Krivanek, 1978, "Human Exposure to Halon 1301," Medical College of Wisconsin, Milwaukee (unpublished).

Trochimowicz, H. J., A. Azar, J. B. Terrill, and L.S. Mullin, 1974, "Blood Levels of Fluorocarbon Related to Cardiac Sensitization," Part II, *Am. Ind. Hyg. Assoc. J.* 35:632-639.

Trochimowicz, H. J., et al., 1978, "The effect of myocardial infarction on the cardiac sensitization potential of certain halocarbons." *J. Occup. Med.* 18(1):26-30.

Van Stee, E. W., and K. C. Back, 1969, "Short-term inhalation exposure to bromotrifluoromethane," *Tox. & Appl. Pharm.* 15:164-174.

M.1.2.7 Flame Extinguishment and Inerting References.

Bajpai, S. N., July 1976, "Extinction of Diffusion Flames by Halons," FMRC Serial No. 22545, Report No. 76-T-59.

Booth, K., B. J. Melia, and R. Hirst, June 24, 1976, "A Method for Critical Concentration Measurements for the Flame Extinguishment of Liquid Surface and Gaseous Diffusion Flames Using a Laboratory 'Cup Burner' Apparatus and Halons 1211 and 1301 as Extinguishants."

Dalzell, W. G., October 7, 1975, "A Determination of the Flammability Envelope of Four Ternary Fuel-Air-Halon 1301 Systems," Fenwal Inc., Report DSR-624.

Riley, J. F., and K. R. Olson, July 1, 1976, "Determination of Halon 1301/1211 Threshold Extinguishment Concentrations Using the Cup Burner Method," Ansul Report AL-530A.

M.1.2.8 Additional References.

United Nations Environment Programme, Montreal Protocol on Substances that Deplete the Ozone Layer—Final Act 1987, UNEP/RONA, Room DC2-0803, United Nations, New York, NY, 10017.

M.1.2.9 EPA Publications.

Environmental Protection Agency, William Jefferson Clinton East Bldg., 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

Safety Guide for Decommissioning Halon Systems, Volume 2 of the U.S. Environmental Protection Agency Outreach Report, "Moving Towards a World Without Halon," 1999.

M.2 Informational References.

(Reserved)

M.3 References for Extracts in Informational Sections.

(Reserved)

Statement of Problem and Substantiation for Public Input

Safety Guide for Decommissioning Halon Systems, Volume 2 of the U.S. Environmental Protection Agency Outreach Report, "Moving Towards a World Without Halon,"

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 1-NFPA 12A-2015 [Chapter 2]	Referenced current SDO names, addresses, standard names, numbers, and editions.

Submitter Information Verification

Submitter Full Name:	Aaron Adamczyk
Organization:	[Not Specified]
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Sun Jul 19 17:36:29 EDT 2015

Public Input No. 7-NFPA 12A-2016 [Section No. M.1.2.5]

M.1.2.5 UL Publications.

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

UL 711, *Rating and Fire Testing of Fire Extinguishers,* ~~2002~~ *2013* .

Statement of Problem and Substantiation for Public Input

UL Standard has been updated/revised to a newer edition.

Submitter Information Verification

Submitter Full Name:	Ronald Farr
Organization:	Ul Llc
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jan 05 10:40:58 EST 2016

Attachment #3

NFPA 2001 *Standard on Clean Agent Fire Extinguishing Systems*

- Public Input

Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]

1.4.1.2*

Agents that meet the criteria of 1.4.1.1 shall be shown in Table 1.4.1.2.

Table 1.4.1.2 Agents Addressed in NFPA 2001

Agent Designation	Chemical Name	Chemistry
FK-5-1-12	Dodecafluoro-2-methylpentan-3-one	$CF_3CF_2C(O)CF(CF_3)_2$
HCFC Blend A	Dichlorotrifluoroethane HCFC-123 (4.75%)	$CHCl_2CF_3$
	Chlorodifluoromethane HCFC-22 (82%)	$CHClF_2$
	Chlorotetrafluoroethane HCFC-124 (9.5%)	$CHClFCF_3$
	Isopropenyl-1-methylcyclohexene (3.75%)	
HCFC-124	Chlorotetrafluoroethane	$CHClFCF_3$
HFC-125	Pentafluoroethane	CHF_2CF_3
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3
HFC-23	Trifluoromethane	CHF_3
HFC-236fa	Hexafluoropropane	$CF_3CH_2CF_3$
FIC-13I1	Trifluoroiodide	CF_3I
IG-01	Argon	Ar
IG-100	Nitrogen	N_2
IG-541	Nitrogen (52%)	N_2
	Argon (40%)	Ar
	Carbon dioxide (8%)	CO_2
IG-55	Nitrogen (50%)	N_2
	Argon (50%)	Ar
HFC Blend B	Tetrafluoroethane (86%)	CH_2FCF_3
	Pentafluoroethane (9%)	CHF_2CF_3
	Carbon dioxide (5%)	CO_2
New Agent	TBA	TBA

Notes:

(1) Other agents could become available at later dates. They could be added via the NFPA process in future editions or by amendments to the standard.

(2) Composition of inert gas agents is given in percent by volume. Composition of HCFC Blend A is given in percent by weight.

(3) The full analogous ASHRAE nomenclature for FK-5-1-12 is FK-5-1-12mmy2.

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 34-NFPA 2001-2016 [Section No. 1.5.1.2.1]	
Public Input No. 35-NFPA 2001-2016 [Section No. 4.2.1.1.1]	
Public Input No. 36-NFPA 2001-2016 [Section No. A.1.4.1]	
Public Input No. 37-NFPA 2001-2016 [Section No. A.1.5.1.2]	
Public Input No. 38-NFPA 2001-2016 [Section No. A.1.6]	
Public Input No. 39-NFPA 2001-2016 [Section No. A.4.1.4.1]	
Public Input No. 40-NFPA 2001-2016 [Section No. A.5.4.2]	
Public Input No. 41-NFPA 2001-2016 [Section No. A.5.4.2.2]	
Public Input No. 42-NFPA 2001-2016 [Section No. A.5.5.1]	
Public Input No. 43-NFPA 2001-2016 [Section No. C.2.7.1.3]	

Submitter Information Verification

Submitter Full Name: Brad Stilwell
Organization: Fike Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 05 12:26:54 EST 2016

Public Input No. 52-NFPA 2001-2016 [Section No. 1.4.2.2]

1.4.2.2 *

Clean agents shall not be used on fires involving the following materials unless the agents have been tested to the satisfaction of the authority having jurisdiction:

(1) Certain chemicals or mixtures of chemicals, such as cellulose nitrate and gunpowder, which are capable of rapid oxidation in the absence of air

(2) Reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium

(3) Metal hydrides

(4) Chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides , pyrophoric materials and hydrazine

Statement of Problem and Substantiation for Public Input

Pyrophoric chemicals are liquids and solids that have the potential to spontaneously ignite in air at temperatures of 130o F (54o C) or below. They often also have corrosive, water reactive, and peroxide forming properties.* Examples of pyrophoric materials include organometallic reagents such as alkyllithiums, alkylzincs, alkylmagnesiums (Grignards) and some finely divided metal powders. Specific examples include diborane (B2H6), diethylzinc (Zn(CH2CH3)2), tert-butyllithium (LiC(CH3)3) and diphosphine (P2H4). Use of clean extinguishing agents to extinguish fires involving such materials must be considered in the same as other special fire hazards included in this paragraph.

* http://www.dehs.umn.edu/PDFs/Pyrophoric_Chemicals_Guide.pdf

http://www.ilpi.com/msds/ref/pyrophoric.html

Submitter Information Verification

Submitter Full Name: Paul Rivers

Organization: 3M Company

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jan 07 17:43:25 EST 2016

Public Input No. 34-NFPA 2001-2016 [Section No. 1.5.1.2.1]

1.5.1.2.1*

Unnecessary exposure to halocarbon clean agents — including exposure at and below the no observable adverse effects level (NOAEL) — and halocarbon decomposition products shall be avoided. Means shall be provided to limit exposure to no longer than 5 minutes. Unprotected personnel shall not enter a protected space during or after agent discharge. 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 1.5.1.2.1(a)]* shall be permitted. The maximum exposure in any case shall not exceed 5 minutes.

(2) Halocarbon systems for spaces that are normally occupied and designed to concentrations above the NOAEL *[see Table 1.5.1.2.1(a)]* shall be permitted if means are provided to limit exposure to the design concentrations shown in Table 1.5.1.2.1(b) through Table 1.5.1.2.1(e) that correspond to an allowable human exposure time of 5 minutes. Higher design concentrations associated with human exposure times less than 5 minutes as shown in Table 1.5.1.2.1(b) through Table 1.5.1.2.1(e) shall not be permitted in normally occupied spaces. An exposure and egress analysis shall be performed and approved.

(3) In spaces that are not normally occupied and protected by a halocarbon system designed to concentrations above the lowest observable adverse effects level (LOAEL) *[see Table 1.5.1.2.1(a)]* and where personnel could possibly be exposed, means shall be provided to limit exposure times using Table 1.5.1.2.1(b) through Table 1.5.1.2.1(e).

(4) In spaces that are not normally occupied and in the absence of the information needed to fulfill the conditions listed in 1.5.1.2.1(3), the following provisions shall apply:

(5) _ 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.

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

(7) _ A pre-discharge alarm and time delay shall be provided in accordance with the provisions of 4.3.5.6 of this standard.

Table 1.5.1.2.1(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*
New Agent	TBA	TBA

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

Table 1.5.1.2.1(b) Time for Safe Human Exposure at Stated Concentrations for HFC-125

HFC-125 Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
7.5	75,000	5.00
8.0	80,000	5.00
8.5	85,000	5.00

HFC-125 Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
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	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 1.5.1.2.1(c) Time for Safe Human Exposure at Stated Concentrations for HFC-227ea

HFC-227ea Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
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 1.5.1.2.1(d) Time for Safe Human Exposure at Stated Concentrations for HFC-236fa

HFC-236fa Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
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

HFC-236fa Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
13.0	130,000	1.65
13.5	135,000	0.92
14.0	140,000	0.79
14.5	145,000	0.64
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 1.5.1.2.1(e) Time for Safe Human Exposure at Stated Concentrations for FIC-13I1

FIC-13I1 Concentration		Maximum Permitted Human Exposure Time (min)
% vol.	ppm	
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.

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]	Applies to new agent.

Submitter Information Verification

Submitter Full Name: Brad Stilwell
Organization: Fike Corporation
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jan 05 12:28:45 EST 2016

Public Input No. 7-NFPA 2001-2015 [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 70 ®, *National Electrical Code* ®, 2014 edition.

NFPA 72 ®, *National Fire Alarm and Signaling Code,* 2013 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

B1

Z535 **.**

20.1

4 , *Standard for*

Pipe Threads, General Purpose, 1983 (R2006).

ANSI C2, *National Electrical Safety Code* , 2012.

ANSI Z535, Standard for

Environmental and Facility Safety Signs , 2011.

2.3.2 ASME Publications.

American Society of Mechanical Engineers

ASME International , Two Park Avenue, New York, NY 10016-5990.

Boiler and Pressure Vessel Code , **2015** .

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

ASME B31.1, *Power Piping* ,

2012

2014 .

2.3.3 ASTM Publications.

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

ASTM A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless, 2012. (Superesedes ASTM A120)

ASTM A120 , *Specification for Seamless Carbon Steel Pipe for High Temperature Service,* 1988.

ASTM SI10, *American National Standard for Metric Practice* , 2010.

2.3.4 CGA Publications.

Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders* ,

2007CAN/CSA-

2013 .

2.3.5 CSA Publications.

Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, ON L4W 5N6, Canada.

CSA Group, 178 Rexdale Blvd., Toronto ON, Canada, M9W 1R3 .

CSA Z234.1, *Canadian Metric Practice Guide* , 2000 (R2011). **Withdrawn.**

2.3.6 IEEE Publications.

IEEE, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141.

IEEE C2, National Electrical Safety Code (NESC), 2012.

2.3.7 IMO Publications.

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

Fire Safety Systems (FSS) Code, 2007. (Includes below referenced circular)

IMO MSC/Circular 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.

2.3.

~~7~~

8 ISO Publications.

International Organization for Standardization,

~~1 ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneve 20,~~

ISO Central Secretariat, BIBC II, 8, Chemin de Blandonnet, 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~~

2007 .

2.3.

~~8~~

9 TC Publications.

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

TP 127 E, *Ship Safety Electrical Standards* , 2008.

2.3.

~~9~~

10 UL Publications.

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

~~ANSI/~~

UL 2127, *Standard for Inert Gas Clean Agent Extinguishing System Units* ,

~~2012~~

2015 .

~~ANSI/~~

UL 2166, *Standard for Halocarbon Clean Agent Extinguishing System Units* ,

~~2012~~

2015 .

2.3.

~~10~~

11 ULC Publications.

Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON M1R 3B4, Canada.

ULC CAN

/ULC S524-06

S524 , *Standard for the Installation of Fire Alarm Systems* ,

2011

2014 .

CAN/

ULC S529

-09

, *Smoke Detectors for Fire Alarm Systems* , 2009.

2.3.

11

12 U.S. Government Publications.

U.S.

Government Printing

Government **Publishing** Office, **732 North Capitol Street, NW,** **Washington** **DC** **,**

DC 20402

20401-0001 .

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

USCG Title 46, Code of Federal Regulations, Part 72.

USCG Title 46, Code of Federal Regulations, Subchapter J, “Electrical Engineering.”

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

2.3.

12

13 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2015 edition.

Statement of Problem and Substantiation for Public Input

Referenced current SDO names, addresses, standard names, numbers and editions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 8-NFPA 2001-2015 [Chapter E]	

Submitter Information Verification

Submitter Full Name: Aaron Adamczyk

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 19 00:47:03 EDT 2015

Public Input No. 47-NFPA 2001-2016 [Section No. 2.2]

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, 2015 edition.

NFPA 70® , National Electrical Code®, 2014 edition.

NFPA 72® , National Fire Alarm and Signaling Code, 2013 edition.

Statement of Problem and Substantiation for Public Input

Adding with acceptance of Public Input 44.

Submitter Information Verification

Submitter Full Name:	Kimberly Gruner
Organization:	Fike Corporation
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Jan 06 14:36:15 EST 2016

Public Input No. 29-NFPA 2001-2016 [Section No. 2.3.9]

2.3.9 UL Publications.

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

ANSI/UL 2127, *Standard for Inert Gas Clean Agent Extinguishing System Units*, 2012, Revised 2015 .

ANSI/UL 2166, *Standard for Halocarbon Clean Agent Extinguishing System Units*, 2012, Revised 2015 .

Statement of Problem and Substantiation for Public Input

UL Referenced Standards have been updated/revised to a newer edition.

Submitter Information Verification

Submitter Full Name: Ronald Farr
Organization: Ul Llc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 05 11:14:59 EST 2016

Public Input No. 48-NFPA 2001-2016 [Section No. 2.3.10]

2.3.10 ULC Publications.

Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON M1R 3B4, Canada.

CAN/ULC S524-~~06~~ 14 , *Standard for the Installation of Fire Alarm Systems*, ~~2011~~ 2014 .

CAN/ULC S529-09, *Smoke Detectors for Fire Alarm Systems*, 2009.

Statement of Problem and Substantiation for Public Input

ULC referenced standard has been revised/updated to a newer edition.

Submitter Information Verification

Submitter Full Name: Ronald Farr
Organization: Ul Llc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 07 09:16:20 EST 2016

Public Input No. 55-NFPA 2001-2016 [Section No. 4.1.4.4]

4.1.4.4

A means shall be provided to determine and monitor the pressure in containers of inert gas agents, superpressurized liquid agents, and superpressurized liquefied compressed gas agents and to provide notification of a low pressure condition . Visual and audible signals in the protected area and a trouble signal to a constantly attended remote or central station alarm service shall be provided to indicate a low-pressure condition.

Statement of Problem and Substantiation for Public Input

There currently is no specific requirement to monitor and alert responsible persons for a low-pressure condition in land-based clean extinguishing agent systems. Currently, if there is a low pressure condition, such a condition can exist without responsible persons knowing of the condition. Providing this requirement alleviates that condition and is consistent with similar requirements in paragraph 8.6.5.

Submitter Information Verification

Submitter Full Name: Paul Rivers
Organization: 3M Company
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 07 17:54:34 EST 2016

Public Input No. 28-NFPA 2001-2016 [Section No. 4.2.1.1.1]

4.2.1.1.1

In no case shall the value used for the minimum pipe design pressure be less than that specified in Table 4.2.1.1.1(a) and Table 4.2.1.1.1(b) for the conditions shown. For inert gas clean agents that employ the use of a pressure-reducing device, Table 4.2.1.1.1(a) shall be used for piping upstream of the pressure reducer, and 4.2.1.1.2 shall be used to determine minimum pipe design pressure for piping downstream of the pressure reducer. The pressure-reducing device shall be readily identifiable. For halocarbon clean agents, Table 4.2.1.1.1(b) shall be used. If different fill densities, pressurization levels, or higher storage temperatures from those shown in Table 4.2.1.1.1(a) or Table 4.2.1.1.1(b) are approved for a given system, the minimum design pressure for the piping shall be adjusted to the maximum pressure in the agent container at maximum temperature, using the basic design criteria specified in 4.2.1.1(1) and 4.2.1.1(2).

Table 4.2.1.1.1(a) Minimum Design Working Pressure for Inert Gas Clean Agent System Piping

	Agent Container Gauge Pressure at 70°F (21°C)		Agent Container Gauge Pressure at 130°F (55°C)		Minimum Design Pressure of Piping Upstream of Pressure Reducer	
Agent	psi	kPa	psi	kPa	psi	kPa
IG-01	2370	16,341	2650	18,271	2370	16,341
	2964	20,436	3304	22,781	2964	20,436
	4510	31,097	5402	37,244	4510	31,097
IG-541	2175	14,997	2575	17,755	2175	14,997
	2900	19,996	3433	23,671	2900	19,996
	4503	31,050	5359	36,950	4503	31,050
IG-55	2175	15,000	2541	17,600	2175	15,000
	2900	20,000	3434	23,700	2900	20,000
	4350	30,000	5222	36,100	4350	30,000
IG-100	2404	16,575	2799	19,299	2404	16,575
	3236	22,312	3773	26,015	3236	22,312
	4061	28,000	4754	32,778	4061	28,000

Table 4.2.1.1.1(b) Minimum Design Working Pressure for Halocarbon Clean Agent System Piping

	Agent Container Maximum Fill Density		Agent Container Charging Pressure at 70°F (21°C)		Agent Container Pressure at 130°F (55°C)		Minimum Piping Design Pressure	
Agent	lb/ft^3	kg/m^3	psi	bar	psi	bar	psi	bar
HFC-227ea	79	1265	44*	3	135	9	416	29
	75	1201	150	10	249	17	200	14
	72	1153	360	25	520	36	416	29
	72	1153	600	41	1025	71	820	57
HCFC Blend A	56.2	900	600	41	850	59	680	47
	56.2	900	360	25	540	37	432	30
HFC 23	54	865	608.9†	42	2182	150	1746	120
	48	769	608.9†	42	1713	118	1371	95
	45	721	608.9†	42	1560	108	1248	86
	40	641	608.9†	42	1382	95	1106	76
	35	561	608.9†	42	1258	87	1007	69
	30	481	608.9†	42	1158	80	927	64
HCFC-124	74	1185	240	17	354	24	283	20

Agent	Agent Container Maximum Fill Density		Agent Container Charging Pressure at 70°F (21°C)		Agent Container Pressure at 130°F (55°C)		Minimum Piping Design Pressure	
	lb/ft3	kg/m3	psi	bar	psi	bar	psi	bar
HCFC-124	74	1185	360	25	580	40	464	32
HFC-125	54	865	360	25	615	42	492	34
HFC 125	56	897	600	41	1045	72	836	58
HFC-236fa	74	1185	240	17	360	25	280	19
HFC-236fa	75	1201	360	25	600	41	480	33
HFC-236fa	74	1185	600	41	1100	76	880	61
HFC Blend B	58	929	360	25	586	40	469	32
	58	929	600	41	888	61	710	50
FK-5-1-12	90	1442	150	10	175	12	150	10
	90	1442	195	13	225	16	195	13
	90	1442	360	25	413	28	360	25
	75	1201	500	34	575	40	500	34
	90	1442	610	42	700	48	610	42

*Nitrogen delivered to agent cylinder through a flow restrictor upon system actuation. Nitrogen supply cylinder pressure is 1800 psi (124 bar) at 70°F (21°C).

†Not superpressurized with nitrogen.

Additional Proposed Changes

File Name	Description	Approved
Table_Addition_4.2.1.1.1_a_.xlsx	Add Information to existing table	

Statement of Problem and Substantiation for Public Input

300 bar IG-541 added to existing table to cover existing systems.

Submitter Information Verification

Submitter Full Name: Katherine Adrian
Organization: Tyco Fire Protection Products
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jan 04 13:25:57 EST 2016

Addition to Table 4.2.1.1.1(a) Minimum Design Working Pressure for Inert Gas Clean Agent System Pipi

Agent	Agent Container Gauge Pressure at 70°F (21°C)		Agent Container Gauge Pressure at 130°F (55°C)		Minimum Design Pressure of Piping Upstream of Pressure Reducer	
	psi	kPa	psi	kPa	psi	kPa
IG-541	4352	30,006	4998	34460	4352	30,006

ing

Public Input No. 35-NFPA 2001-2016 [Section No. 4.2.1.1.1]

4.2.1.1.1

In no case shall the value used for the minimum pipe design pressure be less than that specified in Table 4.2.1.1.1(a) and Table 4.2.1.1.1(b) for the conditions shown. For inert gas clean agents that employ the use of a pressure-reducing device, Table 4.2.1.1.1(a) shall be used for piping upstream of the pressure reducer, and 4.2.1.1.2 shall be used to determine minimum pipe design pressure for piping downstream of the pressure reducer. The pressure-reducing device shall be readily identifiable. For halocarbon clean agents, Table 4.2.1.1.1(b) shall be used. If different fill densities, pressurization levels, or higher storage temperatures from those shown in Table 4.2.1.1.1(a) or Table 4.2.1.1.1(b) are approved for a given system, the minimum design pressure for the piping shall be adjusted to the maximum pressure in the agent container at maximum temperature, using the basic design criteria specified in 4.2.1.1(1) and 4.2.1.1(2).

Table 4.2.1.1.1(a) Minimum Design Working Pressure for Inert Gas Clean Agent System Piping

	Agent Container Gauge Pressure at 70°F (21°C)		Agent Container Gauge Pressure at 130°F (55°C)		Minimum Design Pressure of Piping Upstream of Pressure Reducer	
Agent	psi	kPa	psi	kPa	psi	kPa
IG-01	2370	16,341	2650	18,271	2370	16,341
	2964	20,436	3304	22,781	2964	20,436
	4510	31,097	5402	37,244	4510	31,097
IG-541	2175	14,997	2575	17,755	2175	14,997
	2900	19,996	3433	23,671	2900	19,996
	4503	31,050	5359	36,950	4503	31,050
IG-55	2175	15,000	2541	17,600	2175	15,000
	2900	20,000	3434	23,700	2900	20,000
	4350	30,000	5222	36,100	4350	30,000
IG-100	2404	16,575	2799	19,299	2404	16,575
	3236	22,312	3773	26,015	3236	22,312
	4061	28,000	4754	32,778	4061	28,000

Table 4.2.1.1.1(b) Minimum Design Working Pressure for Halocarbon Clean Agent System Piping

	Agent Container Maximum Fill Density		Agent Container Charging Pressure at 70°F (21°C)		Agent Container Pressure at 130°F (55°C)		Minimum Piping Design Pressure	
Agent	lb/ft^3	kg/m^3	psi	bar	psi	bar	psi	bar
HFC-227ea	79	1265	44*	3	135	9	416	29
	75	1201	150	10	249	17	200	14
	72	1153	360	25	520	36	416	29
	72	1153	600	41	1025	71	820	57
HCFC Blend A	56.2	900	600	41	850	59	680	47
	56.2	900	360	25	540	37	432	30
HFC 23	54	865	608.9†	42	2182	150	1746	120
	48	769	608.9†	42	1713	118	1371	95
	45	721	608.9†	42	1560	108	1248	86
	40	641	608.9†	42	1382	95	1106	76
	35	561	608.9†	42	1258	87	1007	69
	30	481	608.9†	42	1158	80	927	64
HCFC-124	74	1185	240	17	354	24	283	20

	Agent Container Maximum Fill Density		Agent Container Charging Pressure at 70°F (21°C)		Agent Container Pressure at 130°F (55°C)		Minimum Piping Design Pressure	
Agent	lb/ft^3	kg/m^3	psi	bar	psi	bar	psi	bar
HCFC-124	74	1185	360	25	580	40	464	32
HFC-125	54	865	360	25	615	42	492	34
HFC 125	56	897	600	41	1045	72	836	58
HFC-236fa	74	1185	240	17	360	25	280	19
HFC-236fa	75	1201	360	25	600	41	480	33
HFC-236fa	74	1185	600	41	1100	76	880	61
HFC Blend B	58	929	360	25	586	40	469	32
	58	929	600	41	888	61	710	50
FK-5-1-12	90	1442	150	10	175	12	150	10
	90	1442	195	13	225	16	195	13
	90	1442	360	25	413	28	360	25
	75	1201	500	34	575	40	500	34
	90	1442	610	42	700	48	610	42
New Agent	TBA	TBA	360	25	TBA	TBA	TBA	TBA

*Nitrogen delivered to agent cylinder through a flow restrictor upon system actuation. Nitrogen supply cylinder pressure is 1800 psi (124 bar) at 70°F (21°C).

†Not superpressurized with nitrogen.

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]	New agent requirement.

Submitter Information Verification

Submitter Full Name: Brad Stilwell
Organization: Fike Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 05 12:31:46 EST 2016

Public Input No. 25-NFPA 2001-2015 [New Section after 4.2.1.5]

Dirt trap.

A dirt trap consisting of a tee with a capped nipple, at least 50 mm (2 inches) long , shall be installed at the end of each pipe run.

Statement of Problem and Substantiation for Public Input

1. Regardless of initial pipe cleanliness, rust and scale can form in pipes over time.
2. Loosened pipe scale will be discharged into the protected space, thereby contaminating that space and negating the principle of "clean" that is a basis of "clean agent" systems..
3. Dirt traps are required by ISO 14520, 6.3.1.2, which demonstrates that the international community for fixed-gas fire extinguishing systems recognizes risk related to pipe scale.

Submitter Information Verification

Submitter Full Name: Joseph Senecal

Organization: Kidde-Fenwal, Inc.

Street Address:

City:

State:

Zip:

Submittal Date: Wed Dec 16 14:55:35 EST 2015

Public Input No. 45-NFPA 2001-2016 [New Section after 4.2.3.7]

TITLE OF NEW CONTENT

Type your content here ...

4.2.3.8 Where grooved fittings are used to join pipe, the manufacturer's pressure and temperature ratings of the fitting shall not be exceeded.

Statement of Problem and Substantiation for Public Input

Table A.4.2.3.1(a) includes grooved couplings as acceptable fittings for clean agent systems. Note "b" in the Table states: "Check with grooved fitting manufacturers for pressure ratings." The proposed 4.2.3.8 would make it mandatory to follow the manufacturer's pressure and temperature ratings for grooved fittings.

The addition parallels 4.2.3.7 which addresses compression type fittings and is in keeping with the NFPA manual of style.

Submitter Information Verification

Submitter Full Name: John Spalding

Organization: Healey Fire Protection, Inc.

Affilliation: Fire Suppression Systems Association

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jan 06 14:12:26 EST 2016

Public Input No. 1-NFPA 2001-2015 [Section No. 4.3.1.2 [Excluding any Sub-Sections]]

> Automatic detection and automatic actuation shall be used. <u>The use of a dry contact closure from another fire alarm control unit providing the detection shall not be permitted.Detection devices within the protectedd space shall be connected to the fire alarm control unit listed for releasing the suppression agent.</u>

Statement of Problem and Substantiation for Public Input

Many systems are being installed with a building fire alarm system being used for activation of a fire alarm control unit listed for releasing through a dry contact interface. The fire alarm control unit responsible for releasing is required to be a standalone unit monitored by the building fire alarm system unless the building fire alarm system is providing both the detection and the release of the suppression agent. This revision will correct and clarify the requirements for automatic detection and functionality of the fire alarm control unit responsible for release of the suppression agent. This dry contact interface used is an unsupervised connection and is often not installed within 3' of the control unit used for releasing the suppression agent. Additionally a relay is not considered a detection device even though it may be activated by another fire alarm control unit with automatic detection devices.

Submitter Information Verification

Submitter Full Name: JON KAPIS
Organization: SABAH INTERNATIONAL
Affilliation: None
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jul 08 16:10:50 EDT 2015

Public Input No. 19-NFPA 2001-2015 [Section No. 4.3.1.3]

4.3.1.3 – *

Initiating and releasing circuits shall be installed in raceways.

4.3.1.3.1 Other than as permitted in 4.3.1.3.1 2 , alternating current (ac) and direct current (dc) wiring shall not be combined in a common conduit or raceway.

4.3.1.3.1 – 2

It shall be permitted to combine ac and dc wiring in a common conduit or raceway where shielded and grounded.

4.3.1.3.2.3

The requirements of 4.3.1.3 for initiating circuits shall not apply to the wireless pathways of low-power radio systems.

A.4.3.1.3

The use of raceways is intended to protect against physical damage to conductors and cabling.

Statement of Problem and Substantiation for Public Input

The two (2) requirements of 4.3.1.3 were separated in accordance with the Manual of Style.
The proposed change recognizes the advancement in technology for the use of wireless detection systems.
The Annex material addresses the reason for initiating and releasing circuits to be in raceways.

Submitter Information Verification

Submitter Full Name: John Spalding
Organization: Healey Fire Protection Inc
Affilliation: Fire Suppression Systems Association
Street Address:
City:
State:
Zip:
Submittal Date: Wed Nov 25 15:01:26 EST 2015

Public Input No. 49-NFPA 2001-2016 [Section No. 4.3.1.3]

4.3.1.3 *

Initiating and releasing circuits shall be installed in raceways.

4.3.1.3.1

Other than as permitted in 4.3.1.3.

~~1~~

2 , alternating current (ac) and direct current (dc) wiring shall not be combined in a common conduit or raceway.

4.3.1.3.

~~1~~

2 It shall be permitted to combine ac and dc wiring in a common conduit or raceway where shielded and grounded.

4.3.1.3.3 The requirements of 4.3.1.3 shall not apply to the wireless pathways of low-power radio systems.

A.4.3.1.3 The use of raceways is intended to protect against physical damage to conductors and cabling.

Statement of Problem and Substantiation for Public Input

To clarify that this requirement is intended to guard against physical damage to conductors and cabling. The two requirements of 4.3.1.3 were separated in accordance with the Manual of Style. Also 4.3.1.3 implies that wireless technology is not permitted. This will clarify that the above section refers to both wired and wireless as permitted by NFPA 72.

Submitter Information Verification

Submitter Full Name: Vince Baclawski
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 07 09:32:15 EST 2016

Public Input No. 3-NFPA 2001-2015 [New Section after 4.3.5.2]

TITLE OF NEW CONTENT

Type your content here ...4.3.5.2.1 Audible and visisble alarms for pending discharge or continued operation after discharge shall not function during a building fire alarm event, unless casued by the event within the protected area.

Statement of Problem and Substantiation for Public Input

This language will ensure that the building notification appliances are not activated within the protected area when the notification appliances used to signal pre-discharge and continuing discharge of the suppression agent, thus eliminating conflicting and completing signals. This would require that building alarm notification appliances are seperately zoned for the protected area and capable of being controlled to eliminate conflicting and competing signals.

Submitter Information Verification

Submitter Full Name: JON KAPIS

Organization: SABAH INTERNATIONAL

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 08 16:19:51 EDT 2015

Public Input No. 54-NFPA 2001-2016 [New Section after 6.3]

6.3.1

The design quantity to ensure complete extinguishment shall be confirmed by test.

Statement of Problem and Substantiation for Public Input

No performance based requirement exists to verify that the quantity used is indeed sufficient to extinguish the fire. Requiring a test to determine that extinguishment provides a mechanism to validate the suppression solution is effective. It also aligns with the requirements included in paragraph 5.4.2.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 53-NFPA 2001-2016 [Section No. 6.3]	6.3.1 is subparagraph to 6.3.

Submitter Information Verification

Submitter Full Name: Paul Rivers
Organization: 3M Company
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 07 17:50:30 EST 2016

Public Input No. 53-NFPA 2001-2016 [Section No. 6.3]

6.3 Clean Agent Requirements.

The design quantity of clean agent required for local application systems shall be based on the rate of discharge and the time that the discharge must be maintained to ensure complete extinguishment. The minimum design quantity shall be no less than 1.5 times the minimum quantity required for extinguishment at any selected system discharge rate.

Statement of Problem and Substantiation for Public Input

The quantity of agent needs to be defined as that designed. That design quantity should be determined by test.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 54-NFPA 2001-2016 [New Section after 6.3]	

Submitter Information Verification

Submitter Full Name: Paul Rivers
Organization: 3M Company
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 07 17:46:14 EST 2016

Public Input No. 24-NFPA 2001-2015 [New Section after 7.1.3.3]

Owners Inspection.

On a monthly basis, inspection shall be conducted in accordance with the manufacturer’s listed installation and maintenance manual orowner’s manual.

As a minimum, this “quick check” or inspection shall include verification of the following:

(1)Release panel is in service.

(2)Manual actuators are unobstructed.

(3)Maintenance Tag is in place.

(4)System shows no physical damage or condition that might prevent operation.

(5)Pressure gauges if provided are in required operational range.

(6)Protected equipment and or hazard has not been changed and or modified.

(7)Noted deficiencies have been corrected.

If any deficiencies are found, appropriate corrective action shall be taken immediately.

Where the corrective action involves maintenance, it shall be conducted by a service technician.

Personnel making inspections shall keep records for those extinguishing systems that were found to require corrective actions.

At least monthly, the date the inspection is performed and the initials of the person performing the inspection shall be recorded. The recordsshall be retained until the next semiannual maintenance.

A service technician who performs maintenance on an extinguishing system shall be trained and shall have passed a written or online test that is acceptable to the authority having jurisdiction.

Additional Proposed Changes

File Name	Description	Approved
2001_PC_3_-_Held.pdf	PC 3 held	

Statement of Problem and Substantiation for Public Input

Note: This Public Input originated as Public Comment No. 18 and was reported at as "Reject but Hold" in the F2014 Second Draft Report for NFPA 79, per the Regs at 4.4.8.3.1.
Submitter's Substantiation: Provide documentation by owner's representative that due diligence is being performed checking that systems are being maintained in service.

Submitter Information Verification

Submitter Full Name: TC GFE-AAA

Organization: NFPA

Street Address:

City:

State:

Zip:

Submittal Date: Tue Dec 15 10:31:57 EST 2015

Public Comment No. 3-NFPA 2001-2013 [New Section after 7.1.3.3]

TITLE OF NEW CONTENT

Owners Inspection.

On a monthly basis, inspection shall be conducted in accordance with the manufacturer's listed installation and maintenance manual or owner's manual.

As a minimum, this "quick check" or inspection shall include verification of the following:

(1) Release panel is in service.

(2) Manual actuators are unobstructed

(3) Maintenance Tag is in place.

(4) System shows no physical damage or condition that might prevent operation.

(5) Pressure gauges if provided are in required operational range.

(6) Protected equipment and or hazard has not been changed and or modified.

(7) Noted deficiencies have been corrected.

If any deficiencies are found, appropriate corrective action shall be taken immediately.

Where the corrective action involves maintenance, it shall be conducted by a service technician

Personnel making inspections shall keep records for those extinguishing systems that were found to require corrective actions.

At least monthly, the date the inspection is performed and the initials of the person performing the inspection shall be recorded. The records shall be retained until the next semiannual maintenance.

A service technician who performs maintenance on an extinguishing system shall be trained and shall have passed a written or online test that is acceptable to the authority having jurisdiction.

Statement of Problem and Substantiation for Public Comment

Provide documentation by owners representative that due dilligence is being performed checking that systems are being maintained in service.

Submitter Information Verification

Submitter Full Name: BEN SMITH

Organization: GLOBAL RISK CONSULTANTS

Affilliation: Member

Street Address:

City:

State:

Zip:

Submittal Date: Tue Nov 05 13:28:45 EST 2013

Committee Statement

Committee Action: Rejected but held

Resolution: The committee agrees that this concept should be included in the standard. However, it constitutes new material at this time and is being held for further consideration at the next revision cycle.

Public Input No. 44-NFPA 2001-2016 [New Section after 7.7.1]

7.7.1.2

Systems integrated with the Clean Agent Fire Extinguishing System shall be planned, tested, documented, and maintained in accordance with NFPA 4 Standard for Integrated Fire Protection and Life Safety System Testing.

Statement of Problem and Substantiation for Public Input

Many installations utilize various individual systems (Fire Suppression, Fire Alarm or signaling system, emergency communication system, fire doors, dampers, elevators, smoke control, HVAC, supervising station, etc.) for fire protection and life safety where each may utilize their own code, standard, or acceptance criteria. NFPA 4 is a new standard that provides requirements for testing integrated systems together so that the entire fire protection and life safety system objective is accomplished.

Submitter Information Verification

Submitter Full Name: Kimberly Gruner

Organization: Fike Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jan 06 14:10:45 EST 2016

Public Input No. 46-NFPA 2001-2016 [Section No. 7.7.1]

7.7.1 General.

7.7.1.1 The completed system shall be reviewed and tested by qualified personnel to meet the approval of the authority having jurisdiction. Only listed equipment and devices shall be used in the systems. To determine that the system has been properly installed and will function as specified, the following tests shall be performed.

Statement of Problem and Substantiation for Public Input

Adding a section number to conform with manual of style upon acceptance of Public Input 44.

Submitter Information Verification

Submitter Full Name: Kimberly Gruner
Organization: Fike Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 06 14:31:51 EST 2016

Public Input No. 36-NFPA 2001-2016 [Section No. A.1.4.1]

A.1.4.1

The agents currently listed possess the physical properties as detailed in Table A.1.4.1(a) through Table A.1.4.1(d). These data will be revised from time to time as new information becomes available. Additional background information and data on these agents can be found in several references: Fernandez (1991), Hanauska (1991), Robin (1991), and Sheinson (1991).

Table A.1.4.1(a) Physical Properties of Clean Halocarbon Agents (U.S. Units)

Physical Property	Units	FIC-13I1	FK-5-1-12	HCFC Blend A	HFC Blend B	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC
Molecular weight	N/A	195.9	316.04	92.9	99.4	136.5	120.0	170	70.01	1
Boiling point at 760 mm Hg	°F	-8.5	120.2	-37	-14.9	10.5	-54	2.4	-115.6	2
Freezing point	°F	-166	-162.4	161	-153.9	-326	-153	-204	-247.4	-1
Critical temperature	°F	252	335.6	256	219.9	252.5	150.8	214	79.1	25
Critical pressure	psi	586	270.44	964	588.9	527	525	424	700	46
Critical volume	ft^3/lbm	0.0184	0.0251	0.028	0.031	0.0286	0.0279	0.0280	0.0304	0.0
Critical density	lbm/ft^3	54.38	39.91	36	32.17	34.96	35.81	35.77	32.87	34
Specific heat, liquid at 77°F	Btu/lb-°F	0.141	0.2634	0.3	0.339	0.271	0.354	0.281	0.987 at 68°F	0.3
Specific heat, vapor at constant pressure (1 atm) and 77°F	Btu/lb-°F	0.86	0.2127	0.16	0.203	0.18	0.19	0.193	0.175 at 68°F	0.
Heat of vaporization at boiling point	Btu/lb	48.1	37.8	97	93.4	71.3	70.5	56.6	103	68
Thermal conductivity of liquid at 77°F	Btu/hr-ft-°F	0.04	0.034	0.052	0.0478	0.0395	0.0343	0.034	0.0305	0.0
Viscosity, liquid at 77°F	lb/ft-hr	0.473	1.27	0.508	0.485	0.622	0.338	0.579	0.107	0.6
Relative dielectric strength at 1 atm at 734 mm Hg, (N_2 = 1)	N/A	1.41 at 77°F	2.3 at 77°F	1.32 at 77°F	1.014 at 77°F	1.55 at 77°F	0.955 at 70°F	2 at 77°F	1.04 at 77°F	1.01 7
Solubility of water in agent	wt%	0.01 at 70°F	<0.001 at 70°F	0.12 at 70°F	0.11 at 70°F	770 at 77°F	770 at 77°F	0.06 at 70°F	500 at 50°F	74 6

Table A.1.4.1(b) Physical Properties of Inert Gas Agents (U.S. Units)

Physical Property	Units	IG-01	IG-100	IG-541	IG-55
Molecular weight	N/A	39.9	28.0	34.0	33.95
Boiling point at 760 mm Hg	°F	-302.6	-320.4	-320	-310.2
Freezing point	°F	-308.9	-346.0	-109	-327.5
Critical temperature	°F	-188.1	-232.4	N/A	-210.5
Critical pressure	psia	711	492.9	N/A	602
Specific heat, vapor at constant pressure (1 atm) and 77°F	Btu/lb °F	0.125	0.445	0.195	0.187
Heat of vaporization at boiling point	Btu/lb	70.1	85.6	94.7	77.8
Relative dielectric strength at 1 atm at 734 mm Hg, 77°F (N_2 = 1.0)	N/A	1.01	1.0	1.03	1.01
Solubility of water in agent at 77°F	N/A	0.006%	0.0013%	0.015%	0.006%

Table A.1.4.1(c) Physical Properties of Clean Halocarbon Agents (SI Units)

Physical Property	Units	FIC-13I1	FK-5-1-12	HCFC Blend A	HFC Blend B	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-
Molecular weight	N/A	195.91	316.04	92.90	99.4	136.5	120	170	70.01	15
Boiling point at 760 mm Hg	°C	-22.5	49	-38.3	-26.1	-12.0	-48.1	-16.4	-82.1	-1
Freezing point	°C	-110	-108	<107.2	-103	-198.9	-102.8	-131	-155.2	-1(
Critical temperature	°C	122	168.66	124.4	101.1	122.6	66	101.7	26.1	12
Critical pressure	kPa	4041	1865	6647	4060	3620	3618	2912	4828	32
Critical volume	cc/mole	225	494.5	162	198	243	210	274	133	27
Critical density	kg/m^3	871	639.1	577	515.3	560	574	621	527	55
Specific heat, liquid at 25°C	kJ/kg - °C	0.592 at 25°C	1.103 at 25°C	1.256 at 25°C	1.44 at 25°C	1.153 at 25°C	1.407 at 25°C	1.184 at 25°C	4.130 at 20°C	1.26 25
Specific heat, vapor at constant pressure (1 atm) and 25°C	kJ/kg - °C	0.3618 at 25°C	0.891 at 25°C	0.67 at 25°C	0.848 at 25°C	0.742 at 25°C	0.797 at 25°C	0.808 at 25°C	0.731 at 20°C	0.84 25
Heat of vaporization at boiling point	kJ/kg	112.4	88	225.6	217.2	165.9	164.1	132.6	239.3	16(
Thermal conductivity of liquid at 25°C	W/m - °C	0.07	0.059	0.09	0.082	0.0684	0.0592	0.069	0.0534	0.0

Physical Property	Units	FIC-13I1	FK-5-1-12	HCFC Blend A	HFC Blend B	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-
Viscosity, liquid at 25°C	centipoise	0.196	0.524	0.21	0.202	0.257	0.14	0.184	0.044	0.2
Relative dielectric strength at 1 atm at 734 mm Hg (N_2 = 1.0)	N/A	1.41 at 25°C	2.3 at 25°C	1.32 at 25°C	1.014 at 25°C	1.55 at 25°C	0.955 at 21°C	2 at 25°C	1.04 at 25°C	1.01 25
Solubility of water in agent	ppm	1.0062% by weight	<0.001	0.12% by weight	0.11% by weight	700 at 25°C	700 at 25°C	0.06% by weight	500 at 10°C	740 20

Table A.1.4.1(d) Physical Properties of Inert Gas Agents (SI Units)

Physical Property	Units	IG-01	IG-100	IG-541	IG-55
Molecular weight	N/A	39.9	28.0	34.0	33.95
Boiling point at 760 mm Hg	°C	-189.85	-195.8	-196	-190.1
Freezing point	°C	-189.35	-210.0	-78.5	-199.7
Critical temperature	°C	-122.3	-146.9	N/A	-134.7
Critical pressure	kPa	4,903	3,399	N/A	4,150
Specific heat, vapor at constant pressure (1 atm) and 25°C	kJ/kg °C	0.519	1.04	0.574	0.782
Heat of vaporization at boiling point	kJ/kg	163	199	220	181
Relative dielectric strength at 1 atm at 734 mm Hg, 25°C (N_2 = 1.0)	N/A	1.01	1.0	1.03	1.01
Solubility of water in agent at 25°C	N/A	0.006%	0.0013%	0.015%	0.006%

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]	Required for new agent

Submitter Information Verification

Submitter Full Name: Brad Stilwell
Organization: Fike Corporation
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jan 05 12:37:27 EST 2016

Public Input No. 37-NFPA 2001-2016 [Section No. A.1.5.1.2]

A.1.5.1.2

Table A.1.5.1.2(a) 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 SNAP evaluation this aspect (of the rigor) of the test protocol.

Table A.1.5.1.2(a) 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*
New Agent	TBA	TBA	TBA

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 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 heart beats 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 (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 1.5.1.2.1, 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 fire fighting. 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 1.5.1.2.1. 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.

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 (front part) region of the nose and extending back to the lower respiratory tract (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 (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 (nose breathing) or lower respiratory tract (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:

$$C \times t = k \quad \textbf{[A.1.5.1.2]}$$

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 DL 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 fire fighters, 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 (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 (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 A.1.5.1.2(b) 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 may need to be considered in clean-up procedures where high levels of HF were generated. (More information can be obtained from the American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240, 513-742-2020.)

Table A.1.5.1.2(b) 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

Exposure Time	Concentration of Hydrogen Fluoride (ppm)	Reaction
	>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 ACGIH TLV, the American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline (ERPG) represents limits established for emergency release of chemicals. These limits 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 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. (More information can be obtained from the American Industrial Hygiene Association, 2700 Prosperity Ave., Suite 250, Fairfax, VA 22031, 703-849-8888, fax 703-207-3561.)

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]	Required for new agent

Submitter Information Verification

Submitter Full Name: Brad Stilwell
Organization: Fike Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 05 12:41:50 EST 2016

Public Input No. 38-NFPA 2001-2016 [Section No. A.1.6]

A.1.6

Many factors impact the environmental acceptability of a fire suppression agent. Uncontrolled fires pose significant impact by themselves. All extinguishing agents should be used in ways that eliminate or minimize the potential environmental impact *(see Table A.1.6)*. General guidelines to be followed to minimize this impact include the following:

(1) Not performing unnecessary discharge testing

(2) Considering the ozone depletion and global warming impact of the agent under consideration and weighing those impacts against the fire safety concerns

(3) Recycling all agents where possible

(4) Consulting the most recent environmental regulations on each agent

The unnecessary emission of clean extinguishing agents with non-zero ODP, non-zero GWP, or both should be avoided. All phases of design, installation, testing, and maintenance of systems using these agents should be performed with the goal of no emission into the environment.

GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale that compares the gas in question to the same mass of carbon dioxide whose GWP is by convention equal to 1.

It is important to understand that the impact of a gas on climate change is a function of both the GWP of the gas and the amount of the gas emitted.

The ODP of an agent provides a relative comparison of the ability to react with ozone at altitudes within the stratosphere. ODP values are reported relative to the same mass CFC-11, which has an ODP equal to 1. When the environmental profile of a compound is considered, both the ODP and the GWP values should be considered to ensure that the agent selected complies with all local and regional regulations balanced with end user specifications. Good independent resources for environmental properties in terms of GWP and ODP of clean agent alternatives are available from the Montreal Protocol and the Intergovernmental Panel on Climate Change (IPCC).

Table A.1.6 **Potential Environmental Impacts**

Agent	GWP (IPCC 2013)	ODP
FIC-13I1	≤1	0*
FK-5-1-12	≤1	0
HCFC Blend A	1500	0.048
HFC Blend B	1400	0
HCFC-124	527	0.022
HFC-125	3170	0
HFC-227ea	3350	0
HFC-23	12,400	0
HFC-236fa	8060	0
IG-01	0	0
IG-100	0	0
IG-541	0	0
IG-55	0	0
New Agent	TBA	TBA

Note: GWP is reported over a 100-year integrated time horizon.

*Agent might have a nonzero ODP if released at altitudes high above ground level.

Statement of Problem and Substantiation for Public Input

There is a new zero ODP and low GWP agent that can be used for fire suppression. This agent is being tested for

NOAEL and LOAEL values at this time. Upon successful test results and submission to the EPA, the technical information will be forwarded to NFPA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 33-NFPA 2001-2016 [Section No. 1.4.1.2]	required for new agent

Submitter Information Verification

Submitter Full Name:	Brad Stilwell
Organization:	Fike Corporation
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jan 05 12:50:59 EST 2016

Public Input No. 50-NFPA 2001-2016 [Section No. A.1.6]

A.1.6

Many factors impact the environmental acceptability of a fire suppression agent. Uncontrolled fires pose significant impact by themselves. All extinguishing agents should be used in ways that eliminate or minimize the potential environmental impact *(see Table A.1.6)*. General guidelines to be followed to minimize this impact include the following:

(1) Not performing unnecessary discharge testing

(2) Considering the ozone depletion and global warming impact of the agent under consideration and weighing those impacts against the fire safety concerns

(3) Recycling all agents where possible

(4) Consulting the most recent environmental regulations on each agent

The unnecessary emission of clean extinguishing agents with non-zero ODP, non-zero GWP, or both should be avoided. All phases of design, installation, testing, and maintenance of systems using these agents should be performed with the goal of no emission into the environment.

GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale that compares the gas in question to the same mass of carbon dioxide whose GWP is by convention equal to 1.

It is important to understand that the impact of a gas on climate change is a function of both the GWP of the gas and the amount of the gas emitted.

The ODP of an agent provides a relative comparison of the ability to react with ozone at altitudes within the stratosphere. ODP values are reported relative to the same mass CFC-11, which has an ODP equal to 1. When the environmental profile of a compound is considered, both the ODP and the GWP values should be considered to ensure that the agent selected complies with all local and regional regulations balanced with end user specifications. Good independent resources for environmental properties in terms of GWP and ODP of clean agent alternatives are available from the Montreal Protocol and the Intergovernmental Panel on Climate Change (IPCC).

Table A.1.6 **Potential Environmental Impacts**

Agent	**GWP (IPCC 2013)**	**ODP**
FIC-13I1	≤1	0*
FK-5-1-12	~~≤1~~ <1	0
HCFC Blend A	1500	0.048
HFC Blend B	1400	0
HCFC-124	527	0.022
HFC-125	3170	0
HFC-227ea	3350	0
HFC-23	12,400	0
HFC-236fa	8060	0
IG-01	0	0
IG-100	0	0
IG-541	0	0
IG-55	0	0

Note: GWP is reported over a 100-year integrated time horizon.

*Agent might have a nonzero ODP if released at altitudes high above ground level.

Additional Proposed Changes

File Name	Description	Approved
14_feb_GWP_tables_from_WG1AR5_Chapter08.pdf	Table 8.A.1 in the referenced IPCC AR 5 2013 report	

Statement of Problem and Substantiation for Public Input

Corrected GWP data of <1 aligns with Table 8.A.1 in the referenced IPCC 2013 report. The chemical formula CF3CF2C(O)CF(CF3)2 in the report is the same as that associated with FK-5-1-12 in NFPA 2001, Table 1.4.1.2.

Submitter Information Verification

Submitter Full Name: Paul Rivers

Organization: 3M Company

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jan 07 17:28:54 EST 2016

Appendix 8.A: Lifetimes, Radiative Efficiencies and Metric Values

Table 8.A.1 | Radiative efficiencies (REs), lifetimes/adjustment times, AGWP and GWP values for 20 and 100 years, and AGTP and GTP values for 20, 50 and 100 years. Climate–carbon feedbacks are included for CO_2 while no climate feedbacks are included for the other components (see discussion in Sections 8.7.1.4 and 8.7.2.1, Supplementary Material and notes below the table; Supplementary Material Table 8.SM.16 gives analogous values including climate–carbon feedbacks for non-CO_2 emissions). For a complete list of chemical names and CAS numbers, and for accurate replications of metric values, see Supplementary Material Section 8.SM.13 and references therein.

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency ($W m^{-2} ppb^{-1}$)	AGWP 20-year ($W m^{-2} yr kg^{-1}$)	**GWP 20-year**	AGWP 100-year ($W m^{-2} yr kg^{-1}$)	**GWP 100-year**	AGTP 20-year ($K kg^{-1}$)	**GTP 20-year**	AGTP 50-year ($K kg^{-1}$)	**GTP 50-year**	AGTP 100-year ($K kg^{-1}$)	**GTP 100-year**
Carbon dioxide	CO_2	see*	1.37e-5	2.49e-14	**1**	9.17e-14	**1**	6.84e-16	**1**	6.17e-16	**1**	5.47e-16	**1**
Methane	CH_4	12.4†	3.63e-4	2.09e-12	**84**	2.61e-12	**28**	4.62e-14	**67**	8.69e-15	**14**	2.34e-15	**4**
Fossil methane‡	CH_4	12.4†	3.63e-4	2.11e-12	**85**	2.73e-12	**30**	4.68e-14	**68**	9.55e-15	**15**	3.11e-15	**6**
Nitrous Oxide	N_2O	121†	3.00e-3	6.58e-12	**264**	2.43e-11	**265**	1.89e-13	**277**	1.74e-13	**282**	1.28e-13	**234**
Chlorofluorocarbons													
CFC-11	CCl_3F	45.0	0.26	1.72e-10	**6900**	4.28e-10	**4660**	4.71e-12	**6890**	3.01e-12	**4890**	1.28e-12	**2340**
CFC-12	CCl_2F_2	100.0	0.32	2.69e-10	**10,800**	9.39e-10	**10,200**	7.71e-12	**11,300**	6.75e-12	**11,000**	4.62e-12	**8450**
CFC-13	$CClF_3$	640.0	0.25	2.71e-10	**10,900**	1.27e-09	**13,900**	7.99e-12	**11,700**	8.77e-12	**14,200**	8.71e-12	**15,900**
CFC-113	CCl_2FCClF_2	85.0	0.30	1.62e-10	**6490**	5.34e-10	**5820**	4.60e-12	**6730**	3.85e-12	**6250**	2.45e-12	**4470**
CFC-114	$CClF_2CClF_2$	190.0	0.31	1.92e-10	**7710**	7.88e-10	**8590**	5.60e-12	**8190**	5.56e-12	**9020**	4.68e-12	**8550**
CFC-115	$CClF_2CF_3$	1,020.0	0.20	1.46e-10	**5860**	7.03e-10	**7670**	4.32e-12	**6310**	4.81e-12	**7810**	4.91e-12	**8980**
Hydrochlorofluorocarbons													
HCFC-21	$CHCl_2F$	1.7	0.15	1.35e-11	**543**	1.35e-11	**148**	1.31e-13	**192**	1.59e-14	**26**	1.12e-14	**20**
HCFC-22	$CHClF_2$	11.9	0.21	1.32e-10	**5280**	1.62e-10	**1760**	2.87e-12	**4200**	5.13e-13	**832**	1.43e-13	**262**
HCFC-122	$CHCl_2CF_2Cl$	1.0	0.17	5.43e-12	**218**	5.43e-12	**59**	4.81e-14	**70**	6.25e-15	**10**	4.47e-15	**8**
HCFC-122a	$CHFClCFCl_2$	3.4	0.21	2.36e-11	**945**	2.37e-11	**258**	2.91e-13	**426**	2.99e-14	**48**	1.96e-14	**36**
HCFC-123	$CHCl_2CF_3$	1.3	0.15	7.28e-12	**292**	7.28e-12	**79**	6.71e-14	**98**	8.45e-15	**14**	6.00e-15	**11**
HCFC-123a	$CHClFCF_2Cl$	4.0	0.23	3.37e-11	**1350**	3.39e-11	**370**	4.51e-13	**659**	4.44e-14	**72**	2.81e-14	**51**
HCFC-124	$CHClFCF_3$	5.9	0.20	4.67e-11	**1870**	4.83e-11	**527**	7.63e-13	**1120**	7.46e-14	**121**	4.03e-14	**74**
HCFC-132c	CH_2FCFCl_2	4.3	0.17	3.07e-11	**1230**	3.10e-11	**338**	4.27e-13	**624**	4.14e-14	**67**	2.58e-14	**47**
HCFC-141b	CH_3CCl_2F	9.2	0.16	6.36e-11	**2550**	7.17e-11	**782**	1.27e-12	**1850**	1.67e-13	**271**	6.09e-14	**111**
HCFC-142b	CH_3CClF_2	17.2	0.19	1.25e-10	**5020**	1.82e-10	**1980**	3.01e-12	**4390**	8.46e-13	**1370**	1.95e-13	**356**
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.22	1.17e-11	**469**	1.17e-11	**127**	1.17e-13	**170**	1.38e-14	**22**	9.65e-15	**18**
HCFC-225cb	$CHClFCF_2CClF_2$	5.9	0.29	4.65e-11	**1860**	4.81e-11	**525**	7.61e-13	**1110**	7.43e-14	**120**	4.01e-14	**73**
(E)-1-Chloro-3,3,3-trifluoroprop-1-ene	trans-$CF_3CH=CHCl$	26.0 days	0.04	1.37e-13	**5**	1.37e-13	**1**	1.09e-15	**2**	1.54e-16	**<1**	1.12e-16	**<1**

(continued on next page)

Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	GWP 20-year	AGWP 100-year (W m^{-2} yr kg^{-1})	GWP 100-year	AGTP 20-year (K kg^{-1})	GTP 20-year	AGTP 50-year (K kg^{-1})	GTP 50-year	AGTP 100-year (K kg^{-1})	GTP 100-year
Hydrofluorocarbons													
HFC-23	CHF_3	222.0	0.18	2.70e-10	**10,800**	1.14e-09	**12,400**	7.88e-12	**11,500**	7.99e-12	**13,000**	6.95e-12	**12,700**
HFC-32	CH_2F_2	5.2	0.11	6.07e-11	**2430**	6.21e-11	**677**	9.32e-13	**1360**	8.93e-14	**145**	5.17e-14	**94**
HFC-41	CH_3F	2.8	0.02	1.07e-11	**427**	1.07e-11	**116**	1.21e-13	**177**	1.31e-14	**21**	8.82e-15	**16**
HFC-125	CHF_2CF_3	28.2	0.23	1.52e-10	**6090**	2.91e-10	**3170**	3.97e-12	**5800**	1.84e-12	**2980**	5.29e-13	**967**
HFC-134	CHF_2CHF_2	9.7	0.19	8.93e-11	**3580**	1.02e-10	**1120**	1.82e-12	**2660**	2.54e-13	**412**	8.73e-14	**160**
HFC-134a	CH_2FCF_3	13.4	0.16	9.26e-11	**3710**	1.19e-10	**1300**	2.09e-12	**3050**	4.33e-13	**703**	1.10e-13	**201**
HFC-143	CH_2FCHF_2	3.5	0.13	3.00e-11	**1200**	3.01e-11	**328**	3.76e-13	**549**	3.82e-14	**62**	2.49e-14	**46**
HFC-143a	CH_3CF_3	47.1	0.16	1.73e-10	**6940**	4.41e-10	**4800**	4.76e-12	**6960**	3.12e-12	**5060**	1.37e-12	**2500**
HFC-152	CH_2FCH_2F	0.4	0.04	1.51e-12	**60**	1.51e-12	**16**	1.25e-14	**18**	1.71e-15	**3**	1.24e-15	**2**
HFC-152a	CH_3CHF_2	1.5	0.10	1.26e-11	**506**	1.26e-11	**138**	1.19e-13	**174**	1.47e-14	**24**	1.04e-14	**19**
HFC-161	CH_3CH_2F	66.0 days	0.02	3.33e-13	**13**	3.33e-13	**4**	2.70e-15	**4**	3.76e-16	**<1**	2.74e-16	**<1**
HFC-227ca	$CF_3CF_2CHF_2$	28.2	0.27	1.27e-10	**5080**	2.42e-10	**2640**	3.31e-12	**4830**	1.53e-12	**2480**	4.41e-13	**806**
HFC-227ea	CF_3CHFCF_3	38.9	0.26	1.34e-10	**5360**	3.07e-10	**3350**	3.61e-12	**5280**	2.12e-12	**3440**	7.98e-13	**1460**
HFC-236cb	$CH_2FCF_2CF_3$	13.1	0.23	8.67e-11	**3480**	1.11e-10	**1210**	1.94e-12	**2840**	3.92e-13	**636**	1.01e-13	**185**
HFC-236ea	CHF_2CHFCF_3	11.0	0.30[a]	1.03e-10	**4110**	1.22e-10	**1330**	2.18e-12	**3190**	3.53e-13	**573**	1.06e-13	**195**
HFC-236fa	$CF_3CH_2CF_3$	242.0	0.24	1.73e-10	**6940**	7.39e-10	**8060**	5.06e-12	**7400**	5.18e-12	**8400**	4.58e-12	**8380**
HFC-245ca	$CH_2FCF_2CHF_2$	6.5	0.24[b]	6.26e-11	**2510**	6.56e-11	**716**	1.07e-12	**1570**	1.09e-13	**176**	5.49e-14	**100**
HFC-245cb	$CF_3CF_2CH_3$	47.1	0.24	1.67e-10	**6680**	4.24e-10	**4620**	4.58e-12	**6690**	3.00e-12	**4870**	1.32e-12	**2410**
HFC-245ea	$CHF_2CHFCHF_2$	3.2	0.16[c]	2.15e-11	**863**	2.16e-11	**235**	2.59e-13	**378**	2.70e-14	**44**	1.79e-14	**33**
HFC-245eb	$CH_2FCHFCF_3$	3.1	0.20[c]	2.66e-11	**1070**	2.66e-11	**290**	3.15e-13	**460**	3.31e-14	**54**	2.20e-14	**40**
HFC-245fa	$CHF_2CH_2CF_3$	7.7	0.24	7.29e-11	**2920**	7.87e-11	**858**	1.35e-12	**1970**	1.51e-13	**245**	6.62e-14	**121**
HFC-263fb	$CH_3CH_2CF_3$	1.2	0.10[c]	6.93e-12	**278**	6.93e-12	**76**	6.31e-14	**92**	8.02e-15	**13**	5.70e-15	**10**
HFC-272ca	$CH_3CF_2CH_3$	2.6	0.07	1.32e-11	**530**	1.32e-11	**144**	1.46e-13	**213**	1.61e-14	**26**	1.09e-14	**20**
HFC-329p	$CHF_2CF_2CF_2CF_3$	28.4	0.31	1.13e-10	**4510**	2.16e-10	**2360**	2.94e-12	**4290**	1.37e-12	**2220**	3.96e-13	**725**
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.7	0.22	6.64e-11	**2660**	7.38e-11	**804**	1.30e-12	**1890**	1.62e-13	**262**	6.24e-14	**114**
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	16.1	0.42[b]	1.08e-10	**4310**	1.51e-10	**1650**	2.54e-12	**3720**	6.62e-13	**1070**	1.54e-13	**281**
HFC-1132a	$CH_2{=}CF_2$	4.0 days	0.004[d]	3.87e-15	**<1**	3.87e-15	**<1**	3.08e-17	**<1**	4.35e-18	**<1**	3.18e-18	**<1**
HFC-1141	$CH_2{=}CHF$	2.1 days	0.002[d]	1.54e-15	**<1**	1.54e-15	**<1**	1.23e-17	**<1**	1.73e-18	**<1**	1.27e-18	**<1**
(Z)-HFC-1225ye	$CF_3CF{=}CHF(Z)$	8.5 days	0.02	2.14e-14	**<1**	2.14e-14	**<1**	1.70e-16	**<1**	2.40e-17	**<1**	1.76e-17	**<1**
(E)-HFC-1225ye	$CF_3CF{=}CHF(E)$	4.9 days	0.01	7.25e-15	**<1**	7.25e-15	**<1**	5.77e-17	**<1**	8.14e-18	**<1**	5.95e-18	**<1**
(Z)-HFC-1234ze	$CF_3CH{=}CHF(Z)$	10.0 days	0.02	2.61e-14	**1**	2.61e-14	**<1**	2.08e-16	**<1**	2.93e-17	**<1**	2.14e-17	**<1**
HFC-1234yf	$CF_3CF{=}CH_2$	10.5 days	0.02	3.22e-14	**1**	3.22e-14	**<1**	2.57e-16	**<1**	3.62e-17	**<1**	2.65e-17	**<1**
(E)-HFC-1234ze	trans-$CF_3CH{=}CHF$	16.4 days	0.04	8.74e-14	**4**	8.74e-14	**<1**	6.98e-16	**<1**	9.82e-17	**<1**	7.18e-17	**<1**
(Z)-HFC-1336	$CF_3CH{=}CHCF_3(Z)$	22.0 days	0.07[d]	1.54e-13	**6**	1.54e-13	**2**	1.23e-15	**2**	1.73e-16	**<1**	1.26e-16	**<1**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency ($W m^{-2} ppb^{-1}$)	AGWP 20-year ($W m^{-2} yr kg^{-1}$)	**GWP 20-year**	AGWP 100-year ($W m^{-2} yr kg^{-1}$)	**GWP 100-year**	AGTP 20-year ($K kg^{-1}$)	**GTP 20-year**	AGTP 50-year ($K kg^{-1}$)	**GTP 50-year**	AGTP 100-year ($K kg^{-1}$)	**GTP 100-year**
HFC-1243zf	$CF_3CH=CH_2$	7.0 days	0.01	1.37e-14	**1**	1.37e-14	**<1**	1.09e-16	**<1**	1.53e-17	**<1**	1.12e-17	**<1**
HFC-1345zfc	$C_2F_5CH=CH_2$	7.6 days	0.01	1.15e-14	**<1**	1.15e-14	**<1**	9.19e-17	**<1**	1.30e-17	**<1**	9.48e-18	**<1**
3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene	$C_4F_9CH=CH_2$	7.6 days	0.03	1.25e-14	**<1**	1.25e-14	**<1**	9.92e-17	**<1**	1.40e-17	**<1**	1.02e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene	$C_6F_{13}CH=CH_2$	7.6 days	0.03	9.89e-15	**<1**	9.89e-15	**<1**	7.87e-17	**<1**	1.11e-17	**<1**	8.12e-18	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene	$C_8F_{17}CH=CH_2$	7.6 days	0.03	8.52e-15	**<1**	8.52e-15	**<1**	6.79e-17	**<1**	9.57e-18	**<1**	7.00e-18	**<1**
Chlorocarbons and Hydrochlorocarbons													
Methyl chloroform	CH_3CCl_3	5.0	0.07	1.44e-11	**578**	1.47e-11	**160**	2.17e-13	**317**	2.07e-14	**34**	1.22e-14	**22**
Carbon tetrachloride	CCl_4	26.0	0.17	8.69e-11	**3480**	1.59e-10	**1730**	2.24e-12	**3280**	9.68e-13	**1570**	2.62e-13	**479**
Methyl chloride	CH_3Cl	1.0	0.01[a]	1.12e-12	**45**	1.12e-12	**12**	9.93e-15	**15**	1.29e-15	**2**	9.20e-16	**2**
Methylene chloride	CH_2Cl_2	0.4	0.03[b]	8.18e-13	**33**	8.18e-13	**9**	6.78e-15	**10**	9.26e-16	**2**	6.72e-16	**1**
Chloroform	$CHCl_3$	0.4	0.08	1.50e-12	**60**	1.50e-12	**16**	1.25e-14	**18**	1.70e-15	**3**	1.24e-15	**2**
1,2-Dichloroethane	CH_2ClCH_2Cl	65.0 days	0.01	8.24e-14	**3**	8.24e-14	**<1**	6.67e-16	**<1**	9.29e-17	**<1**	6.77e-17	**<1**
Bromocarbons, Hydrobromocarbons and Halons													
Methyl bromide	CH_3Br	0.8	0.004	2.16e-13	**9**	2.16e-13	**2**	1.87e-15	**3**	2.47e-16	**<1**	1.78e-16	**<1**
Methylene bromide	CH_2Br_2	0.3	0.01	9.31e-14	**4**	9.31e-14	**1**	7.66e-16	**1**	1.05e-16	**<1**	7.65e-17	**<1**
Halon-1201	$CHBrF_2$	5.2	0.15	3.37e-11	**1350**	3.45e-11	**376**	5.17e-13	**756**	4.96e-14	**80**	2.87e-14	**52**
Halon-1202	CBr_2F_2	2.9	0.27	2.12e-11	**848**	2.12e-11	**231**	2.43e-13	**356**	2.61e-14	**42**	1.75e-14	**32**
Halon-1211	$CBrClF_2$	16.0	0.29	1.15e-10	**4590**	1.60e-10	**1750**	2.70e-12	**3950**	6.98e-13	**1130**	1.62e-13	**297**
Halon-1301	$CBrF_3$	65.0	0.30	1.95e-10	**7800**	5.77e-10	**6290**	5.46e-12	**7990**	4.16e-12	**6750**	2.28e-12	**4170**
Halon-2301	CH_2BrCF_3	3.4	0.14	1.59e-11	**635**	1.59e-11	**173**	1.96e-13	**286**	2.01e-14	**33**	1.32e-14	**24**
Halon-2311 / Halothane	$CHBrClCF_3$	1.0	0.13	3.77e-12	**151**	3.77e-12	**41**	3.35e-14	**49**	4.34e-15	**7**	3.10e-15	**6**
Halon-2401	$CHFBrCF_3$	2.9	0.19	1.68e-11	**674**	1.68e-11	**184**	1.94e-13	**283**	2.07e-14	**34**	1.39e-14	**25**
Halon-2402	$CBrF_2CBrF_2$	20.0	0.31	8.59e-11	**3440**	1.35e-10	**1470**	2.12e-12	**3100**	7.08e-13	**1150**	1.66e-13	**304**
Fully Fluorinated Species													
Nitrogen trifluoride	NF_3	500.0	0.20	3.19e-10	**12,800**	1.47e-09	**16,100**	9.39e-12	**13,700**	1.02e-11	**16,500**	9.91e-12	**18,100**
Sulphur hexafluoride	SF_6	3,200.0	0.57	4.37e-10	**17,500**	2.16e-09	**23,500**	1.29e-11	**18,900**	1.47e-11	**23,800**	1.54e-11	**28,200**
(Trifluoromethyl) sulphur pentafluoride	SF_5CF_3	800.0	0.59	3.36e-10	**13,500**	1.60e-09	**17,400**	9.93e-12	**14,500**	1.10e-11	**17,800**	1.11e-11	**20,200**
Sulphuryl fluoride	SO_2F_2	36.0	0.20	1.71e-10	**6840**	3.76e-10	**4090**	4.58e-12	**6690**	2.55e-12	**4140**	9.01e-13	**1650**
PFC-14	CF_4	50,000.0	0.09	1.22e-10	**4880**	6.08e-10	**6630**	3.61e-12	**5270**	4.12e-12	**6690**	4.40e-12	**8040**
PFC-116	C_2F_6	10,000.0	0.25	2.05e-10	**8210**	1.02e-09	**11,100**	6.07e-12	**8880**	6.93e-12	**11,200**	7.36e-12	**13,500**
PFC-c216	$c\text{-}C_3F_6$	3,000.0	0.23[e]	1.71e-10	**6850**	8.44e-10	**9200**	5.06e-12	**7400**	5.74e-12	**9310**	6.03e-12	**11,000**
PFC-218	C_3F_8	2,600.0	0.28	1.66e-10	**6640**	8.16e-10	**8900**	4.91e-12	**7180**	5.56e-12	**9010**	5.83e-12	**10,700**
PFC-318	$c\text{-}C_4F_8$	3,200.0	0.32	1.77e-10	**7110**	8.75e-10	**9540**	5.25e-12	**7680**	5.96e-12	**9660**	6.27e-12	**11,500**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
PFC-31-10	C_4F_{10}	2,600.0	0.36	1.71e-10	**6870**	8.44e-10	**9200**	5.08e-12	**7420**	5.75e-12	**9320**	6.02e-12	**11,000**
Perfluorocyclopentene	$c\text{-}C_5F_8$	31.0 days	0.08[f]	1.71e-13	**7**	1.71e-13	**2**	1.37e-15	**2**	1.92e-16	**<1**	1.40e-16	**<1**
PFC-41-12	$n\text{-}C_5F_{12}$	4,100.0	0.41	1.58e-10	**6350**	7.84e-10	**8550**	4.69e-12	**6860**	5.33e-12	**8650**	5.62e-12	**10,300**
PFC-51-14	$n\text{-}C_6F_{14}$	3,100.0	0.44	1.47e-10	**5890**	7.26e-10	**7910**	4.35e-12	**6370**	4.94e-12	**8010**	5.19e-12	**9490**
PFC-61-16	$n\text{-}C_7F_{16}$	3,000.0	0.50	1.45e-10	**5830**	7.17e-10	**7820**	4.31e-12	**6290**	4.88e-12	**7920**	5.13e-12	**9380**
PFC-71-18	C_8F_{18}	3,000.0	0.55	1.42e-10	**5680**	6.99e-10	**7620**	4.20e-12	**6130**	4.76e-12	**7710**	5.00e-12	**9140**
PFC-91-18	$C_{10}F_{18}$	2,000.0	0.55	1.34e-10	**5390**	6.59e-10	**7190**	3.98e-12	**5820**	4.49e-12	**7290**	4.68e-12	**8570**
Perfluorodecalin (cis)	$Z\text{-}C_{10}F_{18}$	2,000.0	0.56	1.35e-10	**5430**	6.64e-10	**7240**	4.01e-12	**5860**	4.52e-12	**7340**	4.72e-12	**8630**
Perfluorodecalin (trans)	$E\text{-}C_{10}F_{18}$	2,000.0	0.48	1.18e-10	**4720**	5.77e-10	**6290**	3.48e-12	**5090**	3.93e-12	**6380**	4.10e-12	**7500**
PFC-1114	$CF_2{=}CF_2$	1.1 days	0.002	2.68e-16	**<1**	2.68e-16	**<1**	2.13e-18	**<1**	3.00e-19	**<1**	2.20e-19	**<1**
PFC-1216	$CF_3CF{=}CF_2$	4.9 days	0.01	6.42e-15	**<1**	6.42e-15	**<1**	5.11e-17	**<1**	7.21e-18	**<1**	5.27e-18	**<1**
Perfluorobuta-1,3-diene	$CF_2{=}CFCF{=}CF_2$	1.1 days	0.003	3.29e-16	**<1**	3.29e-16	**<1**	2.61e-18	**<1**	3.69e-19	**<1**	2.70e-19	**<1**
Perfluorobut-1-ene	$CF_3CF_2CF{=}CF_2$	6.0 days	0.02	8.38e-15	**<1**	8.38e-15	**<1**	6.67e-17	**<1**	9.41e-18	**<1**	6.88e-18	**<1**
Perfluorobut-2-ene	$CF_3CF{=}CFCF_3$	31.0 days	0.07	1.62e-13	**6**	1.62e-13	**2**	1.30e-15	**2**	1.82e-16	**<1**	1.33e-16	**<1**
Halogenated Alcohols and Ethers													
HFE-125	CHF_2OCF_3	119.0	0.41	3.10e-10	**12,400**	1.14e-09	**12,400**	8.91e-12	**13,000**	8.14e-12	**13,200**	5.97e-12	**10,900**
HFE-134 (HG-00)	CHF_2OCHF_2	24.4	0.44	2.90e-10	**11,600**	5.10e-10	**5560**	7.42e-12	**10,800**	3.02e-12	**4900**	7.83e-13	**1430**
HFE-143a	CH_3OCF_3	4.8	0.18	4.72e-11	**1890**	4.80e-11	**523**	6.95e-13	**1020**	6.66e-14	**108**	3.99e-14	**73**
HFE-227ea	$CF_3CHFOCF_3$	51.6	0.44	2.22e-10	**8900**	5.92e-10	**6450**	6.15e-12	**8980**	4.22e-12	**6850**	1.98e-12	**3630**
HCFE-235ca2 (enflurane)	CHF_2OCF_2CHFCl	4.3	0.41	5.30e-11	**2120**	5.35e-11	**583**	7.36e-13	**1080**	7.14e-14	**116**	4.44e-14	**81**
HCFE-235da2 (isoflurane)	$CHF_2OCHClCF_3$	3.5	0.42	4.49e-11	**1800**	4.50e-11	**491**	5.62e-13	**822**	5.72e-14	**93**	3.73e-14	**68**
HFE-236ca	$CHF_2OCF_2CHF_2$	20.8	0.56[g]	2.42e-10	**9710**	3.89e-10	**4240**	6.03e-12	**8820**	2.10e-12	**3400**	4.98e-13	**912**
HFE-236ea2 (desflurane)	$CHF_2OCHFCF_3$	10.8	0.45	1.39e-10	**5550**	1.64e-10	**1790**	2.93e-12	**4280**	4.64e-13	**753**	1.42e-13	**260**
HFE-236fa	$CF_3CH_2OCF_3$	7.5	0.36	8.35e-11	**3350**	8.98e-11	**979**	1.53e-12	**2240**	1.68e-13	**273**	7.54e-14	**138**
HFE-245cb2	$CF_3CF_2OCH_3$	4.9	0.33	5.90e-11	**2360**	6.00e-11	**654**	8.77e-13	**1280**	8.40e-14	**136**	4.99e-14	**91**
HFE-245fa1	$CHF_2CH_2OCF_3$	6.6	0.31	7.22e-11	**2900**	7.59e-11	**828**	1.25e-12	**1820**	1.27e-13	**206**	6.35e-14	**116**
HFE-245fa2	$CHF_2OCH_2CF_3$	5.5	0.36	7.25e-11	**2910**	7.45e-11	**812**	1.15e-12	**1670**	1.10e-13	**179**	6.21e-14	**114**
2,2,3,3,3-Pentafluoropropan-1-ol	$CF_3CF_2CH_2OH$	0.3	0.14	1.72e-12	**69**	1.72e-12	**19**	1.42e-14	**21**	1.95e-15	**3**	1.42e-15	**3**
HFE-254cb1	$CH_3OCF_2CHF_2$	2.5	0.26	2.76e-11	**1110**	2.76e-11	**301**	2.99e-13	**438**	3.34e-14	**54**	2.28e-14	**42**
HFE-263fb2	$CF_3CH_2OCH_3$	23.0 days	0.04	1.22e-13	**5**	1.22e-13	**1**	9.72e-16	**1**	1.37e-16	**<1**	9.98e-17	**<1**
HFE-263m1	$CF_3OCH_2CH_3$	0.4	0.13	2.70e-12	**108**	2.70e-12	**29**	2.25e-14	**33**	3.06e-15	**5**	2.22e-15	**4**
3,3,3-Trifluoropropan-1-ol	$CF_3CH_2CH_2OH$	12.0 days	0.02	3.57e-14	**1**	3.57e-14	**<1**	2.85e-16	**<1**	4.01e-17	**<1**	2.93e-17	**<1**
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$	22.5	0.53	1.68e-10	**6720**	2.81e-10	**3070**	4.23e-12	**6180**	1.59e-12	**2580**	3.93e-13	**718**
HFE-338mmz1	$(CF_3)_2CHOCHF_2$	21.2	0.44	1.48e-10	**5940**	2.40e-10	**2620**	3.70e-12	**5410**	1.31e-12	**2130**	3.14e-13	**575**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$	7.5	0.44	7.93e-11	**3180**	8.52e-11	**929**	1.45e-12	**2120**	1.60e-13	**259**	7.16e-14	**131**
Sevoflurane (HFE-347mmz1)	$(CF_3)_2CHOCH_2F$	2.2	0.32	1.98e-11	**795**	1.98e-11	**216**	2.06e-13	**302**	2.37e-14	**38**	1.64e-14	**30**
HFE-347mcc3 (HFE-7000)	$CH_3OCF_2CF_2CF_3$	5.0	0.35	4.78e-11	**1910**	4.86e-11	**530**	7.18e-13	**1050**	6.87e-14	**111**	4.05e-14	**74**
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$	6.6	0.42	7.45e-11	**2990**	7.83e-11	**854**	1.29e-12	**1880**	1.31e-13	**212**	6.55e-14	**120**
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	6.0	0.48[h]	7.86e-11	**3150**	8.15e-11	**889**	1.30e-12	**1900**	1.27e-13	**206**	6.81e-14	**124**
HFE-347mmy1	$(CF_3)_2CFOCH_3$	3.7	0.32	3.32e-11	**1330**	3.33e-11	**363**	4.27e-13	**624**	4.28e-14	**69**	2.76e-14	**51**
HFE-356mec3	$CH_3OCF_2CHFCF_3$	3.8	0.30	3.53e-11	**1410**	3.55e-11	**387**	4.60e-13	**673**	4.58e-14	**74**	2.94e-14	**54**
HFE-356mff2	$CF_3CH_2OCH_2CF_3$	105.0 days	0.17	1.54e-12	**62**	1.54e-12	**17**	1.26e-14	**18**	1.74e-15	**3**	1.26e-15	**2**
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$	5.7	0.37	6.40e-11	**2560**	6.59e-11	**719**	1.03e-12	**1500**	9.97e-14	**162**	5.50e-14	**101**
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$	3.5	0.38	4.08e-11	**1640**	4.09e-11	**446**	5.11e-13	**747**	5.20e-14	**84**	3.39e-14	**62**
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	3.8	0.32	3.77e-11	**1510**	3.79e-11	**413**	4.91e-13	**718**	4.89e-14	**79**	3.14e-14	**57**
HFE-356mmz1	$(CF_3)_2CHOCH_3$	97.1 days	0.15	1.25e-12	**50**	1.25e-12	**14**	1.02e-14	**15**	1.41e-15	**2**	1.02e-15	**2**
HFE-365mcf3	$CF_3CF_2CH_2OCH_3$	19.3 days	0.05	8.51e-14	**3**	8.51e-14	**<1**	6.80e-16	**<1**	9.56e-17	**<1**	6.99e-17	**<1**
HFE-365mcf2	$CF_3CF_2OCH_2CH_3$	0.6	0.26[i]	5.35e-12	**215**	5.35e-12	**58**	4.53e-14	**66**	6.10e-15	**10**	4.40e-15	**8**
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	5.0	0.30	5.65e-11	**2260**	5.75e-11	**627**	8.48e-13	**1240**	8.12e-14	**132**	4.79e-14	**88**
4,4,4-Trifluorobutan-1-ol	$CF_3(CH_2)_2CH_2OH$	4.0 days	0.01	1.73e-15	**<1**	1.73e-15	**<1**	1.38e-17	**<1**	1.94e-18	**<1**	1.42e-18	**<1**
2,2,3,3,4,4,5,5-Octafluorocyclopentanol	$-(CF_2)_4CH(OH)-$	0.3	0.16	1.18e-12	**47**	1.18e-12	**13**	9.67e-15	**14**	1.33e-15	**2**	9.69e-16	**2**
HFE-43-10pccc124 (H-Galden 1040x, HG-11)	$CHF_2OCF_2OC_2F_4OCHF_2$	13.5	1.02	2.00e-10	**8010**	2.58e-10	**2820**	4.52e-12	**6600**	9.46e-13	**1530**	2.38e-13	**436**
HFE-449s1 (HFE-7100)	$C_4F_9OCH_3$	4.7	0.36	3.80e-11	**1530**	3.86e-11	**421**	5.54e-13	**809**	5.32e-14	**86**	3.21e-14	**59**
n-HFE-7100	n-$C_4F_9OCH_3$	4.7	0.42	4.39e-11	**1760**	4.45e-11	**486**	6.39e-13	**934**	6.14e-14	**99**	3.70e-14	**68**
i-HFE-7100	i-$C_4F_9OCH_3$	4.7	0.35	3.68e-11	**1480**	3.73e-11	**407**	5.35e-13	**783**	5.14e-14	**83**	3.10e-14	**57**
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	0.8	0.30	5.21e-12	**209**	5.21e-12	**57**	4.52e-14	**66**	5.97e-15	**10**	4.29e-15	**8**
n-HFE-7200	n-$C_4F_9OC_2H_5$	0.8	0.35[i]	5.92e-12	**237**	5.92e-12	**65**	5.14e-14	**75**	6.78e-15	**11**	4.87e-15	**9**
i-HFE-7200	i-$C_4F_9OC_2H_5$	0.8	0.24	4.06e-12	**163**	4.06e-12	**44**	3.52e-14	**52**	4.65e-15	**8**	3.34e-15	**6**
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	25.0	0.65	2.75e-10	**11,000**	4.91e-10	**5350**	7.06e-12	**10,300**	2.94e-12	**4770**	7.75e-13	**1420**
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	12.9	0.86	2.10e-10	**8430**	2.67e-10	**2910**	4.69e-12	**6860**	9.28e-13	**1500**	2.42e-13	**442**
1,1,1,3,3,3-Hexafluoropropan-2-ol	$(CF_3)_2CHOH$	1.9	0.26	1.67e-11	**668**	1.67e-11	**182**	1.66e-13	**243**	1.97e-14	**32**	1.38e-14	**25**
HG-02	$HF_2C-(OCF_2CF_2)_2-OCF_2H$	12.9	1.24[i]	1.97e-10	**7900**	2.50e-10	**2730**	4.40e-12	**6430**	8.70e-13	**1410**	2.27e-13	**415**
HG-03	$HF_2C-(OCF_2CF_2)_3-OCF_2H$	12.9	1.76[i]	2.06e-10	**8270**	2.62e-10	**2850**	4.60e-12	**6730**	9.10e-13	**1480**	2.37e-13	**434**
HG-20	$HF_2C-(OCF_2)_2-OCF_2H$	25.0	0.92[i]	2.73e-10	**10,900**	4.86e-10	**5300**	7.00e-12	**10,200**	2.91e-12	**4730**	7.68e-13	**1400**
HG-21	$HF_2C-OCF_2CF_2OC-F_2OCF_2O-CF_2H$	13.5	1.71[i]	2.76e-10	**11,100**	3.57e-10	**3890**	6.23e-12	**9110**	1.31e-12	**2120**	3.29e-13	**602**

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Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	AGWP 20-year (W m^{-2} yr kg^{-1})	**GWP 20-year**	AGWP 100-year (W m^{-2} yr kg^{-1})	**GWP 100-year**	AGTP 20-year (K kg^{-1})	**GTP 20-year**	AGTP 50-year (K kg^{-1})	**GTP 50-year**	AGTP 100-year (K kg^{-1})	**GTP 100-year**
HG-30	$HF_2C–(OCF_2)_3–OCF_2H$	25.0	1.65[i]	3.77e-10	**15,100**	6.73e-10	**7330**	9.68e-12	**14,100**	4.03e-12	**6530**	1.06e-12	**1940**
1-Ethoxy-1,1,2,2,3,3,3-heptafluoropropane	$CF_3CF_2CF_2OCH_2CH_3$	0.8	0.28[i]	5.56e-12	**223**	5.56e-12	**61**	4.80e-14	**70**	6.36e-15	**10**	4.57e-15	**8**
Fluoroxene	$CF_3CH_2OCH{=}CH_2$	3.6 days	0.01[i]	4.97e-15	**<1**	4.97e-15	**<1**	3.95e-17	**<1**	5.58e-18	**<1**	4.08e-18	**<1**
1,1,2,2-Tetrafluoro-1-(fluoromethoxy)ethane	$CH_2FOCF_2CF_2H$	6.2	0.34[i]	7.68e-11	**3080**	7.99e-11	**871**	1.29e-12	**1880**	1.28e-13	**207**	6.68e-14	**122**
2-Ethoxy-3,3,4,4,5-pentafluorotetrahydro-2,5-bis[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]-furan	$C_{12}H_5F_{19}O_2$	1.0	0.49[i]	5.09e-12	**204**	5.09e-12	**56**	4.53e-14	**66**	5.86e-15	**10**	4.19e-15	**8**
Fluoro(methoxy)methane	CH_3OCH_2F	73.0 days	0.07[g]	1.15e-12	**46**	1.15e-12	**13**	9.34e-15	**14**	1.30e-15	**2**	9.46e-16	**2**
Difluoro(methoxy)methane	CH_3OCHF_2	1.1	0.17[g]	1.32e-11	**528**	1.32e-11	**144**	1.18e-13	**173**	1.52e-14	**25**	1.08e-14	**20**
Fluoro(fluoromethoxy)methane	CH_2FOCH_2F	0.9	0.19[g]	1.20e-11	**479**	1.20e-11	**130**	1.05e-13	**153**	1.37e-14	**22**	9.84e-15	**18**
Difluoro(fluoromethoxy)methane	CH_2FOCHF_2	3.3	0.30[g]	5.65e-11	**2260**	5.66e-11	**617**	6.88e-13	**1010**	7.11e-14	**115**	4.69e-14	**86**
Trifluoro(fluoromethoxy)methane	CH_2FOCF_3	4.4	0.33[g]	6.82e-11	**2730**	6.89e-11	**751**	9.59e-13	**1400**	9.27e-14	**150**	5.72e-14	**105**
HG′-01	$CH_3OCF_2CF_2OCH_3$	2.0	0.29	2.03e-11	**815**	2.03e-11	**222**	2.06e-13	**301**	2.42e-14	**39**	1.68e-14	**31**
HG′-02	$CH_3O(CF_2CF_2O)_2CH_3$	2.0	0.56	2.16e-11	**868**	2.16e-11	**236**	2.19e-13	**320**	2.57e-14	**42**	1.79e-14	**33**
HG′-03	$CH_3O(CF_2CF_2O)_3CH_3$	2.0	0.76	2.03e-11	**812**	2.03e-11	**221**	2.05e-13	**299**	2.41e-14	**39**	1.67e-14	**31**
HFE-329me3	$CF_3CFHCF_2OCF_3$	40.0	0.48	1.79e-10	**7170**	4.17e-10	**4550**	4.85e-12	**7090**	2.89e-12	**4690**	1.12e-12	**2040**
3,3,4,4,5,5,6,6,7,7,7-Undecafluoroheptan-1-ol	$CF_3(CF_2)_4CH_2CH_2OH$	20.0 days	0.06	3.91e-14	**2**	3.91e-14	**<1**	3.12e-16	**<1**	4.39e-17	**<1**	3.21e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,9-Pentadecafluorononan-1-ol	$CF_3(CF_2)_6CH_2CH_2OH$	20.0 days	0.07	3.00e-14	**1**	3.00e-14	**<1**	2.40e-16	**<1**	3.37e-17	**<1**	2.46e-17	**<1**
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,11-Nonadecafluoroundecan-1-ol	$CF_3(CF_2)_8CH_2CH_2OH$	20.0 days	0.05	1.72e-14	**<1**	1.72e-14	**<1**	1.37e-16	**<1**	1.93e-17	**<1**	1.41e-17	**<1**
2-Chloro-1,1,2-trifluoro-1-methoxyethane	CH_3OCF_2CHFCl	1.4	0.21	1.12e-11	**449**	1.12e-11	**122**	1.05e-13	**153**	1.31e-14	**21**	9.24e-15	**17**
PFPMIE (perfluoropolymethylisopropyl ether)	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	800.0	0.65	1.87e-10	**7500**	8.90e-10	**9710**	5.52e-12	**8070**	6.11e-12	**9910**	6.15e-12	**11,300**
HFE-216	$CF_3OCF{=}CF_2$	8.4 days	0.02	1.92e-14	**<1**	1.92e-14	**<1**	1.53e-16	**<1**	2.15e-17	**<1**	1.58e-17	**<1**
Trifluoromethyl formate	$HCOOCF_3$	3.5	0.31[i]	5.37e-11	**2150**	5.39e-11	**588**	6.73e-13	**984**	6.85e-14	**111**	4.47e-14	**82**
Perfluoroethyl formate	$HCOOCF_2CF_3$	3.5	0.44[i]	5.30e-11	**2130**	5.32e-11	**580**	6.64e-13	**971**	6.76e-14	**110**	4.41e-14	**81**
Perfluoropropyl formate	$HCOOCF_2CF_2CF_3$	2.6	0.50[i]	3.45e-11	**1380**	3.45e-11	**376**	3.80e-13	**555**	4.19e-14	**68**	2.85e-14	**52**
Perfluorobutyl formate	$HCOOCF_2CF_2CF_2CF_3$	3.0	0.56[i]	3.59e-11	**1440**	3.59e-11	**392**	4.19e-13	**613**	4.45e-14	**72**	2.97e-14	**54**
2,2,2-Trifluoroethyl formate	$HCOOCH_2CF_3$	0.4	0.16[i]	3.07e-12	**123**	3.07e-12	**33**	2.55e-14	**37**	3.48e-15	**6**	2.52e-15	**5**
3,3,3-Trifluoropropyl formate	$HCOOCH_2CH_2CF_3$	0.3	0.13[i]	1.60e-12	**64**	1.60e-12	**17**	1.31e-14	**19**	1.80e-15	**3**	1.31e-15	**2**
1,2,2,2-Tetrafluoroethyl formate	$HCOOCHFCF_3$	3.2	0.35[i]	4.30e-11	**1720**	4.31e-11	**470**	5.17e-13	**755**	5.39e-14	**87**	3.57e-14	**65**
1,1,1,3,3,3-Hexafluoropropan-2-yl formate	$HCOOCH(CF_3)_2$	3.2	0.33[i]	3.05e-11	**1220**	3.05e-11	**333**	3.66e-13	**535**	3.81e-14	**62**	2.53e-14	**46**
Perfluorobutyl acetate	$CH_3COOCF_2CF_2CF_2CF_3$	21.9 days	0.12[i]	1.52e-13	**6**	1.52e-13	**2**	1.21e-15	**2**	1.71e-16	**<1**	1.25e-16	**<1**
Perfluoropropyl acetate	$CH_3COOCF_2CF_2CF_3$	21.9 days	0.11[i]	1.59e-13	**6**	1.59e-13	**2**	1.27e-15	**2**	1.78e-16	**<1**	1.30e-16	**<1**
Perfluoroethyl acetate	$CH_3COOCF_2CF_3$	21.9 days	0.10[i]	1.89e-13	**8**	1.89e-13	**2**	1.51e-15	**2**	2.12e-16	**<1**	1.55e-16	**<1**
Trifluoromethyl acetate	CH_3COOCF_3	21.9 days	0.07[i]	1.90e-13	**8**	1.90e-13	**2**	1.52e-15	**2**	2.14e-16	**<1**	1.56e-16	**<1**

(continued on next page)

Table 8.A.1 (continued)

Acronym, Common Name or Chemical Name	**Chemical Formula**	Lifetime (Years)	Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$)	AGWP 20-year ($W\ m^{-2}\ yr\ kg^{-1}$)	**GWP 20-year**	AGWP 100-year ($W\ m^{-2}\ yr\ kg^{-1}$)	**GWP 100-year**	AGTP 20-year ($K\ kg^{-1}$)	**GTP 20-year**	AGTP 50-year ($K\ kg^{-1}$)	**GTP 50-year**	AGTP 100-year ($K\ kg^{-1}$)	**GTP 100-year**
Methyl carbonofluoridate	$FCOOCH_3$	1.8	0.07[i]	8.74e-12	**350**	8.74e-12	**95**	8.60e-14	**126**	1.03e-14	**17**	7.21e-15	**13**
1,1-Difluoroethyl carbonofluoridate	$FCOOCF_2CH_3$	0.3	0.17[i]	2.46e-12	**99**	2.46e-12	**27**	2.02e-14	**30**	2.78e-15	**5**	2.02e-15	**4**
1,1-Difluoroethyl 2,2,2-trifluoroacetate	$CF_3COOCF_2CH_3$	0.3	0.27[i]	2.83e-12	**113**	2.83e-12	**31**	2.33e-14	**34**	3.20e-15	**5**	2.32e-15	**4**
Ethyl 2,2,2-trifluoroacetate	$CF_3COOCH_2CH_3$	21.9 days	0.05[i]	1.26e-13	**5**	1.26e-13	**1**	1.00e-15	**1**	1.41e-16	**<1**	1.03e-16	**<1**
2,2,2-Trifluoroethyl 2,2,2-trifluoroacetate	$CF_3COOCH_2CF_3$	54.8 days	0.15[i]	6.27e-13	**25**	6.27e-13	**7**	5.06e-15	**7**	7.07e-16	**1**	5.15e-16	**<1**
Methyl 2,2,2-trifluoroacetate	CF_3COOCH_3	0.6	0.18[i]	4.80e-12	**192**	4.80e-12	**52**	4.08e-14	**60**	5.47e-15	**9**	3.95e-15	**7**
Methyl 2,2-difluoroacetate	HCF_2COOCH_3	40.1 days	0.05[i]	3.00e-13	**12**	3.00e-13	**3**	2.41e-15	**4**	3.38e-16	**<1**	2.47e-16	**<1**
Difluoromethyl 2,2,2-trifluoroacetate	$CF_3COOCHF_2$	0.3	0.24[i]	2.48e-12	**99**	2.48e-12	**27**	2.04e-14	**30**	2.81e-15	**5**	2.04e-15	**4**
2,2,3,3,4,4,4-Heptafluorobutan-1-ol	$C_3F_7CH_2OH$	0.6	0.20	3.10e-12	**124**	3.10e-12	**34**	2.61e-14	**38**	3.52e-15	**6**	2.55e-15	**5**
1,1,2-Trifluoro-2-(trifluoromethoxy)-ethane	$CHF_2CHFOCF_3$	9.8	0.35	9.91e-11	**3970**	1.14e-10	**1240**	2.03e-12	**2960**	2.88e-13	**467**	9.74e-14	**178**
1-Ethoxy-1,1,2,3,3,3-hexafluoropropane	$CF_3CHFCF_2OCH_2CH_3$	0.4	0.19	2.14e-12	**86**	2.14e-12	**23**	1.77e-14	**26**	2.43e-15	**4**	1.76e-15	**3**
1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2,2-tetrafluoroethoxy)-propane	$CF_3CF_2CF_2OCHFCF_3$	67.0	0.58	1.98e-10	**7940**	5.95e-10	**6490**	5.57e-12	**8140**	4.29e-12	**6960**	2.39e-12	**4380**
2,2,3,3-Tetrafluoro-1-propanol	$CHF_2CF_2CH_2OH$	91.3 days	0.11	1.19e-12	**48**	1.19e-12	**13**	9.72e-15	**14**	1.35e-15	**2**	9.79e-16	**2**
2,2,3,4,4,4-Hexafluoro-1-butanol	$CF_3CHFCF_2CH_2OH$	94.9 days	0.19	1.56e-12	**63**	1.56e-12	**17**	1.27e-14	**19**	1.76e-15	**3**	1.28e-15	**2**
2,2,3,3,4,4,4-Heptafluoro-1-butanol	$CF_3CF_2CF_2CH_2OH$	0.3	0.16	1.49e-12	**60**	1.49e-12	**16**	1.23e-14	**18**	1.69e-15	**3**	1.23e-15	**2**
1,1,2,2-Tetrafluoro-3-methoxy-propane	$CHF_2CF_2CH_2OCH_3$	14.2 days	0.03	4.82e-14	**2**	4.82e-14	**<1**	3.84e-16	**<1**	5.41e-17	**<1**	3.96e-17	**<1**
perfluoro-2-methyl-3-pentanone	$CF_3CF_2C(O)CF(CF_3)_2$	7.0 days	0.03	9.14e-15	**<1**	9.14e-15	**<1**	7.27e-17	**<1**	1.03e-17	**<1**	7.51e-18	**<1**
3,3,3-Trifluoro-propanal	CF_3CH_2CHO	2.0 days	0.004	9.86e-16	**<1**	9.86e-16	**<1**	7.84e-18	**<1**	1.11e-18	**<1**	8.10e-19	**<1**
2-Fluoroethanol	CH_2FCH_2OH	20.4 days	0.02	8.07e-14	**3**	8.07e-14	**<1**	6.45e-16	**<1**	9.07e-17	**<1**	6.63e-17	**<1**
2,2-Difluoroethanol	CHF_2CH_2OH	40.0 days	0.04	2.78e-13	**11**	2.78e-13	**3**	2.23e-15	**3**	3.12e-16	**<1**	2.28e-16	**<1**
2,2,2-Trifluoroethanol	CF_3CH_2OH	0.3	0.10	1.83e-12	**73**	1.83e-12	**20**	1.50e-14	**22**	2.07e-15	**3**	1.50e-15	**3**
1,1′-Oxybis[2-(difluoromethoxy)-1,1,2,2-tetrafluoroethane	$HCF_2O(CF_2CF_2O)_2CF_2H$	26.0	1.15[k]	2.47e-10	**9910**	4.51e-10	**4920**	6.38e-12	**9320**	2.75e-12	**4460**	7.45e-13	**1360**
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12-hexadecafluoro-2,5,8,11-Tetraoxadodecane	$HCF_2O(CF_2CF_2O)_3CF_2H$	26.0	1.43[k]	2.26e-10	**9050**	4.12e-10	**4490**	5.83e-12	**8520**	2.51e-12	**4080**	6.81e-13	**1250**
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12,13,13,15,15-eicosafluoro-2,5,8,11,14-Pentaoxapentadecane	$HCF_2O(CF_2CF_2O)_4CF_2H$	26.0	1.46[k]	1.83e-10	**7320**	3.33e-10	**3630**	4.71e-12	**6880**	2.03e-12	**3300**	5.50e-13	**1010**

Notes:

For CH_4 we estimate an uncertainty of ±30% and ±40% for 20- and 100-year time horizon, respectively (for 90% uncertainty range). The uncertainty is dominated by AGWP for CO_2 and indirect effects. The uncertainty in GWP for N_2O is estimated to ±20% and ±30% for 20- and 100-year time horizon, with the largest contributions from CO_2. The uncertainty in GWP for HFC-134a is estimated to ±25% and ±35% for 20- and 100-year time horizons while for CFC-11 the GWP the corresponding numbers are approximately ±20% and ±35% (not accounting for the indirect effects). For CFC-12 the corresponding numbers are ±20 and ±30. The uncertainties estimated for HFC-134a and CFC-11 are assessed as representative for most other gases with similar or longer lifetimes. For shorter-lived gases, the uncertainties will be larger. For GTP, few estimates are available in the literature. The uncertainty is assessed to be of the order of ±75% for the methane GTP_{100}.

* No single lifetime can be given. The impulse response function for CO_2 from Joos et al. (2013) has been used. See also Supplementary Material Section 8.SM.11.

† Perturbation lifetime is used in calculation of metrics, not the lifetime of the atmospheric burden.

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