

# NFPA® 12A

## Standard on Halon 1301 Fire Extinguishing Systems

### 2025 Edition



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## NFPA® 12A

### Standard on

## Halon 1301 Fire Extinguishing Systems

### 2025 Edition

This edition of NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, was prepared by the Technical Committee on Gaseous Fire Extinguishing Systems. It was issued by the Standards Council on November 16, 2024, with an effective date of December 6, 2024, and supersedes all previous editions.

This edition of NFPA 12A was approved as an American National Standard on December 6, 2024.

### Origin and Development of NFPA 12A

The Committee on Halogenated Fire Extinguishing Systems was formed in the fall of 1966 and held its first meeting during December of that year. The Committee was organized into four Subcommittees who separately prepared various portions of the standard for review by the full Committee at meetings held in September and December of 1967.

The standard was submitted and adopted at the NFPA Annual Meeting in Atlanta, Georgia, May 20–24, 1968. The 1968 edition was the first edition of this standard and was adopted in tentative form in accordance with NFPA regulations. In 1969 the Committee determined that the standard had not yet been sufficiently tested and elected to carry it in tentative status for one more year. It was presented for official adoption in 1970. The first official version of the standard was adopted at the NFPA Annual Meeting in Toronto, Ontario, in May 1970. Revisions were made in 1972, 1973, 1977, and 1980.

The 1985 edition was a complete revision of the standard. The standard was revised in 1987 and again in 1989.

The standard was completely rewritten for the 1992 edition to state the requirements more clearly and to separate the mandatory requirements from the advisory text in an effort to make the document more usable, enforceable, and adoptable. The main topic addressed in the revision was the decommissioning and removal of systems.

The standard was updated to conform to the *Manual of Style for NFPA Technical Committee Documents* for the 2004 edition.

For the 2009 edition, the standard was revised to address testing and recharging of Halon 1301 cylinders.

The 2015 edition incorporated support for electronic storage of system maintenance records.

For the 2018 edition, the annex chapter on nozzle and piping calculations (Annex H) was revised to correct errors, comply with the *Manual of Style for NFPA Technical Committee Documents*, and clarify the details of the procedure.

The 2022 edition was a partial revision that incorporated several clarifications and corrections. The requirements for cylinder requalification were updated to establish better agreement with Code of Federal Regulations Title 49, “Transportation,” and a recommendation to follow the HRC Code of Practice for Halon Reclaiming Companies was added.

For 2025 edition, provisions for recycling Halon 1301 have been included.

### Foreword

Halon 1301 (bromotrifluoromethane, or CBrF<sub>3</sub>) is a colorless, odorless, electrically nonconductive gas that is an effective medium for extinguishing fires. Halon 1301 is included in the Montreal Protocol on Substances That Deplete the Ozone Layer signed September 16, 1987. The

protocol permits continued availability of halogenated fire extinguishing agents at 1986 production levels. That protocol, and subsequent amendments, restrict the production of this agent. In addition, local jurisdictions within some countries (e.g., the EPA in the United States) have enacted further rules regulating the production, use, handling, and disposal of this agent. The user of this standard is advised to consult local authorities for current regulations. Halon 1301 fire-extinguishing systems are useful within the limits of this standard in extinguishing fires in specific hazards or equipment and in occupancies where an electrically nonconductive medium is essential or desirable, or where cleanup of other media presents a problem.

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**Committee Scope:** This committee shall have primary responsibility for documents on the installation, maintenance, and use of carbon dioxide systems for fire protection. This committee shall also have primary responsibility for documents on fixed fire extinguishing systems utilizing bromotrifluoromethane and other similar halogenated extinguishing agents, covering the installation, maintenance, and use of systems. This committee shall also have primary responsibility for documents on alternative protection options to Halon 1301 and 1211 fire extinguishing systems. It shall not deal with design, installation, operation, testing, and maintenance of systems employing dry chemical, wet chemical, foam, aerosols, or water as the primary extinguishing media.

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## NFPA 12A

## Standard on

## Halon 1301 Fire Extinguishing Systems

2025 Edition

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

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

## Chapter 1 Administration

**1.1 Scope.** This standard contains minimum requirements for total flooding Halon 1301 fire extinguishing systems. It includes only the essentials necessary to make the standard workable in the hands of those skilled in this field. Only those skilled in this work are competent to design, install, maintain, decommission, and remove this equipment. It might be necessary for many of those charged with purchasing, inspecting, testing, approving, operating, and maintaining this equipment to consult with an experienced and competent fire protection engineer to effectively discharge their respective duties. (See Annex C.)

**1.2 Purpose.** This standard is prepared for the use and guidance of those charged with purchasing, designing, installing, testing, inspecting, approving, listing, operating, maintaining, decommissioning, and removing halogenated agent extinguishing systems (Halon 1301), so that such equipment will function as intended throughout its life. Nothing in this standard is intended to restrict new technologies or alternate arrangements provided the level of safety prescribed by this standard is not lowered.

**1.2.1** Pre-engineered systems (packaged systems) consist of system components designed to be installed according to pretested limitations as approved or listed by a testing laboratory. Pre-engineered systems sometimes incorporate special nozzles, flow rates, methods of application, nozzle placement, and pressurization levels that sometimes differ from those detailed elsewhere in this standard. All other requirements of the standard shall apply. Pre-engineered systems shall be installed to protect hazards within the limitations that have been established by the testing laboratories where listed.

**1.3 Units.**

**1.3.1** Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1.3.1 with conversion factors.

**1.3.2\*** If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated shall be regarded as the requirement. A given equivalent value is often approximate.

**1.4 Use and Limitations.**

**1.4.1** Total flooding Halon 1301 fire extinguishing systems are used primarily to protect hazards that are in enclosures or equipment that, in itself, includes an enclosure to contain the agent. Some typical hazards that shall be permitted to use Halon 1301 are as follows:

- (1) Electrical and electronic hazards
- (2) Telecommunications
- (3) Flammable and combustible liquids and gases
- (4) Other high value assets

**1.4.2** Halon 1301 shall not be used on the following:

- (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 sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium
- (3) Metal hydrides
- (4) Chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides and hydrazine

**1.4.3\*** Electrostatic charging of nongrounded conductors can occur during the discharge of liquefied gases. These conductors can discharge to other objects, causing an electric arc of sufficient energy to initiate an explosion.

**1.4.4\*** Where halon systems are used, a fixed enclosure shall be provided about the hazard that is adequate to enable the specified concentration to be achieved and maintained for the specified period of time.

Table 1.3.1 Metric Conversion Factors

| Name of Unit    | Unit            | Conversion Factor             |
|-----------------|-----------------|-------------------------------|
| Liter           | L               | 1 gal = 3.785 L               |
| Cubic decimeter | dm <sup>3</sup> | 1 gal = 3.785 dm <sup>3</sup> |
| Pascal          | Pa              | 1 psi = 6894.757 Pa           |
| Bar             | bar             | 1 psi = 0.0689 bar            |
| Bar             | bar             | 1 bar = 10 <sup>5</sup> Pa    |

**1.4.5** Halon 1301 shall be used only in enclosures where ambient temperatures are between  $-70^{\circ}\text{F}$  and  $900^{\circ}\text{F}$  ( $-57^{\circ}\text{C}$  and  $482^{\circ}\text{C}$ ). (See Annex D.)

**1.4.6 Duration of Protection.** An effective agent concentration shall be achieved and maintained for a sufficient period of time to allow effective emergency action by trained personnel. This is equally important in all classes of fires since a persistent ignition source (e.g., an arc, heat source, oxyacetylene torch, or “deep-seated” fire) can lead to a recurrence of the initial event once the agent has dissipated. Halon 1301 extinguishing systems normally provide protection for a period of minutes, but are exceptionally effective for certain applications.

## 1.5 Safety.

### 1.5.1 Hazards to Personnel. (See Annex D.)

**1.5.1.1 Unnecessary Exposure.** Unnecessary exposure to Halon 1301 and its decomposition products shall be avoided. Exposure to high concentrations or for prolonged periods can produce dizziness, impaired coordination, and disturbances in cardiac rhythm.

**1.5.1.2\* Safety Requirements.** Suitable safeguards shall be provided to ensure prompt evacuation and prevent entry into hazardous atmospheres and also to provide means for prompt rescue of any trapped personnel. Safety items such as personnel training, warning signs, discharge alarms, and self-contained breathing equipment shall be considered.

**1.5.2 Electrical Clearances.** All system components shall be located to maintain no less than minimum clearances from live electrical parts. The following references shall be considered as the minimum electrical clearance requirements for the installation of Halon 1301 systems:

- (1) ANSI/IEEE C2, *National Electrical Safety Code*
- (2) NFPA 70
- (3) 29 CFR 1910, Subpart S

**1.5.2.1** When the design basic insulation level (BIL) is not available and when nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

**1.5.3\* Decommissioning and Removal of Systems.** Personnel who are to decommission and remove systems or are to handle system equipment shall be thoroughly trained and competent in safe procedures.

## 1.6 Recycling of Halon 1301.

**1.6.1** When a system is decommissioned, the Halon 1301 shall be reclaimed.

**1.6.2** Before being used, the reclaimed Halon 1301 shall be tested for compliance with 4.1.2.

**1.6.2.1** Halon 1301 that has passed testing shall be designated as recycled Halon 1301.

**1.6.3** Where impurities in reclaimed Halon 1301 are such that it cannot be brought into compliance with 4.1.2, the Halon 1301 shall be destroyed in accordance with the applicable environmental regulations.

## 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*®, 2023 edition.

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

### 2.3 Other Publications.

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

ASME B1.20.1, *Standard on Pipe Threads, General Purpose, Inch*, 2018.

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

*Boiler and Pressure Vessel Code*, 2023.

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

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

ASTM D5632/D5632M, *Standard Specification for Halon 1301, Bromotrifluoromethane (CF<sub>3</sub> Br)*, 2017, reapproved 2022.

**2.3.3 CGA Publications.** Compressed Gas Association, 8484 Westpark Drive, Suite 220, McLean, VA 22102.

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

**2.3.4 IEEE Publications.** IEEE Operations Center, 445 Hoes Lane, Piscataway, NY 08854-4141.

ANSI/IEEE C2, *National Electrical Safety Code*, 2022.

**2.3.5 ULC Publications.** Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON M1R 3A9, Canada.

CAN/ULC S524, *Installation of Fire Alarm Systems*, 2019.

CAN/ULC S529, *Smoke Detectors for Fire Alarm Systems*, 2023.

**2.3.6 US Government Publications.** US Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401.

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, 2020.

## Δ 2.4 References for Extracts in Mandatory Sections. (Reserved)

### Chapter 3 Definitions

#### Δ 3.1 General.

N 3.1.1 The definitions contained in this chapter shall apply to the terms used in this standard.

N 3.1.2 Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used.

N 3.1.3 *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

#### 3.2 NFPA Official Definitions.

3.2.1\* **Approved.** Acceptable to the authority having jurisdiction.

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

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

3.2.4 **Shall.** Indicates a mandatory requirement.

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

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

#### 3.3 General Definitions.

3.3.1 **Clearance.** The air distance between Halon 1301 equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential.

3.3.2 **Filling Density.** The number of pounds of Halon 1301 per cubic foot of container volume.

3.3.3\* **Normally Occupied Area.** One that is intended for occupancy.

N 3.3.4 **Reclaimed Halon 1301.** Agent that has been removed from an existing system.

N 3.3.5 **Recycled Halon 1301.** Agent that has been reclaimed, tested, and processed as necessary, and has been found to be in compliance with the quality requirements of 4.1.2.

### Chapter 4 Components

#### 4.1 Halon 1301 Supply.

##### 4.1.1 Quantities.

4.1.1.1 The amount of Halon 1301 in the system shall be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously.

4.1.1.2 Where required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary. The time needed to obtain Halon 1301 for replenishment to restore systems to operating conditions shall be considered a major factor in determining the reserve supply needed.

4.1.1.3 Where uninterrupted protection is required, both primary and reserve supply shall be permanently connected to the distribution piping and arranged for easy changeover.

4.1.2\* **Quality.** Halon 1301 shall comply with the requirements of either Table 4.1.2 or ASTM D5632/D5632M, *Standard Specification for Halon 1301, Bromotrifluoromethane (CF<sub>3</sub>Br)*.

##### 4.1.3 Storage Container Arrangement.

4.1.3.1 Storage containers and accessories shall be so located and arranged that inspection, testing, recharging, and other maintenance is facilitated and interruption of protection is held to a minimum.

4.1.3.2 Storage containers shall be located as close as possible to the hazard or hazards they protect but shall not be exposed to a fire in a manner likely to impair system performance.

4.1.3.3 Storage containers shall not be located where they are likely to be subject to severe weather conditions or mechanical, chemical, or other damage. Where excessive climatic or mechanical exposures are expected, suitable safeguards or enclosures shall be provided.

**Table 4.1.2 Requirements for Halon 1301 (Bromotrifluoromethane)**

| Property                                       | Requirement  |
|------------------------------------------------|--------------|
| Bromotrifluoromethane, mole percent, minimum   | 99.6         |
| Other halocarbons, mole percent, maximum       | 0.4          |
| Acidity, ppm (by weight), maximum              | 3.0          |
| Water content, percent by weight, maximum      | 0.001        |
| Boiling point, °C at 760 mm Hg                 | -57.75       |
| Boiling range, °C, 5 to 85 percent distilled   | 0.3          |
| High boiling impurities, grams/100 ml, maximum | 0.05         |
| Suspended matter or sediment                   | None visible |

**4.1.3.4** Storage containers shall be securely mounted per the manufacturer's listed or approved installation manual. This shall include mounting the container to the appropriate mounting surface.

**4.1.4 Storage Containers.** (See Annex E.)

**4.1.4.1** The Halon 1301 supply shall be stored in containers designed to hold Halon 1301 in liquefied form at ambient temperatures.

**4.1.4.2** Containers shall not be charged to a filling density greater than 70 lb/ft<sup>3</sup> (1121 kg/m<sup>3</sup>).

**4.1.4.3** Containers shall be superpressurized with dry nitrogen to 360 psi  $\pm$  5 percent or 600 psi  $\pm$  5 percent gauge pressure at 70°F (2482 kPa  $\pm$  5 percent or 4137 kPa  $\pm$  5 percent gauge pressure at 21°C).

**4.1.4.4** Listed pre-engineered systems shall not be required to comply with 4.1.4.3.

**4.1.4.5** Each container shall have a permanent nameplate specifying the agent, tare, and gross weight in addition to the superpressurization level. A label that will require the proper return of the agent shall be affixed to all new and existing containers. Filled containers shall be returned for recycling or recovery of the agent when no longer needed.

**4.1.4.6** If used as shipping containers, the Halon 1301 containers used in these systems shall be designed to meet the requirements of the US Department of Transportation or the Canadian Transport Commission. If not used as shipping containers, they shall be designed, fabricated, inspected, certified, and stamped in accordance with ASME *Boiler and Pressure Vessel Code*.

**4.1.4.7** The design pressure shall be suitable for the maximum pressure developed at 130°F (55°C) or at the maximum controlled temperature limit.

**4.1.4.8** A reliable means of indication shall be provided to determine the pressure in refillable containers. The means of indication shall account for variation of container pressure with temperature.

**4.1.4.9** When manifolded, containers shall be adequately mounted and suitably supported in a rack that provides for convenient individual servicing or content weighings. Automatic means shall be provided to prevent agent loss from the manifold if the system is operated when any containers are removed for maintenance.

**4.1.4.10** In a multiple cylinder system, all cylinders supplying the same manifold outlet for distribution of agent shall be interchangeable and of one select size and charge.

**4.1.4.11** Storage temperatures shall not exceed 130°F (55°C) nor be less than -20°F (-29°C) for total flooding systems unless the system is designed for proper operation with storage temperatures outside this range. External heating or cooling shall be used to keep the temperature of the storage container within desired ranges.

**4.2 Distribution.**

**4.2.1\* Piping.**

**4.2.1.1** Piping shall be of noncombustible material having physical and chemical characteristics such that its integrity under stress can be predicted with reliability. Special corrosion-

resistant materials or coatings shall be required in severely corrosive atmospheres. The thickness of the pipe wall shall be calculated in accordance with ASME B31.1, *Power Piping Code*. The internal pressure for this calculation shall be the maximum storage pressure at the maximum storage temperature [a 70 lb/ft<sup>3</sup> (1121 kg/m<sup>3</sup>) density shall be assumed], but in no case shall be less than the following:

- (1) For 360 psi (2482 kPa) charging pressure, an internal pressure of 620 psi (4274 kPa) (130°F) (55°C)
- (2) For 600 psi (4137 kPa) charging pressure, an internal pressure of 1000 psi (6895 kPa) (130°F) (55°C)

If higher storage temperatures are approved for a given system, the internal pressure shall be adjusted to the maximum internal pressure at maximum temperature. In performing this calculation, all joint factors and threading, grooving, or welding allowances shall be taken into account. (See Annex F.)

**4.2.1.2** Cast-iron pipe, steel pipe conforming to ASTM A120, *Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses*, or nonmetallic pipe shall not be used.

**4.2.1.3** Where used, flexible piping, tubing, or hose (including connections) shall be of approved materials and pressure ratings.

**4.2.1.4** Each pipe section shall be cleaned internally after preparation and before assembly by means of swabbing, utilizing a suitable nonflammable cleaner. The piping network shall be free of particulate matter and oil residue before installation of nozzles or discharge devices.

**4.2.1.5\*** In systems where valve arrangement introduces sections of closed piping, such sections shall be equipped with pressure relief devices or the valves shall be designed to prevent entrapment of liquid. In systems using pressure operated cylinder valves, means shall be provided to vent any container leakage that could build up pressure in the pilot system and cause unwanted opening of the cylinder valve. The means of pressure venting shall be arranged so as not to prevent reliable operation of the cylinder valve.

**4.2.1.6** All pressure relief devices shall be of such design and so located that the discharge therefrom will not injure personnel or be otherwise objectionable.

**4.2.2 Piping Joints.** Piping joints of other than the screwed or flanged type shall be listed or approved for this application.

**4.2.3\* Fittings.** Fittings for 600 psig (4137 kPa) charging pressure systems shall have a minimum working pressure of 1000 psi (6895 kPa). Systems utilizing 360 psig (2482 kPa) charging pressure shall use fittings having a minimum working pressure of 620 psi (4274 kPa).

**4.2.3.1** Class 150 lb and cast-iron fittings shall not be used.

**4.2.3.2** All threads used in joints and fittings shall conform to ASME B1.20.1, *Standard on Pipe Threads, General Purpose, Inch*. Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

**4.2.3.3** Welding, soldering, or brazing alloys shall have a melting point above 1000°F (538°C).

**4.2.3.4** Welding shall be performed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section IX, "Welding and Brazing Qualification."

**4.2.3.5** Where copper, stainless steel, or other suitable tubing is joined with compression-type fittings, the manufacturer's pressure-temperature ratings for the fitting shall not be exceeded.

#### **4.2.4 Valves.**

**4.2.4.1** All valves shall be listed or approved for the intended use.

**4.2.4.2** Valves shall be protected against mechanical, chemical, or other damage.

**4.2.4.3** Special corrosion-resistant materials or coatings shall be used in severely corrosive atmospheres.

#### **4.2.5 Discharge Nozzles.**

**4.2.5.1** Discharge nozzles shall be listed for use, including the flow characteristics and area of coverage. Discharge orifices shall be of corrosion-resistant metal.

**4.2.5.2** Special corrosion-resistant materials or coatings shall be required in severely corrosive atmospheres.

**4.2.5.3\*** Discharge nozzles shall be permanently marked to identify the manufacturer as well as the type and size of the orifice.

**4.2.5.4** Where clogging by external foreign materials is likely, discharge nozzles shall be provided with frangible discs, blow-off caps, or other suitable devices. These devices shall provide an unobstructed opening upon system operation and shall be located so they will not injure personnel.

#### **4.3 Detection, Actuation, Alarm, and Control Systems.**

**4.3.1** Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with *NFPA 70* and *NFPA 72*. In Canada refer to CAN/ULC S524, *Installation of Fire Alarm Systems*, and CAN/ULC S529, *Smoke Detectors for Fire Alarm Systems*.

**4.3.1.1** Automatic detection and automatic actuation shall be used, except as permitted in 4.3.1.2.

**4.3.1.2** Manual-only actuation shall be permitted if acceptable to the authority having jurisdiction.

#### **4.3.2 Automatic Detection.**

**4.3.2.1\*** Automatic detection shall be by any listed or approved method or device capable of detecting and indicating heat, flame, smoke, combustible vapors, or an abnormal condition in the hazard, such as process trouble, that is likely to produce fire.

**4.3.2.2** Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

#### **4.3.3 Operating Devices.**

**4.3.3.1** Operating devices shall include Halon 1301 releasing devices or valves, discharge controls, and shutdown equipment necessary for successful performance of the system.

**4.3.3.2** Operation shall be by listed or approved mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

**4.3.3.3** All devices shall be designed for the service they will encounter and shall not be readily rendered inoperative or susceptible to accidental operation. Devices shall be normally designed to function properly from -20°F to 150°F (-29°C to 65°C) or marked to indicate temperature limitations.

**4.3.3.4** All devices shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

**4.3.3.5** The normal manual control(s) for actuation shall be located for easy accessibility at all times, including time of fire within the protected area. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of this control shall cause the complete system to operate in its normal fashion.

**4.3.3.6** An emergency release of the system resulting from a single manual operation shall be provided. This shall be accomplished by a mechanical manual release or by an electrical manual release when the control equipment monitors the battery voltage level of the standby battery supply and provides a low battery signal. The emergency release shall cause simultaneous operation of automatically operated valves controlling agent release and distribution.

**4.3.3.7\*** Manual controls shall not require a pull of more than 40 lbf (178 N) nor a movement of more than 14 in. (356 mm) to secure operation. At least one manual control for activation shall be located not more than 5 ft (1.5 m) above the floor.

**4.3.3.8** Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers, the supply and discharge rate shall be designed for releasing all of the remaining containers.

**4.3.3.9** All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation.

**4.3.3.10** All manual operating devices shall be identified as to the hazard they protect.

#### **4.3.4 Control Equipment.**

**4.3.4.1 Electric Control Equipment.** The control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation. The control equipment shall be specifically listed or approved for the number and type of actuating devices utilized, and their compatibility shall have been listed or approved.

**4.3.4.2 Pneumatic Control Equipment.** Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken. The control equipment shall be specifically listed or approved for the number and type of actuating devices utilized, and their compatibility shall have been listed or approved.

#### **4.3.5 Operating Alarms and Indicators.**

**4.3.5.1** Alarms or indicators or both shall be used to indicate the operation of the system, hazards to personnel, or failure of any supervised device. The type (audible, visual, or olfactory), number, and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment or both shall be approved.

**4.3.5.2** Audible and highly visible alarms shall be provided to give positive warning of discharge. The operation of the warning devices shall be continued after halon discharge, until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

**4.3.5.3\*** Where abort switches are provided, they shall be located only within the protected area and shall be of a type that requires constant manual pressure to cause abort. The abort switch shall not be of a type that would allow the system to be left in an aborted mode without someone present. In all cases, the normal manual and emergency manual control shall override the abort function. Operation of the abort function shall result in both audible and distinct visual indication of system impairment. The abort switch shall be clearly recognizable for the purpose intended.

**4.3.5.4** Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinctive from alarms indicating operation or hazardous conditions.

**4.3.5.5** Warning and instruction signs at entrances to and inside protected areas shall be provided.

**4.3.5.6** Time delays shall be used only where discharge delay is required for personnel evacuation or to prepare the hazard area for discharge. Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

**4.3.6\* Unwanted System Operation.** Care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted discharges.

## Chapter 5 System Design

### 5.1 Specifications, Plans, and Approvals.

**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 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.

#### 5.1.2 Plans and Approvals.

**5.1.2.1** Plans and calculations shall be submitted for approval to the authority having jurisdiction before installation begins. Their preparation shall be entrusted only to persons fully experienced and qualified in the design of Halon 1301 extinguishing systems.

**5.1.2.2** These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so they can be easily reproduced.

**5.1.2.3** These plans shall contain sufficient detail to enable an evaluation of the hazard(s) and the effectiveness of the system. The detail of the hazards shall include the materials involved in the hazards, the location of the hazards, the enclosure or limits and isolation of the hazards, and the exposures to the hazards.

**5.1.2.4** The detail on the system shall include information and calculations on the amount of Halon 1301; container storage pressure; internal volume of the container; the location, type, and flow rate of each nozzle including equivalent orifice area; the location, size, and equivalent lengths of pipe, fittings, and hose; and the location and size of the storage facility. Details of pipe size reduction method and orientation of tees shall be clearly indicated. Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used. Apparatus and devices used shall be identified. Any special features shall be adequately explained. The manufacturer's version of the flow calculation program shall be identified on the computer calculation printout. Only the currently listed calculation method shall be used.

**5.1.2.5** An as-built instruction and maintenance manual that includes a full sequence of operation and a full set of drawings and calculations shall be maintained in a clearly identified protective enclosure at or near the system control panel.

**5.1.3** When field conditions necessitate any material change from approved plans, the change shall be submitted for approval.

**5.1.3.1** When such material changes from approved plans are made, corrected as-built plans shall be provided.

### 5.2 System Flow Calculations. (See Annex G.)

**5.2.1** As part of the design procedure, system flow calculations shall be performed using a listed calculation method. The system design shall be within the manufacturer's listed limitations.

**5.2.2** Nozzle orifice sizes shall be selected to achieve the designed flow rate. The nozzle shall be selected by consulting the discharge characteristic information in the manufacturer's listed design manual. Flow shall be calculated on the basis of an average container pressure during discharge, taking into account the original pressurization level, storage filling density, and percent in piping for 70°F (21°C) storage temperature as shown in Figure H.1(e).

**5.2.3** Valves shall be rated for equivalent length in terms of the pipe or tubing sizes with which they will be used. The equivalent length of container valves shall be listed and shall include siphon tube, valve, discharge head, and flexible connector.

**5.2.4** The nozzle and fitting orientation shall be in accordance with the manufacturer's listed limitations to ensure proper system performance. (See Annex H.)

**5.2.5** If the final installation varies from the prepared calculations, new calculations representing the as-built installation shall be prepared.

**5.2.6** Halon 1301 total flooding systems shall not be used in concentrations greater than 10 percent in normally occupied areas. Areas that might contain 10 percent Halon 1301 shall be evacuated immediately upon discharge of the agent. Where egress cannot be accomplished within 1 minute, Halon 1301 total flooding systems shall not be used in normally occupied areas in concentrations greater than 7 percent. (See Annex D.)

**5.2.7** Halon 1301 total flooding systems utilizing concentrations greater than 10 percent but not exceeding 15 percent shall be permitted to be used in areas not normally occupied, provided egress can be accomplished within 30 seconds. Where egress cannot be accomplished within 30 seconds or where concentrations greater than 15 percent must be used, provisions shall be made to prevent inhalation by personnel. (See *Annex D*.)

**5.3 Enclosure.** In the design of total flooding systems, the characteristics of the enclosure as identified in 5.3.1 through 5.3.4 shall be considered.

**5.3.1\*** For all types of fires, the area of unclosable openings shall be kept to a minimum.

**5.3.2** To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures.

**5.3.3\*** Where reasonable confinement of agent is not practicable, protection shall be extended to include the adjacent connected hazards or work areas.

**5.3.4** Forced-air ventilating systems including in-room air-conditioning units shall be shut down or closed automatically where their continued operation would adversely affect the performance of the Halon 1301 system or result in propagation of the fire.

#### 5.4 Design Concentration Requirements.

**5.4.1\*** For a particular fuel, either flame extinguishment or inerting concentrations shall be used.

**5.4.1.1 Inerting.** The inerting concentrations shall be used where conditions for subsequent reflash or explosion could exist. These conditions are found when both of the following situations occur:

- (1) The quantity of fuel permitted in the enclosure is sufficient to develop a concentration equal to or greater than one-half of the lower flammable limit throughout the enclosure.
- (2) The volatility of the fuel before the fire is sufficient to reach the lower flammable limit in air (maximum ambient temperature or fuel temperature exceeds the closed cup flash point temperature), or the system response is not rapid enough to detect and extinguish the fire before the volatility of the fuel is increased to a dangerous level as a result of the fire.

**CAUTION:** Under certain conditions, it could be dangerous to extinguish a burning gas jet. As a first measure, the gas supply should be shut off.

**5.4.1.1.1** The minimum design concentrations specified in Table 5.4.1.1.1 shall be used to inert atmospheres involving several flammable liquids and gases. Design inerting concentrations not given in Table 5.4.1.1.1 shall be determined by test plus a 10 percent safety factor. The minimum design concentration shall be 5 percent.

**5.4.1.2\* Flame Extinguishment.** The minimum design concentrations specified in Table 5.4.1.2 shall be used to extinguish normal fires involving several flammable liquids and gases. Design flame extinguishment concentrations not given in Table 5.4.1.2 shall be obtained by test plus a 20 percent safety factor. Minimum design concentrations shall be 5 percent.

**Table 5.4.1.1.1 Halon 1301 Design Concentrations for Inerting**

| Fuel      | Minimum Conc.<br>% by Volume* |
|-----------|-------------------------------|
| Acetone   | 7.6                           |
| Benzene   | 5.0                           |
| Ethanol   | 11.1                          |
| Ethylene  | 13.2                          |
| Hydrogen  | 31.4                          |
| Methane   | 7.7                           |
| n-Heptane | 6.9                           |
| Propane   | 6.7                           |

Note: Includes a safety factor of 10 percent added to experimental values.

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

**5.4.1.3** For combinations of fuels, the flame extinguishment or inerting value for the fuel requiring the greatest concentration shall be used unless tests are made on the actual mixture.

**5.4.2 Fires in Solid Materials.** Flammable solids shall be classified as those that do not develop deep-seated fires and those that do. (See *Annex I*.)

**5.4.2.1 Solid Surface Fires.** To protect materials that do not develop deep-seated fires, a minimum concentration of 5 percent shall be used. (See *Annex J*.)

**5.4.2.2 Deep-Seated Fires.** Where the solid material is in such a form that a deep-seated fire can be established before a flame extinguishing concentration has been achieved, provisions shall be made to the satisfaction of the authority having jurisdiction for a means to effect complete extinguishment of the fire.

#### 5.5 Determination of Halon 1301 Quantity for Total Flooding Systems.

**5.5.1 Total Flooding Quantity.** The amount of Halon 1301 required to achieve the design concentration shall be calculated from the following formula:

**Table 5.4.1.2 Halon 1301 Design Concentrations for Flame Extinguishment (in 25°C at 1 atm)**

| Fuel      | Minimum Design Conc.<br>% by Volume |
|-----------|-------------------------------------|
| Acetone   | 5.0                                 |
| Benzene   | 5.0                                 |
| Ethanol   | 5.0                                 |
| Ethylene  | 8.2                                 |
| Methane   | 5.0                                 |
| n-Heptane | 5.0                                 |
| Propane   | 5.2                                 |

**[5.5.1a]**

$$W = \frac{V}{s} \left( \frac{C}{100 - C} \right)$$

where:

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

$s$  =  $2.2062 + 0.005046t$

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

$V$  = net volume of hazard ft<sup>3</sup> (enclosed volume minus fixed structures impervious to halon)

$C$  = Halon 1301 concentration, percent by volume

**[5.5.1b]**

$$W = \frac{V}{s} \left( \frac{C}{100 - C} \right)$$

where:

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

$s$  =  $0.14781 + 0.000567t$

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

$V$  = net volume of hazard (m<sup>3</sup>) (enclosed volume minus fixed structures impervious to halon)

$C$  = Halon 1301 concentration, percent by volume

**5.5.1.1** This calculation in 5.5.1 includes an allowance for normal leakage from a “tight” enclosure due to agent expansion. (*See Annex K.*)

**5.5.2\*** In addition to the concentration requirements, additional quantities of agent shall be required to compensate for any special conditions that would affect the extinguishing efficiency.

**5.6\* Altitude Adjustments.** The design quantity of Halon 1301 shall be adjusted to compensate for altitudes of more than 3000 ft (1000 m) above or below sea-level and pressures that vary by 10 percent above or below standard sea-level pressure (29.92 in. Hg at 70°F). The Halon 1301 quantity shall be corrected by multiplying the quantity determined in 5.5.1 and 5.5.2 by the ratio of average ambient enclosure pressure to standard sea level pressure.

## **5.7 Distribution System.**

### **5.7.1\* Rate of Application.**

**5.7.1.1** The minimum design rate of application shall be based on the quantity of agent required for the desired concentration and the time allotted to achieve the desired concentration.

**5.7.1.2\* Discharge Time.** The agent discharge shall be substantially completed in a nominal 10 seconds or as otherwise required by the authority having jurisdiction.

**5.7.1.2.1** This period shall be measured as the interval between the first appearance of liquid at the nozzle and the time when the discharge becomes predominantly gaseous.

**5.7.2\*** When an extended discharge is necessary, the rate shall be sufficient to maintain the desired concentration for the duration of application.

## **5.8 Nozzle Choice and Location.**

**5.8.1** Nozzles shall be of the type listed for the intended purpose and shall be placed within the protected enclosure in compliance with listed limitations with regard to spacing, floor coverage, and alignment.

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

## **Chapter 6 Inspection, Maintenance, Testing, and Training**

### **6.1\* Inspection and Tests.**

**6.1.1** At least semiannually, all systems shall be thoroughly inspected, tested, and documented for proper operation by trained competent personnel. Tests shall be in accordance with the appropriate NFPA or Canadian standards.

**6.1.2** The documented report, with recommendations, shall be filed with the owner.

**6.1.3** The documented report shall be permitted to be stored and accessed using paper or electronic media.

**6.1.4\*** The agent quantity and pressure of refillable containers shall be checked. If a container shows a loss in net weight of more than 5 percent or a loss in pressure (adjusted for temperature) of more than 10 percent, it shall be refilled or replaced. When the amount of agent in the container is determined by special measuring devices in lieu of weighing, these devices shall be listed.

**6.1.5** All halon removed from refillable containers during service or maintenance procedures shall be collected for recycling.

**6.1.6** Factory-charged nonrefillable containers that do not have a means of pressure indication shall be weighed at least semiannually. If a container shows a loss in net weight of more than 5 percent, it shall be replaced. All factory-charged nonrefillable containers removed from useful service shall be returned for recycling of the agent.

**6.1.7** The weight and pressure of the container shall be recorded on a tag attached to the container.

### **6.2 Container Test.**

**6.2.1** US Department of Transportation (DOT), Canadian Transport Commission (CTC), or similar design Halon 1301 cylinders shall not be recharged without retesting if the requalification period specified by the regulating authority for the container has elapsed since the date of the last test and inspection.

**6.2.1.1** The retest shall be permitted to consist of a complete visual inspection as described in 49 CFR.

**6.2.1.2** A cylinder shall be permitted to be requalified at any time during or before the month and year that the requalification is due.

**6.2.1.3** A cylinder filled before the requalification becomes due shall be both of the following:

- (1) Permitted to remain in service
- (2) Periodically inspected in accordance with 6.2.2

**6.2.1.4** A cylinder with a specified service life shall not be refilled and offered for transportation after its authorized service life has expired.

**6.2.2** Cylinders continuously in service without discharging shall be given a complete external visual inspection every 5 years, in accordance with CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, Section 5, except that the cylinders need not be emptied or stamped while under pressure.

**6.2.3** Where external visual inspection indicates that the container has been damaged, additional strength tests shall be required.

**CAUTION:** If additional tests used include hydrostatic testing, containers should be thoroughly dried before refilling.

**6.2.4** Before recharging a container, a visual inspection of its interior shall be performed.

**6.3 Hose Test.** All system hoses shall be examined annually for damage. If visual examination shows any deficiency, the hose shall be immediately replaced or tested as specified in 6.3.1.

**6.3.1** All hoses shall be tested at 1500 psi (10342 kPa) for 600 psi (4137 kPa) charging pressure systems, and at 900 psi (6205 kPa) for 360 psi (2482 kPa) charging pressure systems. The test shall be performed as follows:

- (1) Remove the hose from any attachment.
- (2) The hose assembly is then to be placed in a protective enclosure designed to permit visual observation of the test.
- (3) The hose must be completely filled with water before testing.
- (4) Pressure then is applied at a rate-of-pressure rise to reach the test pressure within a minimum of 1 minute. The test pressure is to be maintained for 1 full minute. Observations are then made to note any distortion or leakage.
- (5) If the test pressure has not dropped or if the couplings have not moved, the pressure is released. The hose assembly is then considered to have passed the hydrostatic test if no permanent distortion has taken place.
- (6) Hose assembly passing the test must be completely dried internally. If heat is used for drying, the temperature must not exceed 150°F (66°C).
- (7) Hose assemblies failing a hydrostatic test must be destroyed. They shall be replaced with new assemblies.
- (8) Each hose assembly passing the hydrostatic test shall be marked to show the date of test.

**6.3.2** All hoses shall be tested every 5 years in accordance with 6.3.1.

**6.4 Enclosure Inspection.** At least every 6 months the halon-protected enclosure shall be thoroughly inspected to determine if penetrations or other changes have occurred that could adversely affect halon leakage.

**6.4.1** Where the inspection indicates that conditions exist that could result in inability to maintain the halon concentration,

they shall be corrected. If uncertainty still exists, the enclosures shall be retested for integrity.

## 6.5 Maintenance.

**6.5.1** These systems shall be maintained in full operating condition at all times. Use, impairment, and restoration of this protection shall be reported promptly to the authority having jurisdiction.

**6.5.2** Any troubles or impairments shall be corrected at once by competent personnel.

**6.5.3** Any penetrations made through the halon-protected enclosure shall be sealed immediately. The method of sealing shall restore the original fire resistance rating and tightness of the enclosure.

**6.6 Training.** All persons who could be expected to inspect, test, maintain, operate, or decommission and remove fire extinguishing systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

**6.6.1** Personnel working in a halon-protected enclosure shall receive training regarding halon safety issues.

## 6.7 Approval of Installations. (See Annex L.)

**6.7.1** The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. Only listed or approved equipment and devices shall be used in the systems. To determine that the system has been properly installed and will function as specified, the tests in 6.7.2.1, 6.7.2.2, 6.7.2.3, and 6.7.2.4 shall be performed.

### 6.7.2 Installation Acceptance.

#### 6.7.2.1 Mechanical Acceptance.

**6.7.2.1.1** The piping distribution system shall be inspected to determine that it is in compliance with the system drawings and the hydraulic calculations indicated on the computer printout associated with each agent storage container piping and nozzle configuration.

**6.7.2.1.2** Nozzles and pipe size shall be in accordance with system drawings. Means of pipe size reduction and attitudes of tees shall be checked for conformance to the design.

**6.7.2.1.3** Piping joints, discharge nozzles, and piping supports shall be securely fastened to prevent unacceptable movement during discharge.

**6.7.2.1.4** During assembly, the piping distribution system shall be inspected internally to detect the possibility of any oil or particulate matter soiling the hazard area or affecting the agent distribution due to a reduction in the effective nozzle orifice area.

**6.7.2.1.5** The discharge nozzle shall be oriented in such a manner that optimum agent dispersal can be effected.

**6.7.2.1.6** If nozzle deflectors are installed, they shall be positioned to obtain maximum benefit.

**6.7.2.1.7** The discharge nozzles, piping, and mounting brackets shall be installed in such a manner that they will not potentially cause injury to personnel.

**6.7.2.1.7.1** The liquid phase of the discharge shall not come in contact with people performing their normal tasks.

**6.7.2.1.7.2** Agent shall not directly impinge on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

**6.7.2.1.8** All agent storage containers shall be properly located in accordance with an approved set of system drawings.

**6.7.2.1.9** All containers and mounting brackets shall be securely fastened in accordance with the manufacturer's requirements.

**6.7.2.1.10** If a discharge test is to be conducted, containers for the agent to be used shall be weighed before and after discharge. Fill weight of container shall be verified by weighing or other approved methods.

**6.7.2.1.11** Adequate quantity of agent to produce the desired specified concentration shall be provided. The actual room volumes shall be checked against those indicated on the system drawings to ensure the proper quantity of agent. Fan coast-down and damper closure time shall be taken into consideration.

**6.7.2.1.12** The piping shall be pneumatically tested in a closed circuit for a period of 10 minutes at a gauge pressure of 150 psi (1034 kPa).

**CAUTION:** Pneumatic pressure testing creates a potential risk of injury to personnel in the area, as a result of airborne projectiles, if rupture of the piping system occurs. Prior to conducting the pneumatic pressure test, the protected area shall be evacuated and appropriate safeguards shall be provided for test personnel.

**6.7.2.1.12.1** The pressure test shall be permitted to be omitted if the total piping contains no more than one change in direction fitting between the storage container and the discharge nozzle, and where all piping is physically checked for tightness.

**6.7.2.1.12.2** When pressurizing the piping, pressure shall be increased in 50 psi (3.5 bar) increments.

**6.7.2.1.12.3** At the end of 10 minutes, the pressure drop shall not exceed 20 percent of the test pressure.

**6.7.2.1.13** A puff test with nitrogen shall be performed to check for continuous piping.

**6.7.2.2\* Enclosure Integrity Acceptance.** All total flooding systems shall have the enclosure examined and tested to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified Halon 1301 concentration level for the specified holding period.

### **6.7.2.3 Electrical Acceptance.**

**6.7.2.3.1** All wiring systems shall be properly installed in compliance with system drawings.

**6.7.2.3.2** All field circuitry shall be measured for ground-fault and short-circuit condition. When measuring field circuitry, all electronic components (such as smoke and flame detectors or special electronic equipment for other detectors or their mounting bases) shall be removed and jumpers properly installed to prevent the possibility of damage within these devices. Components shall be replaced after measuring.

**6.7.2.3.3** Power shall be supplied to the control unit from a separate dedicated source that will not be shut down on system operation.

**6.7.2.3.4** Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

**6.7.2.3.5** All auxiliary functions such as alarm sounding or displaying devices, remote annunciators, air-handling shutdown, and power shutdown shall be checked for proper operation in accordance with system requirements and design specifications. If possible, all air-handling and power-cutoff controls shall be of the type that, once interrupted, require manual restart to restore power.

**6.7.2.3.6** Silencing of alarms (if desirable) shall not affect other auxiliary functions such as air handling or power cutoff if required in the design specification.

**6.7.2.3.7** The detection devices shall be checked for proper type and location as specified on the system drawings.

**6.7.2.3.8\*** Detectors shall not be located near obstructions or air ventilation and cooling equipment that would appreciably affect their response characteristics. Where applicable, air changes for the protected area shall be taken into consideration.

**6.7.2.3.9** The detectors shall be installed in a professional manner and in accordance with technical data regarding their installation.

**6.7.2.3.10** Manual pull stations shall be properly installed, readily accessible, accurately identified, and properly protected to prevent damage.

**6.7.2.3.11** All manual stations used to release halon shall require two separate and distinct actions for operation. They shall be properly identified. Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated. Manual stations in this instance shall be clearly identified as to which zone or suppression area they affect.

**6.7.2.3.12** For systems with a main/reserve capability, the main/reserve switch shall be properly installed, readily accessible, and clearly identified.

**6.7.2.3.13** For systems using abort switches, the switches shall be of the deadman type requiring constant manual pressure, properly installed, readily accessible within the hazard area, and clearly identified. Switches that remain in the abort position when released shall not be used for this purpose. Manual pull stations shall always override abort switches.

**6.7.2.3.14** The control unit shall be properly installed and readily accessible.

### **6.7.2.4 Functional Testing.**

**6.7.2.4.1\*** Preliminary functional tests shall include the following:

- (1) If the system is connected to an alarm receiving office, the alarm receiving office shall be notified that the system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not desired. All concerned personnel at the end user's facility shall be notified that a test is to be conducted and instructed as to the sequence of operation.

- (2) Each agent storage container release mechanism shall be disabled so that activation of the release circuit will not release agent. The release circuit shall be reconnected with a functional device in lieu of each agent storage container release mechanism. For electrically actuated release mechanisms, these devices shall sometimes include 24-volt lamps, flash bulbs, or circuit breakers. Pneumatically actuated release mechanisms shall sometimes include pressure gauges.
- (3) Each initiating device shall be checked for proper response.
- (4) All polarized alarm devices and auxiliary relays shall be checked to ensure that polarity has been observed.
- (5) All end-of-line resistors shall be checked to ensure that they have been installed across the detection and alarm bell circuits where required.
- (6) All supervised circuits shall be checked for proper trouble response.
- (7) All supervisory devices shall be checked for proper operation.

**6.7.2.4.2** System functional operational test shall include the following:

- (1) Operate detection initiating circuit(s). All alarm functions shall occur according to the design specification.
- (2) Operate the necessary circuit(s) to initiate halon release.
- (3) Operate manual release. Verify that manual release functions occur according to design specifications.
- (4) If supplied, operate abort switch circuit. Verify that abort functions occur according to this standard (*see 4.3.5.3*). Confirm that visual and audible supervisory signals are received at the control panel.
- (5) All automatic valves shall be tested unless testing the valve will release halon or damage the valve (destructive testing).
- (6) Where required, pneumatic equipment shall be checked for integrity to ensure proper operation.

**6.7.2.4.3** Testing of remote monitoring operations, if applicable, shall include the following:

- (1) Operate one of each type of input device while on standby power. Verify that an alarm signal is received at remote panel after device is operated. Reconnect primary power supply.
- (2) Operate each type of alarm condition on each signal circuit and verify receipt of trouble condition at the remote station.

**6.7.2.4.4** Testing of the control panel primary power source shall include the following:

- (1) Verify that the control panel is connected to a dedicated circuit and labeled properly. This panel shall be readily accessible, yet restricted to unauthorized personnel.
- (2) A primary power failure shall be tested in accordance with the manufacturer's specification, with the system fully operated on standby power for the required design period.

**6.7.2.4.5** When all functional testing is completed, each agent storage container shall be reconnected so that activation of the release circuit will release the agent. The system shall be returned to its fully operational design condition.

## Annex A Explanatory Material

*Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.*

**A.1.3.2** For additional conversions and information see ASTM SI 10, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.

**A.1.4.3** See NFPA 77.

**A.1.4.4** From a performance viewpoint, a total flooding system is designed to develop a concentration of Halon 1301 that will extinguish fires in combustible materials located in an enclosed space. It must also maintain an effective concentration until the maximum temperature has been reduced below the reignition point.

The concentration of Halon 1301 required will depend on the type of combustible material involved. This has been determined for many surface-type fires, particularly those involving liquids and gases. For deep-seated fires, the critical concentration required for extinguishment is less definite and has, in general, been established by practical test work.

It is important that an effective agent concentration not only be achieved, but that it be maintained for a sufficient period of time to allow effective emergency action by trained personnel. This is equally important for all classes of fires since a persistent ignition source (e.g., an arc, heat source, oxyacetylene torch, or "deep-seated" fire) can lead to a recurrence of the initial event once the agent has dissipated. Halon 1301 extinguishing systems normally provide protection for a period of minutes but are exceptionally effective for certain applications. Water supplies for standard sprinklers, on the other hand, are normally designed to provide protection for an extended period of time. The designer, buyer, and emergency force in particular need to closely review the advantages and limitations of available systems as applied to the specific situation at hand, the residual risks being assumed, and the proper emergency procedures.

The discharge of minimum extinguishing concentration of Halon 1301 into enclosures containing operating diesel engines not drawing combustion air from outside the space creates a special problem. Experience has shown that the engine will continue to operate, resulting in a decrease in agent concentration and extensive decomposition of the halon.

**A.1.5.1.2** The steps and safeguards necessary to prevent injury or death to personnel in areas where atmospheres will be made hazardous by the discharge or thermal decomposition of Halon 1301 can include the following:

- (1) Provision of adequate aiseways and routes of exit and keeping them clear at all times.
- (2) Provision of emergency lighting and directional signs as necessary to ensure quick, safe evacuation.
- (3) Provision of alarms within such areas that will operate immediately upon detection of the fire.
- (4) Provision of only outward-swinging, self-closing doors at exits from hazardous areas, and, where such doors are latched, provision of panic hardware.
- (5) Provision of continuous alarms at entrances to such areas until the atmosphere has been restored to normal.

- (6) Provision of warning and instruction signs at entrances to and inside such areas. These signs should inform persons in or entering the protected area that a Halon 1301 system is installed, and can contain additional instructions pertinent to the conditions of the hazard.
- (7) Provision for prompt discovery and rescue of persons rendered unconscious in such areas. This can be accomplished by having such areas searched immediately by trained personnel equipped with proper breathing equipment. Self-contained breathing equipment and personnel trained in its use, and in rescue practices, including artificial respiration, should be readily available.
- (8) Provision of instruction and drills for all personnel within or in the vicinity of such areas, including maintenance or construction people who could be brought into the area, to ensure their correct action when Halon 1301 protective equipment operates.
- (9) Provision of means for prompt ventilation of such areas. Forced ventilation will often be necessary. Care should be taken to really dissipate hazardous atmospheres and not merely move them to another location. Halon 1301 is heavier than air.
- (10) Prohibition against smoking by persons until the atmosphere has been purged of Halon 1301.
- (11) Provision of such other steps and safeguards that a careful study of each particular situation indicates are necessary to prevent injury or death.

**A.1.5.3** Halon system cylinders contain liquefied compressed gas that, if discharged from a cylinder that is not properly connected to system pipe, can propel the cylinder and other equipment with great force. Before disconnecting cylinders from a system, proper safety precautions should be followed. Cylinder outlets should be fitted with antirecoil devices, listed or approved whenever the cylinder outlet is not connected to the system pipe. Safe handling procedures should be followed to transport system cylinders. Actuators should be disabled or removed before the cylinder is released from its bracketing. Proper equipment should be used to transport cylinders, dollies, or carts, and means to secure the cylinder should be used if cylinders need to be transported within a facility. (See CGA P-1, *Safe Handling of Compressed Gas in Containers*.)

Also consult equipment manufacturer representative for specific recommendations.

Further information can be found in the EPA *Safety Guide for Decommissioning Halon Systems*. This guide contains generic information for safe decommissioning of halon systems and manufacturer's specifications for handling specific equipment.

**Δ A.3.2.1 Approved.** The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment, or materials, the "authority having jurisdiction" may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The "authority having jurisdiction" may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

**A.3.2.2 Authority Having Jurisdiction (AHJ).** The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA standards in a broad manner because jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

**A.3.2.3 Listed.** The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

**A.3.3.3 Normally Occupied Area.** Spaces occasionally visited by personnel, such as transformer bays, switch-houses, pump rooms, vaults, engine test stands, cable trays, tunnels, microwave relay stations, flammable liquid storage areas, enclosed energy systems, and so forth, are examples of areas considered not normally occupied.

**A.4.1.2** Transfer of full Halon 1301 containers that do not change ownership does not require recycling or quality testing. Where agent recycling is performed, it is recommended that the guidance of the *HRC Code of Practice for Halon Reclaiming Companies* be followed. All other design features should comply with this standard.

**A.4.2.1** Piping should be installed in accordance with good commercial practice. Care should be taken to avoid possible restrictions due to foreign matter, faulty fabrication, or improper installation.

The piping system should be securely supported with due allowance for agent thrust forces and thermal expansion and contraction and should not be subjected to mechanical, chemical, vibration, or other damage. ASME B31.1, *Power Piping Code*, should be consulted for guidance on this matter. Where explosions are likely, the piping should be attached to supports that are least likely to be displaced.

Although halon systems are not subjected to continuous pressurization, some provisions should be made to ensure that the type of piping installed can withstand the maximum stress at maximum storage temperatures. Maximum allowable stress levels for this condition should be established at values of 90 percent of the minimum yield strength or 50 percent of the minimum tensile strength, whichever is less. All joint factors should be applied after this value is determined.

**A.4.2.1.5** Pressure-operated cylinder valves are opened by the application of "pilot pressure" from the halon cylinder or from a separate pressure source. Depending on the particular valve design, the pilot pressure must be applied either to a special actuation port or to the discharge outlet of the cylinder valve. A leak in source of pilot pressure can build up sufficient pressure in closed sections of pilot actuation pipe to cause the cylinder

valve to open. To prevent such accidental discharge, a pressure vent must be installed in any closed section of pipe that is used to supply pressure. The vent must be sized or otherwise designed so that when actuation is required, sufficient pilot pressure can be built up in the pilot pipe or discharge manifold to reliably open all cylinder valves. [See Table A.4.2.1.5(a) and Table A.4.2.1.5(b).]

**A.4.2.3** Information on specific fittings is provided as follows:

- (1) 300 lb class malleable iron fittings, sizes through 3 in., are acceptable. Forged steel fittings should be used for all larger sizes. Flanged joints should be 600 lb class.
- (2) 300 lb class malleable iron fittings are acceptable through 3 in. internal pipe size, and 1000 ductile iron or forged steel fittings should be used in larger sizes. Flanged joints should be 300 lb class.
- (3) Pressure-temperature ratings have been established for certain types of fittings. A list of ANSI standards covering the different types of fittings is given in Table 126.1 of ASME B31.1, *Power Piping Code*. Where fittings not covered by one of these standards are used, the design recommendations of the manufacturer of the fittings should not be exceeded.

The materials listed in (1) and (2) do not preclude the use of other materials that would satisfy the requirements of 4.2.3.

**A.4.2.5.3** The type and size of the nozzle can be identified by part number, orifice code, orifice diameter, or other suitable

markings. The marking should be readily discernible after installation.

**A.4.3.2.1** Detectors installed at the maximum spacing as listed or approved for fire alarm use could result in excessive delay in agent release, especially where more than one detection device is required to be in alarm before automatic actuation results.

**A.4.3.3.7** Manual controls should be located at the exit from the enclosure, preferably on the door latch side.

**A.4.3.5.3** The abort switch should be located near the means of egress for the area. Abort switches are generally not recommended.

**A.4.3.6** Accidental discharge has been recognized as a significant factor in unwanted Halon 1301 emissions.

Equipment lockout or service disconnects can be instrumental in preventing false discharges when the Halon 1301 system is being tested or serviced. In addition, servicing of air-conditioning systems with the release of refrigerant aerosols, soldering, or turning electric plenum heaters on for the first time after a long period of idleness can trip the Halon 1301 system. When used, an equipment service disconnect switch should be of the keyed-access type if external of the control panel or can be of the toggle type if within the locked control panel. Either type should annunciate at the panel when in the out-of-service mode. Written procedures should be established for taking the Halon 1301 system out of service.

**Table A.4.2.1.5(a) Minimum Piping Requirements Halon 1301 Systems — 360 psi Charging Pressure**

| Pipe/Tubing Type and Joining Method                     | Pipe/Tubing Specification       | Minimum Wall Thickness                 |
|---------------------------------------------------------|---------------------------------|----------------------------------------|
| <b>Steel Pipe — Threaded Connections</b>                | ASTM A106 Seamless, Grade C     | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade B | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade A | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade B            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade A            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 Furnace Weld Class F   | Schedule 40 — ⅛ in. through 1½ in. NPS |
|                                                         |                                 | Schedule 80 — 2 in. through 8 in. NPS  |
| <b>Steel Pipe — Welded or Rolled Groove Connections</b> | ASTM A106 Seamless, Grade C     | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade B | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade A | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade B            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade A            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 Furnace Weld Class F   | Schedule 40 — ⅛ in. through 6 in. NPS  |
| <b>Steel Pipe — Cut Groove Connections</b>              | ASTM A106 Seamless, Grade C     | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade B | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A106/A53 Seamless, Grade A | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade B            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                                         | ASTM A53 ERW Grade A            | Schedule 40 — ⅛ in. through 5 in. NPS  |
|                                                         |                                 | Schedule 80 — 6 in. through 8 in. NPS  |
|                                                         | ASTM A53 Furnace Weld Class F   | Schedule 40 — ⅛ in. through 3 in. NPS  |
|                                                         |                                 | Schedule 80 — 4 in. through 8 in. NPS  |
| <b>Copper Tubing — Compression Fittings</b>             | ASTM B88 Seamless, Drawn        | Type K ¼ in. through 8 in.             |
|                                                         | ASTM B88 Seamless, Drawn        | Type L ¼ in. through 3 in.             |
|                                                         | ASTM B88 Seamless, Drawn        | Type M ¼ in. through 1½ in.            |
|                                                         | ASTM B88 Seamless, Annealed     | Type K ¼ in. through 1 in.             |
|                                                         | ASTM B88 Seamless, Annealed     | Type L ¼ in. through ¾ in.             |
|                                                         | ASTM B88 Seamless, Annealed     | Type M ¼ in. ONLY                      |

Table A.4.2.1.5(b) Minimum Piping Requirements Halon 1301 Systems — 600 psi Charging Pressure

| Pipe/Tubing Type and Joining Method  | Pipe/Tubing Specification       | Minimum Wall Thickness                 |
|--------------------------------------|---------------------------------|----------------------------------------|
| Steel Pipe — Threaded Connections    | ASTM A106 Seamless, Grade C     | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                      | ASTM A106/A53 Seamless, Grade B | Schedule 40 — ⅛ in. through 5 in. NPS  |
|                                      |                                 | Schedule 80 — 6 in. through 8 in. NPS  |
|                                      | ASTM A106/A53 Seamless, Grade A | Schedule 40 — ⅛ in. through 2½ in. NPS |
|                                      |                                 | Schedule 80 — 3 in. through 8 in. NPS  |
|                                      | ASTM A53 ERW Grade B            | Schedule 40 — ½ in. through 3 in. NPS  |
|                                      |                                 | Schedule 80 — 4 in. through 8 in. NPS  |
| Steel Pipe — Welded Connections      | ASTM A53 ERW Grade A            | Schedule 40 — ⅛ in. through 1¼ in. NPS |
|                                      |                                 | Schedule 80 — 1½ in. through 8 in. NPS |
|                                      | ASTM A53 Furnace Weld Class F   | Schedule 40 — ⅛ in. through ½ in. NPS  |
|                                      |                                 | Schedule 80 — ¾ in. through 2½ in. NPS |
|                                      |                                 | Schedule 120 — 3 in. through 8 in. NPS |
|                                      | ASTM A106 Seamless, Grade C     | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                      | ASTM A106/A53 Seamless, Grade B | Schedule 40 — ⅛ in. through 8 in. NPS  |
| Copper Tubing — Compression Fittings | ASTM A106/A53 Seamless, Grade A | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                      | ASTM A53 ERW Grade B            | Schedule 40 — ⅛ in. through 8 in. NPS  |
|                                      | ASTM A53 ERW Grade A            | Schedule 40 — ⅛ in. through 6 in. NPS  |
|                                      |                                 | Schedule 80 — 8 in. NPS                |
|                                      | ASTM A53 Furnace Weld Class F   | Schedule 40 — ⅛ in. through 3 in. NPS  |
|                                      |                                 | Schedule 80 — 4 in. through 6 in. NPS  |
|                                      | ASTM B88 Seamless, Drawn        | Type K ¼ in. through 1¼ in.            |
| Copper Tubing — Compression Fittings | ASTM B88 Seamless, Drawn        | Type L ¼ in. through ¾ in.             |
|                                      | ASTM B88 Seamless, Drawn        | Type M ¼ in. through ⅝ in.             |
|                                      | ASTM B88 Seamless, Annealed     | Type K ¼ in. through ⅝ in.             |
|                                      | ASTM B88 Seamless, Annealed     | Type L DO NOT USE                      |
|                                      | ASTM B88 Seamless, Annealed     | Type M DO NOT USE                      |
|                                      | ASTM B88 Seamless, Annealed     | Type M DO NOT USE                      |

**A.5.3.1** The authority having jurisdiction can require tests to ensure proper performance as defined by this standard.

**A.5.3.3** The design of total flooding Halon 1301 systems only beneath the raised floor of electronic data processing (EDP) facilities when the occupied space above the raised floor is not similarly protected by a total flooding Halon 1301 system does not meet the intent of this standard. Such a design does not comply with the definition of a total flooding system or with this chapter.

**A.5.4.1** Flammable liquid and gas fires are subject to prompt extinguishment when Halon 1301 is quickly introduced into the enclosure in sufficient quantity to provide an extinguishing concentration for the particular materials involved. NFPA 69 should be referred to when possible flammable concentrations of gases make explosion protection techniques necessary.

Where an explosion potential exists due to the presence of gaseous, volatile, or atomized fuels either before or following a fire, NFPA 68 and NFPA 69, covering vapor detection and explosion venting and suppression, should be consulted. In particular, extreme caution should be taken following inerting of a rich fuel-air mixture since compartment leakage or ventilation will cause the mixture to pass through the explosive range of concentrations when fresh air is admitted.

**A.5.4.1.2** The following are flame extinguishment considerations:

- (1) *Applicability of Flame Extinguishment Concentrations.* The minimum design concentration required to extinguish normal fires involving certain flammable gases and

liquids at atmospheric pressure is applicable if the conditions for reflash or explosion do not exist.

- (2) *Temperature Sensitivity.* The flame extinguishing concentration required for some fuels depends on the fuel temperature. All fuels should be tested at least at two temperatures to determine temperature sensitivity.
- (3) *Special Fire Consideration.* Where high temperatures or pressures exist or can result from delayed system activation and for configurations other than simple pool or gas jet fires, added tests specific to the intended application should be made.

The basis of Table 5.4.1.2 is covered in this annex material.

**A.5.5.2** Halon 1301 discharged into an enclosure for total flooding will result in an air-agent mixture that has a higher specific gravity than the air surrounding the enclosure. Therefore, any opening in the walls of the enclosure will allow the heavier air-agent mixture to flow out of the enclosure, being replaced with lighter outside air flowing into the enclosure through the same opening. The rate at which agent is lost through openings depends on the height and width of the opening, the location of the opening in the wall, and the concentration of agent in the enclosure.

Fresh air entering the enclosure will collect toward the top, forming an interface between the air-agent mixture and fresh air. As leakage proceeds, the interface will move toward the bottom of the opening. The space below the interface will contain essentially the original extinguishing concentration of agent, whereas the upper space will be completely unprotected. The rate at which the interface moves downward increases as

concentrations of agent increase, so that simply injecting an overdose of agent initially will not provide an extended period of protection.

**A.5.6** At elevations above sea level, Halon 1301 vapor expands to a greater specific volume because of the reduced atmospheric pressure. A system designed for sea-level conditions will therefore develop an actual higher concentration at elevations above sea level. For example, a system designed to produce a 6 percent Halon 1301 concentration at sea level would actually produce an 8.7 percent concentration if installed at 10,000 ft (3000 m) elevation. This concentration would be higher than recommended for normally occupied areas and with egress times longer than 1 minute. (See 5.2.6 and 5.2.7.)

To correct for this effect, the quantity indicated at sea-level conditions should be reduced for installations at higher elevations of altitude above sea level. Correction factors are given in Table A.5.6.

For elevations substantially below sea level, the effect is the opposite of that described for elevations above sea level. For those instances, the reciprocal of the appropriate correction factor in Table A.5.6 should be used.

**A.5.7.1** The minimum rates established are considered adequate for the usual surface or deep-seated fire. However, where the spread of fire could be faster than normal for the type of fire, or where high values or vital machinery or equipment are involved, rates higher than the minimums can, and in many cases should, be used. Where a hazard contains material that will produce both surface and deep-seated fires, the rate of application should be at least the minimum required for surface fires. Having selected a rate suitable to the hazard, the tables and information that follow in the standard should be used, or such special engineering as is required should be carried out, to obtain the proper combination of container releases, supply piping, and orifice sizes that will produce this desired rate.

**A.5.7.1.2** This point is distinguished by a marked change in both the sound and the appearance of the discharge.

**A.5.7.2** Where leakage is appreciable and the design concentration must be obtained quickly and maintained for an extended period of time, agent quantities provided for leakage compensation can be applied at a reduced rate.

**Table A.5.6 Correction Factors for Altitude**

| Altitude |      | Correction Factor |
|----------|------|-------------------|
| ft       | m    |                   |
| 3000     | 914  | 0.90              |
| 4000     | 1219 | 0.86              |
| 5000     | 1524 | 0.83              |
| 6000     | 1829 | 0.80              |
| 7000     | 2134 | 0.77              |
| 8000     | 2438 | 0.74              |
| 9000     | 2743 | 0.71              |
| 10,000   | 3048 | 0.69              |
| 11,000   | 3353 | 0.66              |
| 12,000   | 3658 | 0.64              |
| 13,000   | 3962 | 0.61              |
| 14,000   | 4267 | 0.59              |
| 15,000   | 4572 | 0.56              |

This type of application is particularly suitable for enclosed rotating electric apparatus, such as generators, motors, and converters, and also could be needed for total flooding protection of deep-seated fires.

The initial discharge should be completed within the limits specified in 5.7.1.2.

**A.5.8.2** Of particular concern in maintaining the integrity of the enclosure is preventing the lifting of ceiling tiles. Clipping of ceiling tiles will prevent their movement during discharge.

For a given type of nozzle, selection of the appropriate nozzle discharge rate is critical to reducing the potential of damage due to discharging agent. Careful consideration of ceiling type and construction, nozzle discharge characteristics, and installation methods is necessary. Maximum flow rates should be based on manufacturer's recommendations.

**A.6.1** Some protected area conditions could require inspections more frequent than semiannually. A service contract with an approved fire protection contractor is recommended. The inspection and test is to be conducted in accordance with the manufacturer's recommendations and procedures and appropriate NFPA standards and guides. Inspection criteria include but are not limited to the following:

- (1) *Detection.* All detectors are to be checked for proper alarm, supervision, and trouble functions.
- (2) *Actuation.*
  - (a) Remove automatic actuation controls from agent containers. Test detection system to operate the necessary circuit(s) to simulate agent release.
  - (b) Operate all manual devices to simulate agent release.
  - (c) After testing, reset and reinstall all actuation controls.
- (3) *Containers.*
  - (a) Examine all containers for evidence of corrosion or mechanical damage.
  - (b) Check container bracketing and supports to determine that their condition is satisfactory.
- (4) *Piping and Nozzles.*
  - (a) Examine piping for any evidence of corrosion.
  - (b) Examine pipe hangers and straps to see that the piping is securely supported.
  - (c) Check nozzles for proper position and alignment and determine that the orifices are clear and unobstructed.
  - (d) Check nozzle seals, if applicable, for signs of deterioration and replace if necessary.
- (5) *Auxiliary Equipment.*
  - (a) Operate all auxiliary and supplementary components such as switches, door and window releases, interconnected valves, damper releases, air-handling equipment shutdown, and supplementary alarms to ensure that they are in proper operating condition.
  - (b) Return all devices to normal "operating" condition after testing.

**A.6.1.4** The charging or recharging of cylinders or the removal or transfer of agent should be done using a closed loop system. A closed loop system permits transfer of halon between supply cylinders, system cylinders, and recovery cylinders, with only minor loss of halon to the atmosphere.

**A.6.7.2.2** See Annex B. The currently preferred method is using a blower door fan unit and smoke pencil. If quantitative results are recorded, these could be useful for comparison at future tests.

**A.6.7.2.3.8** Refer to *NFPA 72* and the manufacturer's recommended guidelines concerning this area.

**A.6.7.2.4.1** Refer to the manufacturer's recommendations in all cases.

## Annex B Enclosure Integrity Procedure

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

### B.1 Procedure Fundamentals.

#### B.1.1 Scope.

**B.1.1.1** This procedure outlines a method to equate enclosure leakage as determined by a door fan test procedure to worst-case halon leakage. The calculation method provided makes it possible to predict the time it will take for a descending interface to fall to a given height or, for the continually mixed cases, the time for the concentration to fall to a given percentage concentration.

**B.1.1.2** Enclosure integrity testing is not intended to verify other aspects of Halon 1301 system reliability, that is, hardware operability, agent mixing, hydraulic calculations, and piping integrity.

**B.1.1.3** This procedure is limited to door fan technology. This is not intended to preclude alternative technology such as acoustic sensors.

**B.1.1.4** This procedure should not be considered to be an exact model of a discharge test. The complexity of this procedure should not obscure the fact that most failures to hold concentration are due to the leaks in the lower surfaces of the enclosure, but the door fan does not differentiate between upper and lower leaks. The door fan provides a worst-case leakage estimate that is very useful for enclosures with complex hidden leaks, but it will generally require more sealing than is necessary to pass a discharge test.

#### B.1.2 Limitations and Assumptions.

**B.1.2.1 Halon System Enclosure.** The following should be considered regarding the halon system and the enclosure:

- (1) *Halon System Design.* This test procedure only concerns halon total flooding fire suppression systems using Halon 1301 that are designed, installed, and maintained in accordance with this standard.
- (2) *Enclosure Construction.* Halon 1301-protected enclosures, absent of any containing barriers above the false ceiling, are not within the scope of this document.
- (3) *Halon Concentration.* Special consideration should be given to Halon 1301 systems with concentrations greater than 10 percent where the concern exists that high concentrations could result in significant overpressures from the discharge event in an enclosure with minimal leakage.
- (4) *Enclosure Height.* Special consideration should be given to high enclosures where the static pressure due to the Halon 1301 column is higher than the pressure possible to attain by means of the door fan.

- (5) *Static Pressures.* Where at all possible, static pressure differentials (HVAC system, elevator connections, etc.) across the enclosure envelope should be minimized during the door fan test. The test can be relied upon only for enclosures having a range of static pressures outlined in B.2.5.2.3.

**B.1.2.2 Door Fan Measurements.** The following should be considered regarding the door fan and its associated measurements:

- (1) *Door Fan Standards.* Guidance regarding fan pressurization apparatus design, maintenance, and operation is provided by ASTM E779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, and CAN/CGSB-149.10-2019, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*.
- (2) *Attached Volumes.* There can be no significant attached volumes within or adjoining the enclosure envelope that will allow detrimental halon leakage that would not be measured by the door fan. Such an attached volume would be significant if it is absent of any leakage except into the design envelope and is large enough to adversely affect the design concentration.
- (3) *Return Path.* All significant leaks must have an unrestricted return path to the door fan.
- (4) *Leak Location.* The difficulty in determining the specific leak location on the enclosure envelope boundaries using the door fan is accounted for by assuming halon leakage occurs through leaks at the worst location. This is when one-half of the total equivalent leakage area is assumed to be at the maximum enclosure height and the other half is at the lowest point in the enclosure. In cases where the below false ceiling leakage area (BCLA) is measured using B.2.6.2, the value attained for BCLA is assumed to exist entirely at the lowest point in the enclosure.
- (5) *Technical Judgment.* Enclosures with large overhead leaks but no significant leaks in the floor slab and walls will yield unrealistically short retention time predictions. Experience has shown that enclosures of this type can be capable of retaining halon for prolonged periods. However, in such cases the authority having jurisdiction can waive the quantitative results in favor of a detailed witnessed leak inspection of all floors and walls with a door fan and smoke pencil.

**B.1.2.3 Retention Calculations.** The following should be considered regarding the retention calculations and the associated theory:

- (1) *Dynamic Discharge Pressures.* Losses due to the dynamic discharge pressures resulting from halon system actuation are not specifically addressed.
- (2) *Static Pressure.* Variable external static pressure differences (wind, etc.) are additive and should be considered.
- (3) *Temperature Differences.* When temperature differences exceeding 18°F (10°C) exist between the enclosure under test and the other side of the door fan, special considerations outlined in this document should be considered.
- (4) *Floor Area.* The floor area is assumed to be the volume divided by the maximum height of the protected enclosure.
- (5) *Descending Interface.* The enclosure integrity procedure assumes a sharp interface. When halon is discharged, a uniform mixture occurs. As leakage takes place, air enters the room. This procedure assumes that the

incoming air rides on top of the remaining mixture. In reality, the interface usually spreads because of diffusion and convection. These effects are not modeled because of their complexity. Where a wide interface is present, the descending interface is assumed to be the midpoint of a wide interface zone. Because of the conservatism built into the procedure, the effects of interface spreading can be ignored. If continual mechanical mixing occurs, a descending interface might not be formed (*see B.2.7.1.6*).

- (6) **Leak Flow Characteristics.** All leak flow is one-dimensional and does not take into account stream functions.
- (7) **Leak Flow Direction.** A particular leak area does not have bidirectional flow at any point in time. Flow through a leak area is either into or out of the enclosure.
- (8) **Leak Discharge.** The outflow from the leak discharges into an infinitely large space.
- (9) **Leak Locations.** Calculations are based on worst-case halon leak locations.
- (10) **Halon Delivery.** The calculations assume that the design concentration of halon will be achieved. If a suspended ceiling exists, it is assumed that the halon discharge will not result in displacement of the ceiling tiles. Increased confidence can be obtained if ceiling tiles are clipped within 4 ft (1.2 m) of the nozzles and all perimeter tiles.

**B.1.3 Definitions.** For the purpose of Annex B, the following definitions apply.

**Attached Volumes.** A space within or adjoining the enclosure envelope that is not protected by halon and cannot be provided with a clearly defined return path.

**Blower.** The component of the door fan used to move air.

**Ceiling Slab.** The boundary of the enclosure envelope at the highest elevation.

**Column Pressure.** The theoretical maximum positive pressure created at the floor slab by the column of the halon-air mixture.

**Descending Interface.** The enclosure integrity procedure assumes a sharp interface. When halon is discharged, a uniform mixture occurs. As leakage takes place, air enters the room. This procedure assumes that the incoming air rides on top of the remaining mixture. In reality, the interface usually spreads because of diffusion and convection. These effects are not modeled because of their complexity. Where a wide interface is present, the descending interface is assumed to be the midpoint of a wide interface zone. Because of the conservatism built into the procedure, the effects of interface spreading can be ignored. If continual mechanical mixing occurs, a descending interface might not be formed. (*See B.2.7.1.6*.)

**Door Fan.** The device used to pressurize or depressurize an enclosure envelope to determine its leakage characteristics. Also called the fan pressurization apparatus.

**Effective Floor Area.** The volume divided by the maximum halon-protected height.

**Effective Flow Area.** The area that results in the same flow area as the existing system of flow areas when it is subjected to the same pressure difference over the total system of flow paths.

**Enclosure.** The volume being tested by the door fan. This includes the halon-protected enclosure and any attached volumes.

**Enclosure Envelope.** The floor, walls, ceiling, or roof that together constitute the enclosure.

**Equivalent Leakage Area (ELA).** The total combined area of all leaks, cracks, joints, and porous surfaces that act as leakage paths through the enclosure envelope. This is represented as the theoretical area of a sharp-edged orifice that would exist if the flow into or out of the entire enclosure at a given pressure were to pass solely through it. For the purposes of this document, the ELA is calculated at the column pressure.

**Fan Pressurization Apparatus.** The device used to pressurize or depressurize an enclosure envelope to determine its leakage characteristics. Also called the *door fan*.

**Floor Slab.** The boundary of the enclosure envelope at the lowest elevation.

**Flow Pressure Gauge.** The component of the door fan used to measure the pressure difference across the blower to give a value used in calculating the flow into or out of the enclosure envelope.

**Halon Protected Enclosure.** The volume protected by the Halon 1301 system.

**Maximum Halon Protected Height.** The design height of the halon column from the floor slab. This does not include the height of unprotected ceiling spaces.

**Minimum Halon Protected Height.** The minimum acceptable height from the floor slab to which the descending interface is allowed to fall during the retention time as specified by the authority having jurisdiction.

**Return Path.** The path outside the enclosure envelope that allows air to travel to/from the leak to/from the door fan.

**Return Path Area.** The effective flow area that the air being moved by the door fan must travel through to complete a return path back to the leak.

**Room Pressure Gauge.** The component of the door fan used to measure the pressure differential across the enclosure envelope.

**Static Pressure Difference.** The pressure differential across the enclosure envelope not caused by the discharge process or by the weight of the Halon 1301. A positive static pressure difference indicates that the pressure inside the enclosure is greater than on the outside, that is, smoke would leave the enclosure at the enclosure boundary.

## B.2 Test Procedure.

**B.2.1 Preliminary Preparations.** Contact the individual(s) responsible for the Halon 1301-protected enclosure and establish, obtain, and provide the following preliminary information:

- (1) Provide a description of the test
- (2) Advise the time required
- (3) Determine the staff needed (to control traffic flow, set HVAC, etc.)
- (4) Determine the equipment required (e.g., ladders)
- (5) Obtain a description of the HVAC system

- (6) Establish the existence of a false ceiling space and the size of ceiling tiles
- (7) Visually determine the readiness of the room with respect to the completion of obvious sealing
- (8) Determine if conflict with other building trades will occur
- (9) Determine the size of doorways
- (10) Determine the existence of adequate return path area outside the enclosure envelope used to accept or supply the door fan air
- (11) Evaluate other conflicting activities in and around space (e.g., interruption to the facility being tested)
- (12) Obtain appropriate architectural HVAC and halon system design documents

**B.2.2 Equipment Required.** The following equipment is required to test an enclosure using fan pressurization technology.

#### B.2.2.1 Door Fan System.

**B.2.2.1.1** The door fan(s) should have a total airflow capacity capable of producing a pressure difference at least equal to the predicted column pressure or 10 Pa, whichever is greater.

**B.2.2.1.2** The fan should have a variable speed control or a control damper in series with the fan.

**B.2.2.1.3** The fan should be calibrated in airflow units or be connected to an airflow metering system.

**B.2.2.1.4** The accuracy of airflow measurement should be  $\pm 5$  percent of the measured flow rate.

**B.2.2.1.5** The room pressure gauge should be capable of measuring pressure differences from 0 Pa to at least 50 Pa. It should have an accuracy of  $\pm 1$  Pa and divisions of 2 Pa or less. Inclined oil-filled manometers are considered to be traceable to a primary standard and need not be calibrated. All other pressure-measurement apparatus (e.g., electronic transducer or magnehelic) should be calibrated at least yearly.

**B.2.2.1.6** Door fan systems should be checked for calibration every 5 years under controlled conditions, and a certificate should be available for inspection at all integrity tests. The calibration should be performed according to manufacturer's specifications.

The certificate should include the following:

- (1) Description of calibration facility and responsible technician
- (2) Date of calibration and serial number of door fan
- (3) Room pressure gauge error estimates at 0.002 in./Hg (7 Pa), 0.0029 in./Hg (10 Pa), 0.0035 in./Hg (12 Pa), 0.0044 in./Hg (15 Pa), 0.006 in./Hg (20 Pa), and 0.0118 in./Hg (40 Pa) measured by both ascending and descending pressures (minimum)
- (4) Fan calibration at a minimum of three leakage areas (approximate): 5.38 ft<sup>2</sup> (0.5 m<sup>2</sup>), 2.69 ft<sup>2</sup> (0.25 m<sup>2</sup>), and 0.54 ft<sup>2</sup> (0.05 m<sup>2</sup>) measured at a pressure of 0.0029 in./Hg (10 Pa)

**B.2.2.1.7** A second blower or multiple blowers with flex duct and panel to flow to above ceiling spaces is optional.

**B.2.2.2 Accessories.** The following equipment is also useful:

- (1) Smoke pencil, fully charged (*see Caution*)

**CAUTION:** Use of chemically generated smoke as a means of leak detection could result in activation of building or halon system smoke detectors. Appropriate precautions should be taken. Due to corrosive nature of the smoke, it should be used sparingly.

- (2) Bright light source
- (3) Floor tile lifter
- (4) Measuring tape
- (5) Masking or duct tape
- (6) Test forms
- (7) Multi-tip screwdrivers
- (8) Shop knife or utility knife
- (9) Several sheets of thin plastic and cardboard
- (10) Door stops
- (11) Signs to post on doors that say "DO NOT SHUT — DOOR FAN TEST IN PROGRESS" or "DO NOT OPEN — DOOR FAN TEST IN PROGRESS"
- (12) Thermometer

#### B.2.2.3 Field Calibration Check.

**B.2.2.3.1** This procedure enables the authority having jurisdiction to obtain an indication of the door fan and system calibration accuracy upon request.

**B.2.2.3.2** The field calibration check should be done in a separate enclosure. Seal off any HVAC registers and grilles if present. Install the door fan per manufacturer's instructions and B.2.4. Determine whether a static pressure exists using B.2.5.2. Check openings across the enclosure envelope for airflow with chemical smoke. If any appreciable flow or pressure exists, choose another room or eliminate the source.

**B.2.2.3.3** Install a piece of rigid material less than  $\frac{1}{8}$  in. (3.2 mm) thickness (free of any penetrations) in an unused blower port or other convenient enclosure opening large enough to accept an approximately 0.01 m<sup>2</sup> sharp-edged round or square opening.

**B.2.2.3.4** Ensure that the door fan flow measurement system is turned to properly measure pressurization or depressurization and operate the blower to achieve a convenient pressure differential, preferably 10 Pa.

**B.2.2.3.5** At the pressure achieved, measure the flow and calibrate an initial ELA value using B.2.6.3. Repeat the ELA measurement under positive pressure and average the two results.

**B.2.2.3.6** Create a sharp-edged round or square opening in the rigid material. The area of this opening should be at least 33 percent of the initial ELA measured. Typical opening sizes are approximately 0.5 ft<sup>2</sup> (0.05 m<sup>2</sup>), 1.1 ft<sup>2</sup> (0.1 m<sup>2</sup>), and 2.2 ft<sup>2</sup> (0.2 m<sup>2</sup>), depending on the initial leakage of the enclosure. Adjust the blower to the previously used positive or negative pressure differential. Measure the flows and calculate an average ELA value using B.2.6.3.

**B.2.2.3.7** Field calibration is acceptable if the difference between the first and second ELA value is within  $\pm 15$  percent of the hole area cut in the rigid material. If the difference in ELA values is greater than  $\pm 15$  percent, the door fan apparatus should be recalibrated according to the manufacturer's recommendations and either ASTM E779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, or CAN/CGSB-149.10-2019, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*.

### B.2.3 Initial Enclosure Evaluation.

#### B.2.3.1 Inspection.

**B.2.3.1.1** Note the areas outside the enclosure envelope that will be used to supply or accept the door fan air.

**B.2.3.1.2** Inspect all openable doors, hatches, and movable partitions for their ability to remain shut during the test.

**B.2.3.1.3** Obtain or generate a sketch of the floor plan showing walls, doorways, and the rooms connected to the test space. Number or name each doorway.

**B.2.3.1.4** Look for large attached volumes open to the test space via the floor or walls of the test space. Note volumes and apparent open connecting areas.

**B.2.3.1.5** Check floor drains and sink drains for traps with liquid.

#### B.2.3.2 Measurement of Enclosure.

**B.2.3.2.1** Measure the halon-protected enclosure volume. Record all dimensions. Deduct the volume of large solid objects to obtain the net volume.

**B.2.3.2.2** Measure the highest point in the halon-protected enclosure.

**B.2.3.2.3** Calculate the effective floor area by dividing the net halon-protected volume by the maximum halon-protected enclosure height.

#### B.2.3.3 Preparation.

**B.2.3.3.1** Advise supervisory personnel in the area about the details of the test.

**B.2.3.3.2** Remove papers and objects likely to be affected by the air currents from the discharge of the door fan.

**B.2.3.3.3** Secure all doorways and openings as for a halon discharge. Post personnel to ensure they stay shut/open. Open doorways inside the halon-protected enclosure even though they may be closed upon discharge.

**B.2.3.3.4** Get the user's personnel and/or the halon contractor to set up the room in the same state as when a discharge would occur, that is, HVAC shut down, dampers closed, and so forth. Confirm that all dampers and closable openings are in the discharge mode position.

### B.2.4 Door Fan Installation.

**B.2.4.1** The door fan apparatus generally consists of a single door fan. A double or multiple door fan for larger spaces or for neutralizing leakage through a suspended ceiling can be used for certain applications.

**B.2.4.2** Set up one blower unit in the most convenient doorway leading into the space. Choose the doorway that opens into the largest return path area. Consideration should be given to individuals requiring access into or out of the facility.

**B.2.4.3** Follow the manufacturer's instructions regarding setup.

**B.2.4.4** Before door fan installation, examine the sealing around the door that the fan will be mounted in to determine whether significant leakage exists. If significant leaks are found, they should be corrected. If the manufacturer's stated door fan sealing system leakage is less than the apparent remaining leak-

age of the doorway, the difference must be added to the leakage calculated in B.2.6 (*see B.2.6.3.5*).

**B.2.4.5** Ensure that all pressure gauges are leveled and zeroed prior to connecting them to the fan apparatus. This should be done by first gently blowing into or drawing from the tubes leading to the pressure gauges so the needle fluid or readout moves through its entire span and stays at the maximum gauge reading for 10 seconds. This confirms proper gauge operation. If using a magnehelic gauge, gently tap the gauge face for 10 seconds. With both ports of each gauge on the same side of the doorway (using tubes if necessary), zero the gauges with their particular adjusting method.

**B.2.4.6** Connect the tubing for the room pressure gauge. Ensure that the tube is at the floor slab elevation and extends at least 10 ft away from the outlet side of the door fan blower, away from its air stream path and away from all significant air streams (i.e., HVAC airflows or openings where airflow could impinge on the tube).

**B.2.4.7** The door fan should be arranged to alternately blow out of (depressurize) and blow into the space (pressurize). Both measurements should be taken as described in B.2.6.

### B.2.5 Door Fan Enclosure Evaluation.

#### B.2.5.1 Pressure Run-up Inspection.

**B.2.5.1.1** Activate the blower and adjust the enclosure pressure to negative 15 Pa or maximum negative achievable (up to -15 Pa).

**B.2.5.1.2** Inspect all dampers with smoke to ensure that they are closing properly. Record problems and notify individuals responsible for the enclosure of the problems.

**B.2.5.1.3** Inspect doors and hatches to ensure correct closure. Record problems and notify individuals responsible for the enclosure of the problems.

**B.2.5.1.4** Inspect the wall perimeter (above and below the false floor) and the floor slab for major leaks. Note location and size of major leaks. Track down major airflow currents.

#### B.2.5.2 Static Pressure Measurement.

**B.2.5.2.1** Seal the blower opening with the door fan properly installed but without the blower operating. Observe the room pressure gauge for at least 30 seconds. Look for minor fluctuations in pressure.

**B.2.5.2.2** Under pre-halon discharge conditions, measure the worst-case (greatest) pressure differential ( $P_{SH}$ ) across a section of envelope containing the largest quantity of leaks expected to leak halon. If the subfloor is pressurized at discharge, measure the differential between the subfloor and outside the envelope. Call this value  $P_{SH}$  (for static at halon discharge). Determine the flow direction with smoke or other indicating method.

**B.2.5.2.3** If the static pressure ( $P_{SH}$ ) has an absolute value greater than 25 percent of the column pressure calculated in B.2.6.1.3, it must be permanently reduced. Large static pressures decrease the level of certainty inherent in this procedure. The most common causes of excessive static pressure are leaky dampers and ducts and failure to shut down air-handling equipment serving the enclosure.

**B.2.5.2.4** Record the position of all doorways, whether open or shut, when the static pressure ( $P_{SH}$ ) was measured.

## B.2.6 Door Fan Measurement.

### B.2.6.1 Total Enclosure Leakage Method.

**B.2.6.1.1** This method determines the equivalent leakage area of the entire enclosure envelope. It is determined by measuring the enclosure leakage under both positive and negative pressures and averaging the readings. This approach is used in order to minimize the influence of static pressures on the ELA calculation.

- (1) Block open all doorways around the enclosure and post personnel to ensure that they stay open.
- (2) Ensure that adequate return path area is provided to allow an unrestricted return airflow path back to the door fan from enclosure leaks.
- (3) Remove 1 percent of the floor tiles (for false floors) if an equivalent area is not already open.
- (4) If halon is designed to discharge above the false ceiling, remove 1 percent of the ceiling tiles.
- (5) Remeasure the static pressure ( $P_{ST}$ ) at the time of the door fan test, between the room (not below the false floor) and the return path space.
- (6) Make every effort to reduce the static pressure ( $P_{ST}$ ) by shutting down air-handling equipment even though it can operate during discharge.
- (7) Record  $P_{ST}$  and determine its direction using smoke or other means.
- (8) Record the position of each doorway, open/shut.
- (9) If the static pressure fluctuates due to wind, use a wind damping system incorporating four averaging tubes on each side of the building to eliminate its effects. The CAN/CGSB-149.10-2019 standard can be used.
- (10) If a subfloor pressurization air handler cannot be shut down for the test and leaks exist in the subfloor, these leaks might not be accurately measured. Every attempt should be made to reduce subfloor leaks to insignificance. During the test as many floor tiles as possible should be lifted to reduce the amount of subfloor pressurization. Note that under such conditions the Suspended Ceiling Leakage Neutralization Method will be difficult to conduct due to massive air turbulence in the room.

**CAUTION:** The removal of raised floor tiles creates a serious safety hazard. Appropriate precautions should be taken.

**B.2.6.1.2** Calculate the column pressure in the halon-protected enclosure using the following equation:

[B.2.6.1.2]

$$P_c = gH_o(r_m - r_a)$$

where:

$P_c$  = pressure due to the halon column (Pa)  
 $g$  = acceleration due to gravity (9.81 m/sec<sup>2</sup>)  
 $H_o$  = height of protected enclosure (m)  
 $r_m$  = halon/air mixture density (kg/m<sup>3</sup>; see Equation B.2.7.1.4)  
 $r_a$  = air density (1.202 kg/m<sup>3</sup>)

If the calculated column pressure is less than 10 Pa, use 10 Pa as the column pressure.

**B.2.6.1.3** Depressurize the enclosure with a door fan blower(s) until the measured pressure differential reading on

the gauge ( $P_m$ ) goes through a total pressure reduction ( $dP_m$ ) equal to the column pressure ( $P_c$ ). As an example, if the static pressure ( $P_{ST}$ ) measured in B.2.6.1.1 was -1 Pa and the calculated column pressure is 10 Pa, blow air out of the room until a  $P_m$  of -11 Pa is obtained. If the static pressure ( $P_{ST}$ ) was +1 Pa and the calculated column pressure is 10 Pa, blow air out of the room until a  $P_m$  of -9 Pa is obtained. If using magnehelic gauges, tap both the room pressure and flow pressure gauges for 10 seconds each. Wait a further 30 seconds before taking the readings.

**B.2.6.1.4** Measure the airflow ( $Q_u$ ) required to obtain the pressure reduction ( $dP_m$ ) required. It is important to ensure that manufacturer instructions are followed to ensure that airflow is accurately measured with respect to direction of flow.

**B.2.6.1.5** The pressure reduction generated  $dP_m$  could be up to 30 percent greater but not lower in absolute value than the calculated column pressure.

**B.2.6.1.6** Repeat B.2.6.1.3 through B.2.6.1.5 while pressurizing the enclosure. As an example, if the static pressure ( $P_{ST}$ ) measured in B.2.6.1.1 was -1 Pa and the calculated column pressure is 10 Pa, blow air into the room until +9 Pa is obtained. If the static pressure was +1 Pa and the calculated column pressure is 10 Pa, blow air into the room until +11 Pa is obtained.

**B.2.6.1.7** Ensure that the door fan flow measurement system is actually turned around between tests to properly measure pressurization or depressurization and that the motor rotation is not simply reversed. Ensure that the airflow entering the room is not deflected upward, which can cause lifting of any existing ceiling tiles.

**B.2.6.1.8** Measure the air temperature within the enclosure ( $T_i$ ) and outside the enclosure ( $T_o$ ).

### B.2.6.2 Suspended Ceiling Leakage Neutralization Method (Optional).

**B.2.6.2.1** When an unobstructed suspended ceiling exists, the leakage area below the ceiling can optionally be measured by neutralizing ceiling leaks. This method can provide a more accurate estimate of halon leakage rates. This method should not be used if the walls between rooms within the zone are sealed at the ceiling slab. This method cannot be used when the halon system is designed to protect above this suspended ceiling. This test method does not imply that leakage above the suspended ceiling is acceptable. This technique can be difficult or impossible to perform under the following conditions:

- (1) Air movement within the room can make it difficult to observe neutralization, particularly in small rooms.
- (2) Obstructions above the suspended ceiling, that is, beams, ducts, and partitions, can make it difficult to obtain uniform neutralization.
- (3) Limited clearance above the suspended ceiling, for example, less than 1 ft (0.3 m), can make it difficult to obtain neutralization.

**B.2.6.2.2** If not already done, obtain the equivalent leakage area of the halon-protected enclosure using the total enclosure leakage method in B.2.6.1.

**B.2.6.2.3** Ceiling level supply registers and return grilles can be temporarily sealed off to increase the accuracy of this method. If sealed,  $P_{ST}$  should be remeasured.

NOTE: Temporary sealing of such openings is not permitted when conducting a Total Enclosure Leakage Test.

**B.2.6.2.4** Install two separate door fans or a multiple-blower door fan with one blower ducted to the above suspended ceiling space and the other into the room space below the suspended ceiling. It is not necessary to measure airflow through the upper fan.

**B.2.6.2.5** Depressurize above and below the suspended ceiling by adjusting two separate blowers until the required pressure reduction and suspended ceiling leak neutralization (i.e., no airflow through the suspended ceiling) is achieved.

Leaks are neutralized when at opened locations in the suspended ceiling smoke does not move up or down when emitted within  $\frac{1}{4}$  in. of the openings. If neutralization is not possible at all locations, ensure that smoke either does not move or moves down (but not up). Choose undisturbed locations away from flex duct flows, airstreams, and lighting fixtures because local air velocities make neutralization difficult to detect.

**B.2.6.2.6** Measure the airflow ( $Q_u$ ) through the fan that is depressurizing the volume below the false ceiling to obtain the pressure reduction ( $dP_m$ ) required.

**B.2.6.2.7** The pressure reduction generated in the volume below the false ceiling can be up to 30 percent greater, but not lower, in absolute value than the calculated column pressure.

**B.2.6.2.8** Repeat B.2.6.2.5 through B.2.6.2.7 while pressurizing the enclosure except that smoke either does not move or moves up but not down.

**B.2.6.2.9** An alternate method for measuring the below-ceiling leaks consists of temporarily sealing identifiable ceiling level leaks using a flexible membrane, such as polyethylene sheet and tape, and then measuring the below-ceiling leakage solely using door fans drawing from the lower part of the room. No flex duct is needed. Examples of sealable leaks are undamped ceiling level supply registers or return grilles or an entire suspended ceiling lower surface.

### B.2.6.3 Equivalent Leakage Area Calculation.

**B.2.6.3.1** Paragraph B.2.6.3 outlines the door fan calculation to be used in conjunction with B.2.6.1 and B.2.6.2.

**B.2.6.3.2** The leakage area is generally derived per CAN/CGSB-149.10-2019, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*. The CGSB document calculates area at 10 Pa only, whereas this procedure calculates area at a minimum of 10 Pa but allows for calculation at the halon column pressure, which could be greater than 10 Pa.

**B.2.6.3.3** The airflow should be corrected for temperature if the difference between the temperature of the air being blown through the door fan and the temperature of the air going into or out of the leaks during the door fan test exceeds 10°C (18°F). If this condition exists, correct the flows as follows:

[B.2.6.3.3]

$$Q = Q_u \left( \frac{T_L + 273}{T_F + 273} \right)^{0.5}$$

where:

$Q_c$  = corrected flow (m<sup>3</sup>/sec)

$Q_u$  = uncorrected flow (m<sup>3</sup>/sec)

$T_L$  = temperature of air going through room leaks (°C)

$T_F$  = temperature of air going through door fan (°C)

NOTE: When depressurizing,  $T_L = T_o$ ,  $T_F = T_r$ . When pressurizing,  $T_L = T_b$ ,  $T_F = T_o$ .

**B.2.6.3.4** For Equation B.2.6.3.3, corrections for barometric pressure are not necessary since they cancel out, and corrections for humidity are too small to be of concern. No other corrections apply. If Equation B.2.6.3.3 is not used, then the following applies:

[B.2.6.3.4]

$$Q_c = Q_u$$

**B.2.6.3.5** After measurements are taken from pressurizing and depressurizing the enclosure, the leakage area in each direction should be calculated, and the results should be averaged. Each leakage area is calculated assuming the density of air is 1.202 kg/m<sup>3</sup> and the discharge coefficient for a hole in a flat plate (door fan) is 0.61. The equation is as follows:

[B.2.6.3.5]

$$A = \frac{1.271Q_c}{\sqrt{\frac{P_m}{P_{ST}}} - \sqrt{\frac{P_{ST}}{P_m}}}$$

where:

$A$  = area of leaks (m<sup>2</sup>)

$Q_c$  = door fan flow, corrected (m<sup>3</sup>/sec)

$P_m$  = measured pressure from door fan gauge (Pa)

$P_{ST}$  = static pressure at time of door fan test (Pa)

The final value for  $A$  is determined by averaging the areas obtained under both a positive and a negative pressure.

**B.2.6.3.6** Equation B.2.6.3.5 should be used for both the total enclosure leakage method (B.2.6.1) and the optional suspended ceiling leakage neutralization method (B.2.6.2). For B.2.6.1, the area of leaks ( $A$ ) equals the equivalent leakage area (ELA). For B.2.6.2, the area of leaks ( $A$ ) equals the below ceiling leakage area (BCLA).

### B.2.7 Retention Calculation.

#### B.2.7.1 Calculation.

**B.2.7.1.1 Total Leakage Area.** Calculate the total leakage area ( $A_T$ ) using the equivalent leakage area (ELA) determined from the door fan measurements as per B.2.6.3. This calculation should be based on a discharge coefficient of 0.61 that is used with the door fan apparatus. The following equations apply:

[B.2.7.1.1a]

$$ELA = \frac{A_d + A_p}{2}$$

where:

$A_d$  = leakage area (depressurization)

$A_p$  = leakage area (pressurization)



[B.2.7.1.1b]

$$A_T = 0.61(ELA)$$

where:

$A_T$  = total leakage area (m<sup>2</sup>)

$ELA$  = equivalent leakage area (m<sup>2</sup>)

**B.2.7.1.2 Lower Leakage Area.** If the leakage area is measured using only B.2.6.1, Total Enclosure Leakage Method, then Equation B.2.7.1.2a should be used to calculate the lower leakage area ( $A_{LL}$ ). If the below ceiling leakage area ( $BCLA$ ) is measured using B.2.6.2, Suspended Ceiling Neutralization Method, Equation B.2.7.1.2b applies instead. These equations are as follows:

[B.2.7.1.2a]

$$A_{LL} = \frac{A_T}{2}$$

[B.2.7.1.2b]

$$A_{LL} = 0.61(BCLA)$$

where:

$A_{LL}$  = lower leakage area (m<sup>2</sup>)

$BCLA$  = below ceiling leakage area (m<sup>2</sup>)

$A_T$  = total leakage area (m<sup>2</sup>)

**B.2.7.1.3 Leak Fraction.** Determine the lower leak fraction ( $F_A$ ) using the following equation:

[B.2.7.1.3]

$$F_A = \frac{A_L}{A_T}$$

where:

$F_A$  = lower leak fraction

$A_L$  = leakage area

If  $F_A$  is >0.5, make  $F_A = 0.5$ .

**B.2.7.1.4 Halon Mixture Density.** Calculate the density of the Halon 1301/air mixture ( $r_m$ ) using the following equation:

[B.2.7.1.4]

$$r_m = 6.283 \frac{c}{100} + \left( r_a \frac{100-c}{100} \right)$$

where:

$r_m$  = halon/air mixture density (kg/m<sup>3</sup>)

$c$  = Halon 1301 concentration (%)

$r_a$  = air density (1.202 kg/m<sup>3</sup>)

**B.2.7.1.5 Static Pressure.** Determine the correct value for ( $P_{SH}$ ) to be used in Equation B.2.7.1.7b; if the ( $P_{SH}$ ) recorded is negative, let it equal zero (0); if it is positive, use the recorded value.

**B.2.7.1.6 Minimum Height.** Determine from the authority having jurisdiction the minimum height from the floor slab ( $H$ ) that is not to be affected by the descending interface during the holding period.

If continuous mechanical mixing occurs during the retention time such that a descending interface does not form and the halon concentration is constant throughout the protected enclosure, calculate an assumed value for  $H$  based on the initial and final specified concentrations using the following equation:

[B.2.7.1.6]

$$H = \frac{C_F}{c} H_o$$

where:

$H$  = assumed value for  $H$  for mixing calculation

$c$  = actual Halon 1301 concentration (%)

$C_F$  = final halon concentration per authority having jurisdiction requirement

$H_o$  = maximum halon protected height

Example:  $H_o = 4$  m, initial concentration = 7%, final = 5%,  $H = \frac{5}{7} \times 4$  m = 2.86 m. Ensure that mixing is not created by ductwork that leaks excessively to zones outside the enclosure.

**B.2.7.1.7 Time.** Calculate the minimum time ( $t$ ) that the enclosure is expected to maintain the descending interface above ( $H$ ), using the following equations:

[B.2.7.1.7a]

$$C_3 = \frac{2g(r_m - r_a)}{r_m + r_a \left( \frac{F_A}{1 - F_A} \right)^2}$$

[B.2.7.1.7b]

$$C_4 = \frac{2P_{SH}}{r_m}$$

[B.2.7.1.7c]

$$t = 2A_R \left( \frac{\sqrt{C_3 H_o + C_4} - \sqrt{C_3 H + C_4}}{C_3 F_A A_T} \right)$$

where:

$t$  = time (sec)

$C_3$  = constant for equation simplification

$C_4$  = constant for equation simplification

$A_R$  = room floor area (m<sup>2</sup>)

$g$  = acceleration due to gravity (9.81 m/sec<sup>2</sup>)

$P_{SH}$  = static pressure during halon discharge (Pa)

$H_o$  = height of ceiling (m)

$H$  = height of interface from floor (m)

**B.2.7.2 Acceptance Criteria.** The time ( $t$ ) that was calculated in B.2.7.1.7 must equal or exceed the holding time period specified by the authority having jurisdiction per 6.7.2.2.

**B.2.7.3 Sample Calculation.**

**B.2.7.3.1 General.** This section provides an example of leakage area calculations and retention calculations. Door fan measurements using the total enclosure leakage method (B.2.6.1) and the optional suspended ceiling leakage neutralization method (B.2.6.2) are both considered.

**B.2.7.3.2 Enclosure and System Data.** The following data regarding the enclosure and the halon system are provided:

- (1) Initial Halon 1301 concentration ( $c$ ): 6.0%
- (2) Volume of halon-protected enclosure ( $V$ ): 153.2 m<sup>3</sup>
- (3) Height of halon-protected enclosure ( $H_0$ ): 2.7 m
- (4) Calculation static pressure measurement ( $P_{SH}$ ): -2.0 Pa (*per B.2.5.2.2; smoke flows into room*)
- (5) Door fan static pressure measurement ( $P_{SF}$ ): -1.0 Pa (*per B.2.6.1.2; smoke flows into room*)
- (6) Temperature inside ( $T_i$ ) enclosure: 18°C
- (7) Temperature outside ( $T_o$ ) enclosure: 20°C
- (8) Minimum acceptable halon height ( $H$ ): 2 m (*per B.2.7.1.6*)

**B.2.7.3.3 Preliminary Calculations.**

**B.2.7.3.3.1** Calculate the effective floor area (*per B.2.3.2.3*) as follows:

[B.2.7.3.3.1]

$$A_R = \frac{153.2}{2.7} = 56.7 \text{ m}^2$$

**B.2.7.3.3.2** Calculate the column pressure in the halon-protected enclosure ( $P_c$ ) using Equation B.2.6.1.2 (*per B.2.6.1.3*). Equation B.2.6.1.2 requires that the halon/air mixture density ( $r_m$ ) be known. Thus, the halon/air mixture density ( $r_m$ ) is first calculated using Equation B.2.7.1.4 (*per B.2.7.1.4*) as follows:

[B.2.7.3.3.2a]

$$\begin{aligned} r_m &= 6.283 \frac{6}{100} + 1.202 \frac{(100-6)}{100} \\ &= 0.377 + 1.130 \\ &= 1.507 \text{ kg/m}^3 \end{aligned}$$

[B.2.7.3.3.2b]

$$\begin{aligned} P_c &= (9.81)(2.7)(1.507 - 1.202) \\ &= 8.1 \text{ Pa} \end{aligned}$$

$P_c < 10$  Pa; therefore  $P_c = 10$  Pa per B.2.6.1.3.

**B.2.7.3.3.3** Determine the target depressurization pressure range (*per B.2.6.1.4 and B.2.6.1.6*) for taking door fan measurements as follows:

dep. target = -1 - 10 = -11 Pa

pressure range = -1 - (10 × 1.3) = -14 Pa

**B.2.7.3.3.4** Determine the target pressurization pressure range (*per B.2.6.1.7*) for taking door fan measurements as follows:

pressure target = -1 + 10 = +9 Pa

pressure range = -1 + (10 × 1.3) = +12 Pa

**B.2.7.3.4 Total Enclosure Leakage Method.**

**B.2.7.3.4.1 Leakage Area Calculation.** The following methodology should be used for the leakage area calculation:

- (1) Depressurize the enclosure into the 11 Pa to 14 Pa range with the door fan. Measure the airflow required and pressure created (*per B.2.6.1.4, B.2.6.1.5, and B.2.6.1.6*) as follows:

[B.2.7.3.4.1a]

$$Q_u = 0.2046 \text{ m}^3/\text{sec} (\text{depressurizing to } -12 \text{ Pa})$$

- (2) Pressurize the enclosure into the +9 Pa to +12 Pa range with the door fan. Measure the airflow required and pressure created (*per B.2.6.1.7*) as follows:

[B.2.7.3.4.1b]

$$Q_u = 0.3480 \text{ m}^3/\text{sec} (\text{pressurizing to } +10 \text{ Pa})$$

- (3) Correct the door fan airflow for the temperature difference between the inside and outside enclosure temperatures (*per B.2.6.3.3*). This correction is not necessary if the temperature difference is less than 10°C (18°F) and is not needed for these sample calculations; however, it is included herein for demonstrative purposes. Using Equation B.2.6.3.5, this correction is as follows:

- (a) For depressurization,

[B.2.7.3.4.1c]

$$Q_c = 0.2046 \left( \frac{20 + 273}{18 + 273} \right)^{0.5} = 0.2053 \text{ m}^3/\text{sec}$$

- (b) For pressurization,

[B.2.7.3.4.1d]

$$Q_c = 0.3480 \left( \frac{18 + 273}{20 + 273} \right)^{0.5} = 0.3468 \text{ m}^3/\text{sec}$$

- (4) Calculate the leakage area ( $A$ ) from the door fan measurements (*per B.2.6.3.5*). Using Equation B.2.6.3.5, the calculations are as follows:

- (a) For depressurization,

[B.2.7.3.4.1e]

$$\begin{aligned} A &= \frac{(1.271)(0.2053)}{\left| \frac{-12}{\sqrt{-12}} - \frac{-1}{\sqrt{-1}} \right|} \\ &= \frac{(1.271)(0.2053)}{|\sqrt{12} - 1|} = 0.1059 \text{ m}^2 \end{aligned}$$

(b) For pressurization,

[B.2.7.3.4.2f]

[B.2.7.3.4.1f]

$$A = \frac{(1.271)(0.3468)}{\left| \frac{10}{\sqrt{10}} - \frac{-1}{\sqrt{-1}} \right|} = \frac{(1.271)(0.3468)}{|\sqrt{10} + 1|} = 0.1059 \text{ m}^2$$

(c) The average is as follows:

[B.2.7.3.4.1g]

$$A = \frac{0.1059 + 0.1059}{2} = 0.1059$$

$$ELA = A = 0.1059 \text{ m}^2$$

#### B.2.7.3.4.2 Retention Calculation.

- (1) Calculate the total leakage area ( $A_T$ ) using Equation B.2.7.1.1b (*per B.2.7.1.1*) as follows:

[B.2.7.3.4.2a]

$$A_T = (0.61)(0.1059) = 0.0646 \text{ m}^2$$

- (2) Calculate the lower leak area ( $A_{LL}$ ) using Equation B.2.7.1.2a (*per B.2.7.1.2*) as follows:

[B.2.7.3.4.2b]

$$A_{LL} = \frac{0.0646}{2} = 0.0323 \text{ m}^2$$

- (3) Calculate the leak fraction ( $F_A$ ) using Equation B.2.7.1.3 (*per B.2.7.1.3*) as follows:

[B.2.7.3.4.2c]

$$F_A = \frac{(0.0323)}{(0.0646)} = 0.5$$

- (4) Calculate the constants for equation simplification ( $C_3$  and  $C_4$ ) using Equations B.2.7.1.7a and B.2.7.1.7b (*per B.2.7.1.7*). Since the value for ( $P_{SH}$ ) is negative, it is set equal to zero (*per B.2.7.1.5*). The calculations are as follows:

[B.2.7.3.4.2d]

$$C_3 = \frac{(2)(9.81)(1.507 - 1.202)}{1.507 + 1.202 \left[ \frac{0.5}{1 - 0.5} \right]^2} = 2.2090$$

[B.2.7.3.4.2e]

$$C_4 = \frac{2(0)}{1.507} = 0$$

- (5) Calculate the minimum time ( $t$ ) that the enclosure is expected to maintain the descending interface using Equation B.2.7.1.7c (*per B.2.7.1.7*) as follows:

$$t = 2(56.7) \frac{\sqrt{(2.2090)(2.7) + 0} - \sqrt{(2.2090)(2) + 0}}{(2.2090)(0.5)(0.0646)}$$

$$= 113.4 \left( \frac{0.3403}{0.0713} \right)$$

$$= 540 \text{ sec} = 9 \text{ min}$$

#### B.2.7.3.5 Suspended Ceiling Leakage Neutralization Method (Optional).

**B.2.7.3.5.1 Leakage Area Calculation.** The following methodology should be used for the leakage area calculation:

- (1) Determine the equivalent leakage area ( $ELA$ ) for the total enclosure as described previously in B.2.7.3.4.1. The result is as follows:

[B.2.7.3.5.1a]

$$ELA = 0.1059 \text{ m}^2$$

- (2) Depressurize the enclosure below the ceiling with the door fan into the -11 Pa to -14 Pa range. Measure the airflow required and the pressure created (*per B.2.6.2.5, B.2.6.2.6, and B.2.6.2.7*) as follows:

[B.2.7.3.5.1b]

$$Q_u = 0.0512 \text{ m}^3/\text{sec} \text{ (depressurizing to -12 Pa)}$$

- (3) Pressurize the enclosure below the ceiling with the door fan into the +9 Pa to +12 Pa range. Measure the airflow required and the pressure created (*per B.2.6.2.8*) as follows:

[B.2.7.3.5.1c]

$$Q_u = 0.0871 \text{ m}^3/\text{sec} \text{ (pressurizing to +10 Pa)}$$

- (4) Correct the door fan airflow for the temperature difference between the inside and outside enclosure temperatures (*per B.2.6.3.3*). This correction is not necessary if the temperature difference is less than 10°C (18°F) and is not needed for these sample calculations; however, it is included herein for demonstrative purposes. Using Equation B.2.6.3.3, this correction is as follows:

- (a) For depressurization,

[B.2.7.3.5.1d]

$$Q_c = 0.0512 \left[ \frac{20 + 273}{18 + 273} \right]^{0.5} = 0.0514 \text{ m}^3/\text{sec}$$

- (b) For pressurization,

[B.2.7.3.5.1e]

$$Q_c = 0.0871 \left[ \frac{18 + 273}{20 + 273} \right]^{0.5} = 0.0868 \text{ m}^3/\text{sec}$$

- (5) Calculate the leakage area ( $A$ ) from the door fan measurements (*per B.2.6.3.5*). Using Equation B.2.6.3.5, the calculations are as follows:

- (a) For depressurization,

[B.2.7.3.5.1f]

$$A = \frac{(1.271)(0.0514)}{\left| \frac{-12}{\sqrt{|-12|}} - \frac{-1}{\sqrt{|-1|}} \right|} = \frac{(1.271)(0.0514)}{|\sqrt{12} - 1|} = 0.0265 \text{ m}^2$$

(b) For pressurization,

[B.2.7.3.5.1g]

$$A = \frac{(1.271)(0.0868)}{\left| \frac{-10}{\sqrt{|10|}} - \frac{-1}{\sqrt{|-1|}} \right|} = \frac{(1.271)(0.0868)}{|\sqrt{10} + 1|} = 0.0265 \text{ m}^2$$

(c) The average is as follows:

[B.2.7.3.5.1h]

$$A = \frac{0.0265 + 0.0265}{2} = 0.0265 \text{ m}^2$$

$$BCLA = A = 0.0265 \text{ m}^2$$

**B.2.7.3.5.2 Retention Calculation.** Use the following for the retention calculation:

- (1) Calculate the total leakage area ( $A_T$ ) using Equation B.2.7.1.1b (*per B.2.7.1.1*) as follows:

[B.2.7.3.5.2a]

$$A_T = (0.61)(0.1059) = 0.0646 \text{ m}^2$$

- (2) Calculate the lower leakage area ( $A_{LL}$ ) using Equation B.3.7.1.2b (*per B.2.7.1.2*) as follows:

[B.2.7.3.5.2b]

$$A_{LL} = (0.61)(0.0265) = 0.0161 \text{ m}^2$$

- (3) Calculate the leak fraction ( $F_A$ ) using Equation B.2.7.1.3 (*per B.2.7.1.3*) as follows:

[B.2.7.3.5.2c]

$$F_A = \frac{(0.0161)}{(0.0646)} = 0.2492$$

- (4) Calculate the constants for equation simplification ( $C_3$  and  $C_4$ ) using Equations B.2.7.1.7a and B.2.7.1.7b (*per B.2.7.1.7*). Since the value for ( $P_{SH}$ ) is negative, it is set equal to zero (*per B.2.7.1.5*). The calculations are as follows:

[B.2.7.3.5.2d]

$$C_3 = \frac{(2)(9.81)(1.507 - 1.202)}{1.507 + 1.202 \left[ \frac{0.2492}{1 - 0.2492} \right]^2}$$

[B.2.7.3.5.2e]

$$C_4 = \frac{2(0)}{1.507} = 0$$

- (5) Calculate the minimum time ( $t$ ) that the enclosure is expected to maintain the descending interface using Equation B.2.7.1.7c (*per B.2.7.1.7*) as follows:

[B.2.7.3.5.2f]

$$t = 2(56.7) \frac{\sqrt{(3.6502)(2.7) + 0} - \sqrt{(3.6502)(2) + 0}}{(3.6502)(0.2492)(0.0646)}$$

$$= 113.4 \frac{0.4374}{0.0588}$$

$$= 840 \text{ sec} = 14 \text{ min}$$

**B.2.7.3.6 Sample Calculation Results.** The minimum time ( $t$ ) that the enclosure is expected to maintain the descending interface above height ( $H$ ) is 9 minutes using the Total Enclosure Leakage Method and 14 minutes using the optional Suspended Ceiling Leakage Neutralization Method. Both of these predictions are conservative, and the actual time is expected to be greater than these values. Because the optional Suspended Ceiling Leakage Neutralization Method is more accurate, its results are closer to what will actually occur.

## B.2.8 Leakage Control.

### B.2.8.1 Leakage Identification.

**B.2.8.1.1** While the enclosure envelope is being pressurized or depressurized, a smoke pencil or other smoke source should be used to locate and identify leaks. The smoke source should not be produced by an open flame or any other source that is a potential source of fire ignition. Chemical smoke should be used only in small quantities, and consideration should be given to the corrosive nature of certain chemical smokes and their effects on the facility being tested.

**B.2.8.1.2** Leakage identification should focus on obvious points of leakage including wall joints, penetrations of all kinds, HVAC ductwork, doors, and windows.

**B.2.8.1.3** Alternate methods for leakage identification are available and should be considered. One method is the use of a directional acoustic sensor that can be selectively aimed at different sound sources. Highly sensitive acoustic sensors are available that can detect air as it flows through an opening. Openings can be effectively detected by placing an acoustic source on the other side of the barrier and searching for acoustic transmission independent of fan pressurization or depressurization. Another alternative is to use an infrared scanning device if temperature differences across the boundary are sufficient.

### B.2.8.2 Leakage Alteration.

#### B.2.8.2.1 Procedure.

**B.2.8.2.1.1** Protected areas should be enclosed with wall partitions that extend from the floor slab to ceiling slab or floor slab to roof.

**B.2.8.2.1.2** If a raised floor continues out of the halon-protected area into adjoining rooms, partitions should be installed under the floor directly under above-floor border partitions. These partitions should be caulked top and bottom. If the adjoining rooms share the same under-floor air handlers, then the partitions should have dampers installed in the same manner as required for ductwork.

**B.2.8.2.1.3** Any holes, cracks, or penetrations leading into or out of the protected area should be sealed. This includes pipe chases and wire troughs. All walls should be caulked around the inside perimeter of the room where the walls rest on the floor slab and where the walls intersect with the ceiling slab or roof above.

**B.2.8.2.1.4** Porous block walls should be sealed slab-to-slab to prevent gas from passing through the block. Multiple coats of paint could be required.

**B.2.8.2.1.5** All doors should have door sweeps or drop seals on the bottoms, weather stripping around the jambs, latching mechanisms, and door-closer hardware. In addition, double doors should have a weather-stripped astragal to prevent leakage between doors and a coordinator to ensure proper sequence of closure.

**B.2.8.2.1.6** Windows should have solid weather stripping around all joints.

**B.2.8.2.1.7** All unused and out-of-service ductwork leading into or from a protected area should be permanently sealed off (airtight) with metal plates caulked and screwed in place. Ductwork still in service with the building air-handling unit should have butterfly blade-type dampers installed with neoprene seals. Dampers should be spring-loaded or motor-operated to provide 100 percent air shutoff. Alterations to air-conditioning, heating, ventilating ductwork, and related equipment should be in accordance with NFPA 90A or NFPA 90B, as applicable.

**B.2.8.2.1.8** All floor drains should have traps, and the traps should be designed to have water or other compatible liquid in them at all times.

#### **B.2.8.2.2 Materials.**

**B.2.8.2.2.1** All materials used in altering leaks on enclosure envelope boundaries, including walls, floors, partitions, finish, acoustical treatment, raised floors, suspended ceilings, and other construction, should have a flame-spread rating that is compatible with the flame-spread requirements of the enclosure.

**B.2.8.2.2.2** Exposed cellular plastics should not be used for altering leakage unless considered acceptable by the authority having jurisdiction.

**B.2.8.2.2.3** Cable openings or other penetrations into the enclosure envelope should be firestopped with material that is compatible with the fire rating of the barrier.

#### **B.2.9 Test Report.**

**B.2.9.1** Upon completion of a door fan test, a written test report should be prepared for the authority having jurisdiction and made part of the permanent record. The test report should include the following:

- (1) Date, time, and location of test
- (2) Names of witnesses to the test
- (3) Room dimensions and volume

- (4) All data generated during test, including computer print-outs
- (5) Descriptions of any special techniques utilized by the test technician (i.e., use of optional ceiling neutralization and temporary sealing of suspended ceiling)
- (6) In the case of technical judgment, a full explanation and documentation of the judgment
- (7) Test equipment make, model, and serial number
- (8) Copy of current calibration certificate of test equipment
- (9) Name and affiliation of testing technician, and signature

### **Annex C Halogenated Extinguishing Agents**

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

**C.1 Introduction.** A halogenated compound is one that contains one or more atoms of an element from the halogen series, which includes fluorine, chlorine, bromine, and iodine. When hydrogen atoms in a hydrocarbon compound, such as methane ( $\text{CH}_4$ ) or ethane ( $\text{CH}_3\text{CH}_3$ ), are replaced with halogen atoms, the chemical and physical properties of the resulting compound are markedly changed. Methane, for example, is a light, flammable gas. Carbon tetrafluoride ( $\text{CF}_4$ ), also a gas, is chemically inert, nonflammable, and extremely low in toxicity. Carbon tetrachloride ( $\text{CCl}_4$ ) is a volatile liquid that not only is nonflammable, but also was widely used for many years as a fire extinguishing agent in spite of its rather high toxicity. Carbon tetrabromide ( $\text{CBr}_4$ ) and carbon tetraiodide ( $\text{CI}_4$ ) are solids that decompose easily under heat. Generally, the presence of fluorine in the compound increases its inertness and stability; the presence of other halogens, particularly bromine, increases the fire extinguishing effectiveness of the compound. Although a very large number of halogenated compounds exist, only the following five have been used to a significant extent as fire extinguishing agents:

- (1) Halon 1011, bromochloromethane,  $\text{CH}_2\text{BrCl}$
- (2) Halon 1211, bromochlorodifluoromethane,  $\text{CBrClF}_2$
- (3) Halon 1202, dibromodifluoromethane,  $\text{CBr}_2\text{F}_2$
- (4) Halon 1301, bromotrifluoromethane,  $\text{CBrF}_3$
- (5) Halon 2402, dibromotetrafluoroethane,  $\text{CBrF}_2\text{CBrF}_2$

**C.2 Halon Nomenclature System.** The halon system for naming halogenated hydrocarbons was devised by the US Army Corps of Engineers to provide a convenient and quick means of reference to candidate fire extinguishing agents. The first digit in the number represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; and the fifth digit, the number of iodine atoms. Terminal zeros are dropped. Valence requirements not accounted for are assumed to be hydrogen atoms (number of hydrogen atoms = first digit times 2, plus 2, minus the sum of the remaining digits).

**C.2.1 Halon 1301.** Halon 1301 chemically is bromotrifluoromethane,  $\text{CBrF}_3$ . Its cumbersome chemical name is often shortened to “bromotri” or even further to “BT.” The compound is used as a low-temperature refrigerant and as a cryogenic fluid, as well as a fire extinguishing agent.

**C.2.1.1 Physical Properties.** A list of important physical properties of Halon 1301 is given in Table C.2.1.1. Under normal conditions, Halon 1301 is a colorless, odorless gas with a density approximately five times that of air. It can be liquefied

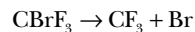
upon compression for convenient shipping and storage. Unlike carbon dioxide, Halon 1301 cannot be solidified at temperatures above  $-270^{\circ}\text{F}$  ( $-167.8^{\circ}\text{C}$ ).

The variation of vapor pressure with temperature for Halon 1301 is shown in Figure C.2.1.1(a) and Figure C.2.1.1(b) (Metric). As the temperature is increased, the vapor pressure and vapor density increase and the liquid density decreases, until the critical temperature of  $152.6^{\circ}\text{F}$  ( $67^{\circ}\text{C}$ ) is reached. At this point, the densities of the liquid and vapor phases become equal and the liquid phase ceases to exist. Above the critical temperature, the material behaves as a gas, but it can no longer be liquefied at any pressure.

**C.2.1.2 Fire Extinguishment Characteristics.** Halon 1301 is an effective fire extinguishing agent that can be used on many types of fires. It is effective in extinguishing surface fires, such as flammable liquids, and on most solid combustible materials except for a few active metals and metal hydrides and materials that contain their own oxidizer, such as cellulose nitrate and gunpowder.

**C.2.1.3 Extinguishing Mechanism.** The mechanism by which Halon 1301 extinguishes fires is not thoroughly known; neither is the combustion process of the fire itself. It appears, however, to be a physicochemical inhibition of the combustion reaction. Halon 1301 has also been referred to as a “chain breaking” agent, meaning that it acts to break the chain reaction of the combustion process. Halon 1301 dissociates in the flame into two radicals:

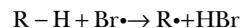
[C.2.1.3a]



Two inhibiting mechanisms have been proposed, one that is based on a free radical process, and another based on ionic activation of oxygen during combustion.

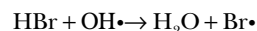
The “free radical” theory supposes that the bromide radical reacts with the fuel to give hydrogen bromide,

[C.2.1.3b]



which then reacts with active hydroxyl radicals in the reaction zone:

[C.2.1.3c]



The bromide radical again reacts with more fuel, and so on, with the result that active  $\text{H}\cdot$ ,  $\text{OH}\cdot$ , and  $\text{O}\cdot$  radicals are removed, and less reactive alkyl radicals are produced.

The “ionic” theory supposes that the uninhibited combustion process includes a step in which  $\text{O}_2$ -ions are formed by the capture of electrons that come from ionization of hydrocarbon molecules. Since bromine atoms have a much higher cross section for the capture of slow electrons than  $\text{O}_2$ , the bromine inhibits the reaction by removing the electrons that are needed for activation of the oxygen.

Portable Halon 1301 extinguishers are covered in NFPA 10.

**Table C.2.1.1 Physical Properties of Halon 1301**

| Physical Properties                                                                                    | US Customary                                                     | SI                                             |
|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------|
| Molecular weight                                                                                       | 148.93                                                           | 148.93                                         |
| Boiling point at 1 atm                                                                                 | $-71.95^{\circ}\text{F}$                                         | $-57.75^{\circ}\text{C}$                       |
| Freezing point                                                                                         | $-270^{\circ}\text{F}$                                           | $-168^{\circ}\text{C}$                         |
| Critical temperature                                                                                   | $152.6^{\circ}\text{F}$                                          | $67.0^{\circ}\text{C}$                         |
| Critical pressure                                                                                      | 575 psia                                                         | 39.6 bar                                       |
| Critical volume                                                                                        | $0.0215 \text{ ft}^3/\text{lb}$                                  | $0.000276 \text{ m}^3/\text{kg}$               |
| Critical density                                                                                       | $46.5 \text{ lb}/\text{ft}^3$                                    | $745 \text{ kg}/\text{m}^3$                    |
| Specific heat, liquid, at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                                | $0.208 \text{ Btu}/\text{lb}\cdot^{\circ}\text{F}$               | $870 \text{ J}/\text{kg}\cdot^{\circ}\text{C}$ |
| Specific heat, vapor, at constant pressure (1 atm) and $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )   | $0.112 \text{ Btu}/\text{lb}\cdot^{\circ}\text{F}$               | $469 \text{ J}/\text{kg}\cdot^{\circ}\text{C}$ |
| Heat of vaporization at boiling point                                                                  | $51.08 \text{ Btu}/\text{lb}$                                    | $118.8 \text{ kJ}/\text{kg}$                   |
| Thermal conductivity of liquid at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                        | $0.024 \text{ Btu}/\text{hr}\cdot\text{ft}\cdot^{\circ}\text{F}$ | $0.85 \text{ W}/\text{m}\cdot\text{K}$         |
| Viscosity, liquid, at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                                    | $1.01 \times 10^{-4} \text{ lb}/\text{ft}\cdot\text{sec}$        | $1.59 \times 10^{-4} \text{ Centipoise}$       |
| Viscosity, vapor, at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                                     | $1.08 \times 10^{-5} \text{ lb}/\text{ft}\cdot\text{sec}$        | $1.63 \times 10^{-5} \text{ Centipoise}$       |
| Surface tension at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                                       | $4 \text{ dynes}/\text{cm}$                                      | $0.004 \text{ N}/\text{m}$                     |
| Refractive index of liquid at $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )                            | 1.238                                                            | 1.238                                          |
| Relative dielectric strength at 1 atm, $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ ) (nitrogen = 1.00) | 1.83                                                             | 1.83                                           |
| Solubility of Halon 1301 in water at 1 atm $77^{\circ}\text{F}$ ( $25^{\circ}\text{C}$ )               | 0.03% by weight                                                  | 0.03% by weight                                |
| Solubility of water in Halon 1301 at $70^{\circ}\text{F}$ ( $21^{\circ}\text{C}$ )                     | 0.0095% by weight                                                | 0.0095% by weight                              |

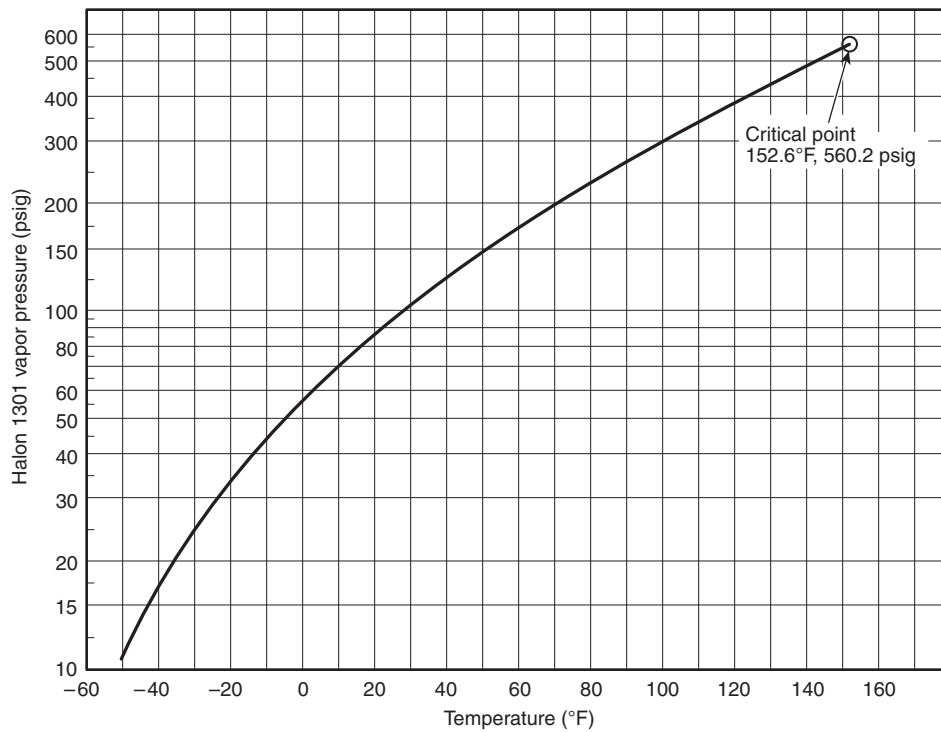


FIGURE C.2.1.1(a) Vapor Pressure of Halon 1301 vs. Temperature.

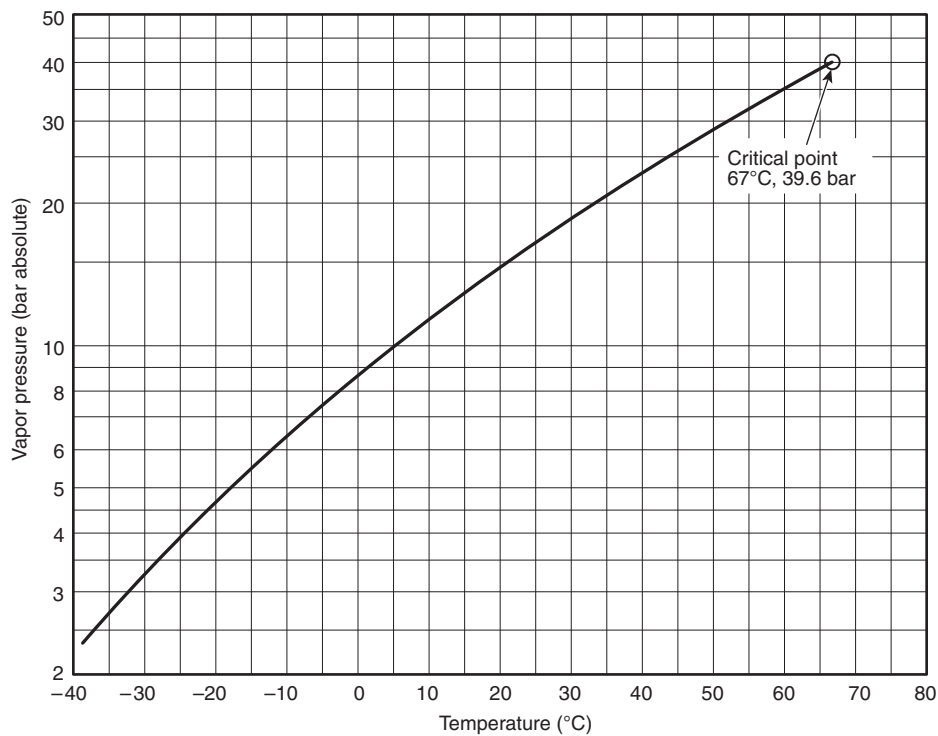


FIGURE C.2.1.1(b) Vapor Pressure of Halon 1301 vs. Temperature (Metric).

## Annex D Hazards to Personnel

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

**D.1 Hazards to Personnel.** The discharge of Halon 1301 to extinguish a fire can create a hazard to personnel from the natural Halon 1301 itself and from the products of decomposition that result from exposure of the agent to the fire or other hot surfaces. Exposure to the natural agent is generally of less concern than is exposure to the decomposition products. However, unnecessary exposure of personnel to either the natural agent or to the decomposition products should be avoided.

Other potential hazards to be considered for individual systems are as follows:

- (1) **Noise.** Discharge of a system can cause noise loud enough to be startling but ordinarily insufficient to cause traumatic injury.
- (2) **Turbulence.** High-velocity discharge from nozzles can be sufficient to dislodge substantial objects or injure people directly in the path. System discharge can also cause enough general turbulence in the enclosures to move unsecured paper and light objects.
- (3) **Cold Temperature.** Direct contact with the vaporizing liquid being discharged from a Halon 1301 system has a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vaporizes rapidly when mixed with air and thus limits the hazard to the immediate vicinity of the discharge point. In humid atmospheres, minor reduction in visibility can occur for a brief period due to the condensation of water vapor.

**D.2 Natural or Undecomposed Halon 1301.** When Halon 1301 is used in systems designed and installed according to this NFPA standard, risk to exposed individuals is minimal. Its toxicity is very low in both animals and humans. The main physiologic actions of Halon 1301 at high inhaled levels are central nervous system (CNS) depression and cardiovascular effects.

**D.2.1 Animals.** Halon 1301 has a 15-minute approximate lethal concentration (ALC) of 83 percent (O<sub>2</sub> added) (Paulet, 1962), suggesting a very low degree of acute inhalation toxicity. In monkeys and dogs, mild CNS effects occur after a few minutes of exposure above 10 percent, progressing to lethargy in monkeys and tremors and convulsion in dogs at levels above 20 percent (Van Stee et al., 1969).

Spontaneous effects on blood pressure and cardiac rhythm occur at much higher levels, approximately 20 percent and 40 percent, respectively (Van Stee et al., 1969).

It has also been known since the early 1900s that the inhalation of many halocarbons and hydrocarbons, like carbon tetrachloride and hexane, can make the heart abnormally sensitive to elevated adrenalin levels, resulting in cardiac arrhythmia and possibly death. This phenomenon has been referred to as cardiac sensitization. Halon 1301 can also sensitize the heart, but only at high inhaled levels. For example, in standard cardiac sensitization screening studies in dogs using 5-minute exposures and large doses of injected adrenalin, the threshold for sensitization is in the 7.5 to 10 percent range (Clark, 1970).

In other studies on dogs, a certain critical blood level was associated with inspired levels needed to sensitize the heart. With exposure to Halon 1301, a relatively insoluble fluorocarbon, blood concentrations rise rapidly, equilibrate within 5 to

10 minutes, and fall rapidly upon cessation of exposure. There is no accumulation of Halon 1301 as indicated by similar blood concentration at 5 to 10 minutes and at 60 minutes of exposure. When dogs exposed to Halon 1301 for 60 minutes are given a large dose of adrenalin, the threshold for cardiac sensitization remains the same as for 5-minute exposures — 7.5 to 10 percent. In addition, studies have shown that sensitization is only a temporary effect, since adrenalin injections given 10 minutes after exposure to known sensitizing levels have not resulted in arrhythmias (Trochimowicz et al., 1974).

All percentage levels in this section refer to volumetric concentrations of Halon 1301 in air.

Using the standard cardiac sensitization test protocol and large doses of adrenalin, dogs with experimentally induced myocardial infarction were tested to determine whether this type of heart condition might significantly lower the threshold for cardiac sensitization (Trochimowicz et al., 1978). Results on Halon 1301 showed no greater potential for cardiac sensitization among dogs having recovered from myocardial infarction than for normal, healthy animals.

Halon 1301 has also been tested for mutagenic and teratogenic effects. In a standard 48-hour Ames Test at levels of 40 percent, no evidence of mutagenicity was seen in *Salmonella typhimurium* bacteria with or without metabolic activation. Pregnant rats exposed to Halon 1301 at levels as high as 5 percent exhibited no embryotoxic or teratogenic effects.

The preceding animal studies show that Halon 1301 is very low in toxicity. Although high inhaled levels can affect the CNS and cardiovascular system, such effects are rapidly and completely reversible upon removal from exposure if the exposure conditions were not severe enough to produce death.

**D.2.2 Humans.** The very low toxicity of Halon 1301 in animal studies has been confirmed by over 20 years of safe manufacture and use. There has never been a death or any permanent injury associated with exposure to Halon 1301.

Exposure to Halon 1301 in the 5 to 7 percent range produces little, if any, noticeable effect. At levels between 7 and 10 percent, mild CNS effects such as dizziness and tingling in the extremities have been reported. Above 10 percent, some subjects report a feeling of impending unconsciousness after a few minutes, although test subjects exposed up to 14 percent for 5 minutes have not actually lost consciousness (Clark, 1970). These types of CNS effects were completely reversible upon removal from exposure.

In many experimental studies on humans, no subject has ever had a serious arrhythmia at Halon 1301 levels below 10 percent. One arrhythmia has been observed at a 14 percent level after a few minutes of exposure, but the subject reverted to a normal rhythm upon removal to fresh air (Hine Laboratories, 1968). In studies at the Medical College of Wisconsin (Stewart et al., 1978), exposure to Halon 1301 up to 7.1 percent for 30 minutes did not produce sufficient adverse effects to harm, confuse, or debilitate human subjects or prevent them from performing simple mechanical tasks, following instructions, or exiting from the Halon 1301 exposure area. In addition, these subjects experienced no significant EKG or EEG abnormalities during or after exposure.

It is considered good practice to avoid all unnecessary exposure to Halon 1301 and to limit exposures to the following times:

- (1) 7 percent and below — 15 minutes
- (2) 7 to 10 percent — 1 minute
- (3) 10 to 15 percent — 30 seconds
- (4) Above 15 percent — prevent exposure

Anyone suffering from the toxic effects of Halon 1301 vapors should immediately move or be moved to fresh air. In treating persons suffering toxic effects due to exposure to this agent, the use of epinephrine (adrenaline) and similar drugs must be avoided because they can produce cardiac arrhythmias, including ventricular fibrillation.

Halon 1301 is colorless and odorless. Discharge of the agent can create a light mist in the vicinity of the discharge nozzle, resulting from condensation of moisture in the air, but the mist rarely persists after discharge is completed. Thus, little hazard is created from the standpoint of reduced visibility. Once discharged into an enclosure, it is difficult to detect its presence through normal human senses; in concentrations above approximately 3 percent, voice characteristics are changed due to the increased density of the agent/air mixture.

In total flooding systems, the high density of Halon 1301 vapor (five times that of air) requires the use of discharge nozzles that will achieve a well-mixed atmosphere to avoid local pockets of higher concentration. Once mixed into the air, the agent will not settle out.

**D.3 Decomposition Products of Halon 1301.** Although Halon 1301 vapor has a low toxicity, its decomposition products can be hazardous. The most accepted theory is that the vapor must decompose before Halon 1301 can inhibit the combustion reactions (*see 1.4.1*). The decomposition takes place on exposure to a flame or to a hot surface at above approximately 900°F (482°C). In the presence of available hydrogen (from water vapor or the combustion process itself), the main decomposition products are the halogen acids (HF, HBr) and free halogens (Br<sub>2</sub>) with small amounts of carbonyl halides (COF<sub>2</sub>, COBr<sub>2</sub>).

The decomposition products of Halon 1301 have a characteristic 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 the fire.

The amount of Halon 1301 that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the concentration of Halon vapor, and the length of time that the agent is in contact with flame or heated surfaces above 900°F (482°C). If there is a very rapid buildup of concentration to the critical value, the fire will be extinguished quickly, and there will be little decomposition. The actual concentration of the decomposition products must then depend on the volume of the room in which the fire was burning and on the degree of mixing and ventilation. For example, extinguishment of a 25 ft<sup>2</sup> (2.3 m<sup>2</sup>) heptane fire in a 10,000 ft<sup>3</sup> (283 m<sup>3</sup>) enclosure within 0.5 second produced only 12 ppm HF. A similar test having an extinguishment time of 10 seconds produced an average HF level of 250 ppm over a 9-minute period.

Clearly, longer exposure of the vapor to temperatures in excess of 900°F (482°C) 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 vapors to the elevated temperature if the concentration of 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.

## Annex E Storage Containers

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

**E.1 Storage Containers.** Storage containers for Halon 1301 must be capable of withstanding the total pressure exerted by the Halon 1301 vapor plus the nitrogen partial pressure, at the maximum temperature contemplated in use. Generally, steel cylinders meeting US Department of Transportation requirements will be used. Manifolder cylinders are used for large installations.

Each container must be equipped with a discharge valve capable of discharging liquid Halon 1301 at the required rate. Containers with top-mounted valves require an internal dip tube extending to the bottom of the cylinder to permit discharge of liquid phase Halon 1301.

**E.1.1 Nitrogen Superpressurization.** Although the 199 psig (1372 kPa) vapor pressure of Halon 1301 at 70°F (21°C) is adequate to expel the contents of the storage containers, this pressure decreases rapidly with temperature. At 0°F (−18°C), for example, the vapor pressure is 56.6 psig (390 kPa), and at −40°F (−40°C) it is only 17.2 psig (119 kPa). The addition of nitrogen to Halon 1301 storage containers to pressurize the agent above the vapor pressure, called “superpressurizing,” will prevent the container pressure from decreasing so drastically at low temperatures.

Superpressurization causes some of the nitrogen to permeate the liquid portion of the Halon 1301. This “solubility” is related both to the degree of superpressurization and to temperature, as follows:

[E.1.1]

$$H_x = \frac{P_n}{X_n}$$

where:

$H_x$  = Henry's Law constant, psi (bar) per mole fraction

$P_n$  = partial pressure of nitrogen above solution, psi (bar)

$X_n$  = nitrogen concentration in liquid Halon 1301, mole fraction

Nitrogen partial pressure can be calculated from the total pressure of the system and the vapor pressure of Halon 1301 [*see Figure E.1.1(a) and Figure E.1.1(b)*] as follows:

$$(1) P_n = P - (1 - X_n)P_v$$

$$(2) P = P_n + P_a$$

where:

$P_a$  = partial pressure of agent vapor

$P_v$  = vapor pressure of agent

By ideal solution law

$$(3) P_a = P_v X_a$$

where:

$P_v$  = vapor pressure of agent

$X_a$  = liquid mole fraction of agent

$$(4) X_a = 1 - X_n, \text{ where } X_n \text{ is liquid mole fraction of nitrogen}$$

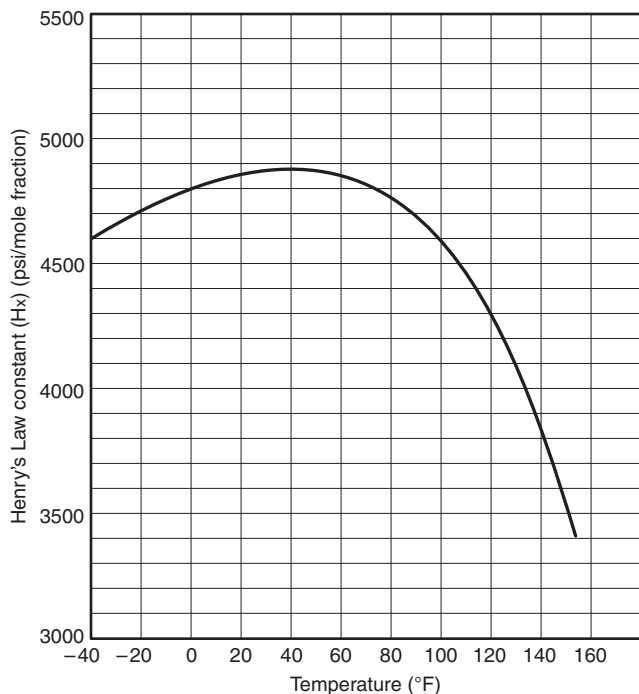
From (2), (3), (4) we get

$$(5) P = P_n + (1 - X_n)P_v, \text{ which is (1)}$$

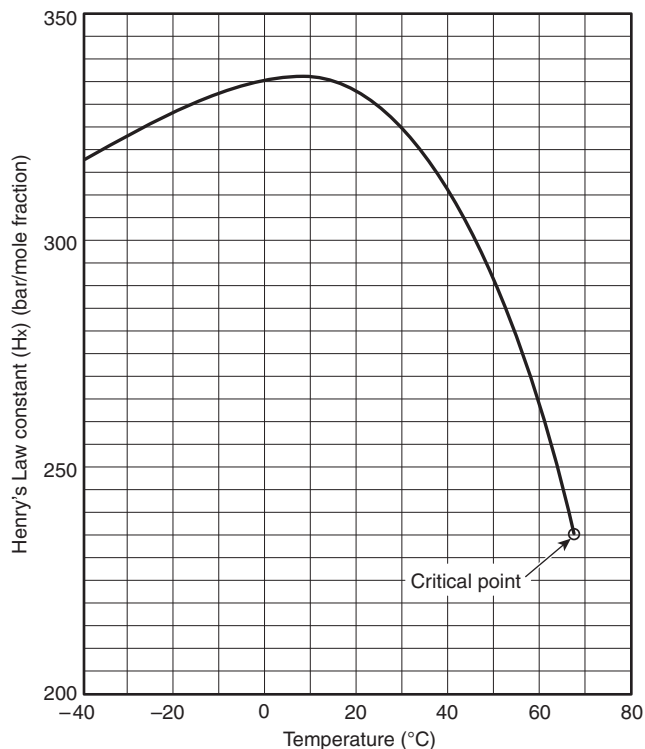
Figure E.1.1(a) and Figure E.1.1(b) (Metric) show that variation of Henry's Law constant,  $H_x$ , with temperature.

Isometric diagrams for Halon 1301 superpressurized with nitrogen, Figure E.1.1(c), Figure E.1.1(d) (Metric) [360 psig (2482 kPa)], and Figure E.1.1(e), Figure E.1.1(f) (Metric) [600 psig (4137 kPa)] show the relationship of storage container pressure vs. temperature with lines of constant fill density.

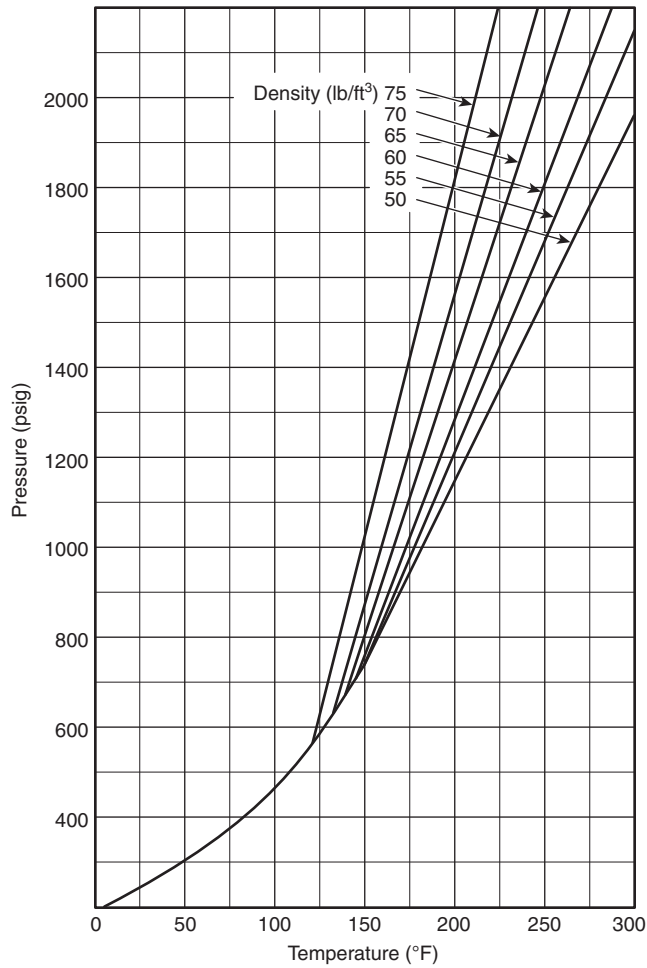
These curves demonstrate the danger in overfilling containers with Halon 1301. A container filled completely with Halon 1301 at 70°F (21°C) and filled to 97.8 lb/ft<sup>3</sup> (1566 kg/m<sup>3</sup>) and subsequently superpressurized to 600 psig (4137 kPa) would develop a pressure of 3000 psig (20685 kPa) when heated to 130°F (54°C); if filled to 70 lb/ft<sup>3</sup> (1121 kg/m<sup>3</sup>) or less as permitted in this standard, a pressure of 1040 psig (7171 kPa) would be developed. The same principles apply to liquid Halon 1301 that becomes trapped between two valves in pipelines. Adequate pressure relief should always be provided in such situations.



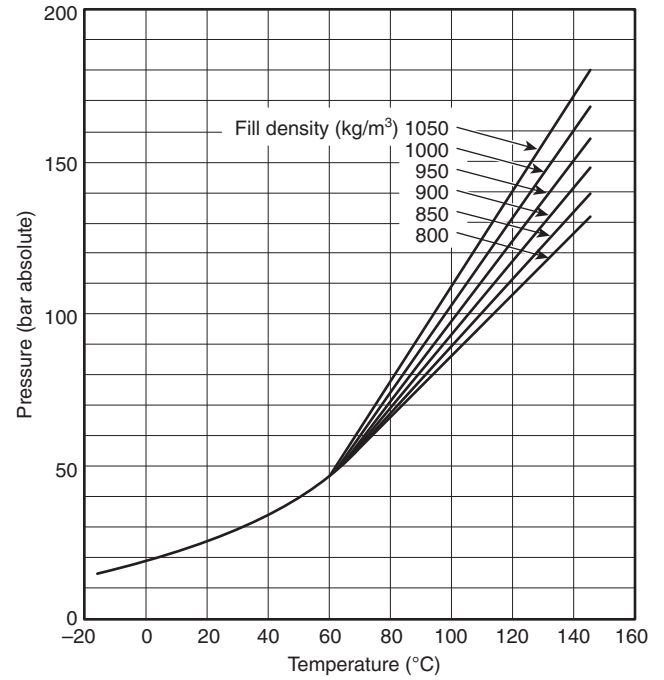
**FIGURE E.1.1(a) Henry's Law Constant for Nitrogen Solubility in Liquid Halon 1301.**



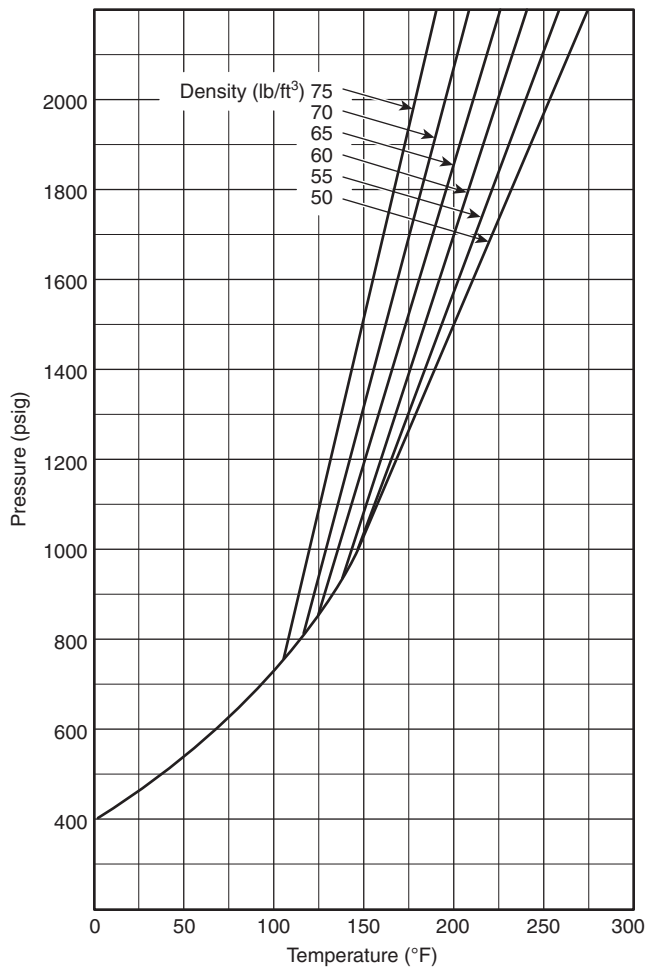
**FIGURE E.1.1(b) Henry's Law Constant for Nitrogen Solubility in Liquid Halon 1301 (Metric).**



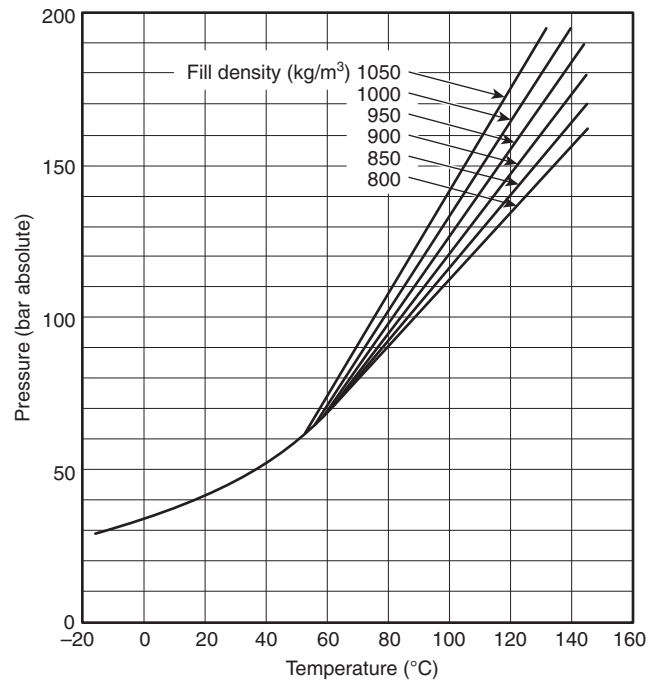
**FIGURE E.1.1(c) Isometric Diagram. Halon 1301 Pressurized to 360 psig at 70°F.**



**FIGURE E.1.1(d) Isometric Diagram. Halon 1301 Pressurized to 2482 kPa at 21°C (Metric).**



**FIGURE E.1.1(e) Isometric Diagram. Halon 1301 Pressurized to 600 psig at 70°F.**



**FIGURE E.1.1(f) Isometric Diagram. Halon 1301 Pressurized to 4137 kPa at 21°C (Metric).**

## Annex F Piping

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

**F.1 Introduction.** The development of the pipe and fittings specifications in this standard is based on field experience and the application of the data and calculation methods found in ASME pipe and fittings codes. Paragraph 4.2.1.1 requires that “the thickness of the pipe wall shall be calculated in accordance with ASME B31.1, *Power Piping Code*.” The text of Annex F is taken from ASME B31.1. The information in Section 4.2, Annex A, and Annex F is based on the equations for calculation of pipe wall thickness found in ASME B31.1. The *SE* values stated in this annex allow calculation of the minimum wall thickness of pipe to be used in Halon 1301 systems. Section F.2 presents calculations to provide minimum pipe schedules (wall thickness) for use with both 360 psi (2482 kPa) and 600 psi (4137 kPa) Halon 1301 fire extinguishing systems in accordance with this standard.

**F.2 Minimum Piping Requirements for Halon 1301 Systems with 360 psi (2482 kPa) and 600 psi (4137 kPa) Charging Pressure.** Limitations on piping to be used for halon systems (or any pressurized fluid) are set by the following:

- (1) Maximum pressure expected within the pipe
- (2) Material of construction of the pipe and tensile strength, yield strength, and temperature limitations of the material
- (3) Joining methods (i.e., threaded, welded, grooved)
- (4) Pipe construction method [i.e., seamless, electric resistance welded (ERW), furnace welded]
- (5) Pipe diameter
- (6) Wall thickness of the pipe

The calculations are based on the following:

- (1) The minimum calculated pressure is 1000 psi (6895 kPa) for systems using an initial charging pressure of 600 psi (4137 kPa) and 620 psi (4275 kPa) for systems using an initial charging pressure of 360 psi (2482 kPa).
- (2) The calculations apply only to steel pipe conforming to ASTM A53/A53M, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, or ASTM A106/A106M, *Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service*, and copper tubing conforming to ASTM B88, *Standard Specification for Seamless Copper Water Tube*.
- (3) The calculations cover threaded, welded, and grooved joints for steel pipe and compression fittings for copper tubing.

The basic equation to find the minimum wall thickness for piping under internal pressure is as follows:

[F.2a]

$$t = \frac{PD}{2SE} + A$$

where:

- $t$  = required wall thickness (in.)
- $P$  = maximum allowable pressure (psi)
- $D$  = outside pipe diameter (in.)
- $A$  = allowance for threading, grooving, etc. (in.)
- $SE$  = maximum allowable stress including joint efficiency (psi)

Note: For these calculations,

$A$  = depth of thread for threaded connections

$A$  = depth of groove for cut groove connections

$A$  = zero for welded or rolled groove connections

$A$  = zero for joints in copper tubing using compression fittings

The term *SE* is defined as  $\frac{1}{4}$  of the tensile strength of the piping material or  $\frac{3}{4}$  of the yield strength (whichever is lower) multiplied by a joint efficiency factor.

Joint efficiency factors are as follows:

- (1) 1.0 for seamless
- (2) 0.85 for ERW
- (3) 0.60 for furnace butt weld (continuous weld) (Class F)

The values for *SE* in Table F.2(a) are taken from Appendix A of ASME B31.1, *Power Piping Code*. Identical values are given in ASME B31.9, *Building Services Piping*.

The basic equation can be rewritten as follows to solve for  $P$  to determine the maximum allowable pressure for which a pipe of thickness  $t$  can be used:

[F.2b]

$$P = 2SE \frac{t - A}{D}$$

As required by 4.2.1.1 of this standard, for systems having a charging pressure of 360 psi (2482 kPa), the calculated pressure ( $P$ ) must be equal to or greater than 620 psi (4275 kPa).

For systems having a charging pressure of 600 psi (4137 kPa), the calculated pressure ( $P$ ) must be equal to or greater than 1000 psi (6895 kPa).

These pressure values are based on a maximum agent storage temperature of 130°F (54°C).

If higher storage temperatures are approved for a given system, the internal pressure should be adjusted to the maximum internal pressure at maximum temperature. In performing this calculation, all joint factors and threading, grooving, or welding allowances should be taken into account.

Paragraph 102.2.4(B) of ASME B31.1, *Power Piping Code*, allows the maximum allowable stress (*SE*) to be exceeded by 20 percent if the duration of the pressure (or temperature) increase is limited to less than 1 percent (14.4 minutes) of any 24-hour period. Since the halon piping is normally unpressurized, the system discharge period typically satisfies this criterion. Therefore, the piping calculations set out in this paragraph are based on values of *SE*, which are 20 percent greater than those shown in Table F.2(a) outlined in Paragraph 4 (per Appendix A of the *Power Piping Code*). The specific values for maximum allowable stress used in these calculations are given in Table F.2(b).

Notes:

- (1) When rolled groove connections or welded connections with internal projections (backup rings, etc.) are used, the hydraulic calculations should consider the additional losses due to friction.

- (2) Pipe supplied as dual stenciled A120/A53 Class F meets the requirements of Class F furnace welded pipe ASTM A53/A53M as listed previously. Ordinary cast-iron pipe, steel pipe conforming to ASTM A120, *Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses*, or nonmetallic pipe should not be used.
- (3) All grooved couplings/fittings should be listed/approved for use with Halon 1301 extinguishing systems.
- (4) These calculations do not apply to extended discharge exceeding 14.4 minutes.
- (5) Compression fittings should be listed or approved for use with the type of tubing and pressures per 4.2.3 of this standard [600 psi (4137 kPa) systems 1000 psi (6895 kPa) working pressure; 360 psi (2482 kPa) systems 620 psi (4275 kPa) working pressure].

**Table F.2(a) SE Values for Pipe and Tubing per ASME B31.1**

| Pipe/Tubing Grade/Type            | Pipe Specification | SE Value (psi) | SE Value (kPa) |
|-----------------------------------|--------------------|----------------|----------------|
| Grade C seamless pipe             | ASTM A106/A106M    | 17,500         | 120,662        |
| Grade B seamless pipe             | ASTM A53/A53M      | 15,000         | 103,425        |
| Grade B seamless pipe             | ASTM A106/A106M    | 15,000         | 103,425        |
| Grade A seamless pipe             | ASTM A53/A53M      | 12,000         | 82,740         |
| Grade A seamless pipe             | ASTM A106/A106M    | 12,000         | 82,740         |
| Grade B ERW pipe                  | ASTM A53/A53M      | 12,800         | 88,256         |
| Grade A ERW pipe                  | ASTM A53/A53M      | 10,200         | 70,329         |
| Class F furnace welded pipe       | ASTM A53/A53M      | 7,200          | 49,608         |
| Seamless copper tubing (annealed) | ASTM B88           | 5,100          | 35,164         |
| Seamless copper tubing (drawn)    | ASTM B88           | 9,000          | 62,055         |

**Table F.2(b) SE Values for Pipe and Tubing That Is Pressurized for Less than 14.4 Minutes per 24-Hour Period**

| Pipe/Tubing Grade/Type            | Pipe Specification | SE Value (psi) | SE Value (kPa) |
|-----------------------------------|--------------------|----------------|----------------|
| Grade C seamless pipe             | ASTM A106/A106M    | 21,000         | 144,795        |
| Grade B seamless pipe             | ASTM A53/A53M      | 18,000         | 124,110        |
| Grade B seamless pipe             | ASTM A106/A106M    | 18,000         | 124,110        |
| Grade A seamless pipe             | ASTM A53/A53M      | 14,400         | 99,288         |
| Grade A seamless pipe             | ASTM A106/A106M    | 14,400         | 99,288         |
| Grade B ERW                       | ASTM A53/A53M      | 15,360         | 105,907        |
| Grade A ERW pipe                  | ASTM A53/A53M      | 12,240         | 84,395         |
| Class F furnace welded pipe       | ASTM A53/A53M      | 8,640          | 59,573         |
| Seamless copper tubing (annealed) | ASTM B88           | 6,120          | 42,197         |
| Seamless copper tubing (drawn)    | ASTM B88           | 10,800         | 74,466         |

### Annex G System Flow Calculations

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

**G.1 Introduction.** The flow of nitrogen-pressurized Halon 1301 has been demonstrated to be a two-phase phenomenon; that is, the fluid in the piping consists of a mixture of liquid and vapor. In past editions of this standard, an effort was made to detail a portion of a complex calculation method that is used to determine pipeline pressures, densities, and other design factors. All the factors necessary for this very complex calculation were not listed. For example, the formulas that address heat transfer between the agent and the piping network were not included nor were the adjustments for the flow of agent through a tee. Many of the necessary final adjustments to the calculations are proprietary. Without this data, and much more, no flow calculation for unbalanced systems can be precise enough.

The tables, graphs, and calculations used in this section are provided to demonstrate the basis on which many calculation methods are founded. This information is not adequate and must not be considered as complete enough for design purposes. Only those calculation methods that are listed should be used for design purposes. Figure G.1 provides a comparison of test data with calculated pressure drop using a two-phase flow equation.

Friction losses occur as the liquid Halon 1301 flows through the pipeline to the discharge orifice. Allowance must be made for the equivalent lengths of the container valve, dip tube, and flexible connectors, selector valves, time delays, and other installed equipment through which the agent must flow. Equiv-

alent lengths for these components must be obtained from the approval laboratory listings for the individual components. Equivalent lengths of common pipe fittings and values are given in Table G.1(a) and Table G.1(b).

Changes in elevation are accounted for by the following equation:

$$\Delta P = \frac{\rho(\Delta EL)}{144} \quad [\text{G.1}]$$

where:

$\Delta P$  = pressure drop (psi)

$\rho$  = pipeline density of agent at point of elevation change (lb/ft<sup>3</sup>)

$\Delta EL$  = net change in elevation within the piping section, increase (+) and decrease (–)

Design flow rates should be high enough to ensure complete mixing of the liquid and vapor phases in the pipeline.

For proper system flow calculation and performance, it is necessary that a homogenous mixture of the liquid and vapor phases be present during equilibrium pipeline flow.

In other words, highly turbulent flow is required in the pipeline to prevent separation of the liquid and vapor phases. Turbulent flow is generally attained when pipeline flow rates exceed the minimum flow rates given in Table G.1(c).

**Table G.1(a) Equivalent Length in Feet of Threaded Pipe Fittings Schedule 40 Steel Pipe**

| Pipe Size (in.) | Elbow Std. 45° | Elbow Std. 90° | Elbow 90° Long Rad. & 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                          |

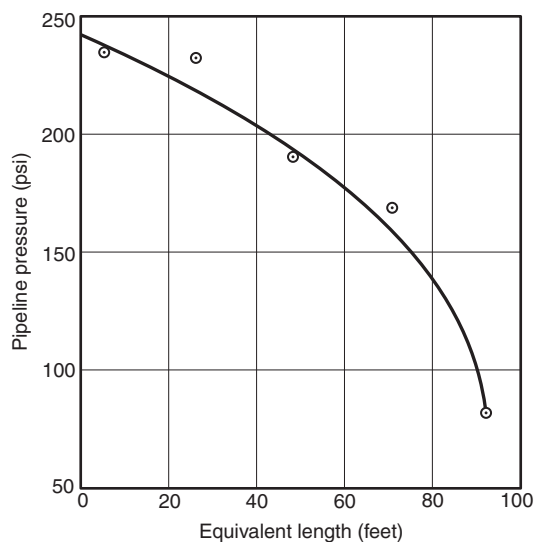
Table G.1(b) Equivalent Length in Feet of Welded Pipe Fittings Schedule 40 Steel Pipe

| Pipe Size (in.) | Elbow Std. 45° | Elbow Std. 90° | Elbow 90° Long Rad. & Tee Thru Flow | Tee Side | Union Coupling or 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               | 1.5            | 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                          |

Table G.1(c) Minimum Design Flow Rates to Achieve Turbulent Pipeline Flow

| Nominal Pipe Diameter (in.) | Schedule 40 Minimum Flow Rate (lb/sec) | Schedule 80 Minimum Flow Rate (lb/sec) |
|-----------------------------|----------------------------------------|----------------------------------------|
| 1/8                         | 0.20                                   | 0.11                                   |
| 1/4                         | 0.34                                   | 0.24                                   |
| 3/8                         | 0.68                                   | 0.48                                   |
| 1/2                         | 1.0                                    | 0.79                                   |
| 3/4                         | 2.0                                    | 1.9                                    |
| 1                           | 3.4                                    | 2.8                                    |
| 1 1/4                       | 5.8                                    | 4.8                                    |
| 1 1/2                       | 8.4                                    | 7.5                                    |
| 2                           | 13                                     | 13                                     |
| 2 1/2                       | 19.5                                   | 17                                     |
| 3                           | 33                                     | 26                                     |
| 4                           | 58                                     | 48                                     |
| 5                           | 95                                     | 81                                     |
| 6                           | 127                                    | 109                                    |

Note: For SI units, 1 lb/sec = 0.454 kg/s.



For SI units: 1 ft = 0.3048 m; 1 psi = 0.0689 bar.

**FIGURE G.1 Comparison of Test Data with Calculated Pressure Drop Using Two-Phase Flow Equation.**

## Annex H Nozzles

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

**H.1 Introduction.** The discharge nozzle is the device that ultimately delivers the agent to the hazard area. Its function is twofold: (1) It distributes the agent in an optimum manner in the hazard, and (2) it controls the system discharge rates. The maximum nozzle flow rate is controlled by the flow that the feed pipe can deliver. The maximum pipeline flow rate can be theoretically calculated by means of the two-phase equation. Figure H.1(a) shows the calculated maximum open-end pipe specific flow rate versus total terminal pressure. The general shape of the curve is also characteristic of nozzle flow curves.

Since the flow rate discharged from a nozzle or pipe depends on the energy available, the terminal pressure must be considered to consist of two parts: (1) the static pressure (the quantity calculated by the pipeline pressure drop), and (2) the velocity head energy.

Both quantities can contribute to the energy available to discharge the agent from the nozzle. The velocity head in psi can be calculated from the following equation:

$$\text{velocity head} = \frac{(3.63)(Q^2)}{\rho D^4}$$

[H.1a]

where:

$Q$  = nozzle rate (lb/sec)

$\rho$  = density (lb/ft<sup>3</sup>) at the terminal static pressure

$D$  = feed pipe diameter (in.)

NOTE: The calculation method described in this standard is based on 70°F (21°C). For unbalanced systems, if the agent

storage temperature is expected to vary by more than 10°F (5.5°C) from this temperature, the actual agent quantity discharged from each nozzle can vary significantly from the calculated agent distribution.

Flow calculations should be based on average pressure conditions existing in the system when half of the agent has been discharged from the nozzles. The average pressure in the storage container is determined on the basis of the pressure recession in the storage container and the effect of percent of agent in the piping during discharge. The calculated pressure recession for both 600 and 360 psi (4137 and 2482 kPa) storage is plotted in Figure H.1(b) and Figure H.1(c), respectively.

The rate of pressure recession in the storage container depends on the initial filling density as illustrated in Figure H.1(b) and Figure H.1(c). If the pipeline has negligible volume compared to the quantity of agent to be discharged, the average container pressure for pressure drop calculations would be the point in the recession curve where 50 percent of the charge has been expelled from the container. In many systems this will not be the case because a substantial portion of the charge will reside in the piping during discharge, reducing the average container pressure during actual discharge from the nozzle.

Figure H.1(d) illustrates the condition where 20 percent of the agent supply by weight resides in the piping during discharge. The average storage pressure for flow calculation for the 600 psi (4137 kPa) system with initial filling density of 70 lb/ft<sup>3</sup> (1121 kg/m<sup>3</sup>) is reduced from a maximum of 403 psi (2779 kPa) to 355 psi (2448 kPa). Proceeding in this way, the average container pressure for flow calculation is a logical function of the percent of agent in the piping as given in Figure H.1(e). Several factors combine to allow a simple extrapolation of the average storage container pressure versus percent of agent in the piping curves up to a calculated 80 percent of the supply in the pipeline.

The percent of agent in piping is defined by the following equation and should not exceed 80 percent of the charged weight:

[H.1b]

$$\text{percent in piping} = 100 \sum \frac{(Vp)(\rho)}{W}$$

where:

$\Sigma$  = summation of  $(Vp)(\rho)$  values for all pipeline sections

$Vp$  = internal volume of each section of piping (ft<sup>3</sup>)

$\rho$  = average pipeline density of agent for each section of piping (lb/ft<sup>3</sup>)

$W$  = initial charge weight of Halon 1301 (lb)

The average density cannot be accurately determined until after the terminal pressure has been calculated. The problem does not have a direct solution; however, Equation H.1c and Table H.1(a) can be used to estimate the percent in piping for calculating purposes. This is based on the probability that the terminal pressure will be near the minimum permitted. Table H.1(b) and Table H.1(c) can be used to calculate the internal volume of the pipe.

$$\text{percent in piping} = \frac{K_1}{(W/V_p) + K_2}$$

where:

$W$  = initial charge weight of Halon 1301 (lb)

$V_p$  = internal pipe volume (ft<sup>3</sup>)

$K_1, K_2$  = constants from Table H.1(a)

An alternative solution is to use Equation H.1(b) with the average density values from Figure H.1(f) for the 600 psi (4137 kPa) systems and from Figure H.1(g) for the 360 psi (2482 kPa) systems.

For piping systems, pressure drop should be calculated by means of the following two-phase equation or by any other method approved by the authority having jurisdiction:

$$Q^2 = \frac{1.013D^{5.25}Y}{L + 8.08D^{1.25}Z}$$

where:

$Q$  = flow rate (lb/sec)

$D$  = inside pipe diameter (in.)

$L$  = equivalent length of pipe (ft)

$Y, Z$  = factors depending on density and pressure

NOTE: This flow equation contains a friction factor based on commercial steel pipe.

The two-phase flow equation becomes specific for Halon 1301 when the  $Y$  and  $Z$  factors are based on the proper pressure and density values using the following equations:

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

$$Z = \ln \frac{P_1}{P}$$

where:

$P_1$  = storage pressure (psia)

$P$  = pipeline pressure (psia)

$\rho_1$  = density at pressure  $P_1$  (lb/ft<sup>3</sup>)

$\rho$  = density at pressure  $P$  (lb/ft<sup>3</sup>)

$\ln$  = natural logarithm

A direct solution of the flow equation for pressure is not possible; however, the equation can be rearranged to solve for  $Y$ , which is related to pressure:

$$Y_2 = Y_1 + \frac{LQ^2}{A} + B(Z_2 - Z_1)Q^2$$

where:

[H.1c]

$Y_1$  =  $Y$  factor at start of section

$Y_2$  =  $Y$  factor at end of section

$Z_1$  =  $Z$  factor at start of section

$Z_2$  =  $Z$  factor at end of section

$A = 1.013 D^{5.25}$

$B = 7.97/D^4$

$L$  = equivalent length of section (ft)

$Q$  = flow rate (lb/sec)

$D$  = inside diameter of pipe (in.)

NOTE:  $A$  and  $B$  factors are for steel pipe.

Precalculated  $A$  and  $B$  factors for steel pipe are given in Table H.1(d).

The  $Y$  and  $Z$  factors depend on both storage pressure and filling density; therefore, separate tables are required for each storage condition. Table H.1(e) through Table H.1(h) are for the 600 psi (4137 kPa) systems with filling densities of 70, 60, 50, and 40 lb/ft<sup>3</sup>. Table H.1(i) through Table H.1(l) are for the 360 psi (2482 kPa) systems with the same filling densities.

**Sample Calculation.** An 80 lb (36 kg) supply of agent is to be discharged in 10 seconds through the piping system shown in Figure H.1(h). The agent storage container is pressurized to 360 psi (2482 kPa) and has a filling density of 70 lb/ft<sup>3</sup> (1121 kg/m<sup>3</sup>). Table H.1(m) shows the two-phase solution.

(1) Calculate  $A$  and  $B$ :

For 1 in. pipe,  $A = 1.302$  and  $B = 6.59$ .

For 3/4 in. pipe,  $A = 0.3666$  and  $B = 17.3$ .

(2) Determine piping volume using Table H.1(b).

For 1 in. pipe,  $V_p = 0.0060 \text{ ft}^3/\text{ft} \times 27 \text{ ft} = 0.162 \text{ ft}^3$

For 3/4 in. pipe,  $V_p = 0.0037 \text{ ft}^3/\text{ft} \times 30 \text{ ft} = 0.111 \text{ ft}^3$

Total  $V_p = 0.273 \text{ ft}^3$

(3) Estimate percent in piping, using the following equation:

$$\% \text{ in piping} = \frac{6730}{(80/0.273) + 52} = 19.5\%$$

(4) Determine average container pressure during discharge using Figure H.1(e), based on the estimated 19.5 percent in piping the average storage container pressure is 243 psi (1675 kPa).

(5) Calculate the elevation correction. Before calculating pressure drop due to friction, the pressure change due to elevation in Section 1-2 of Table H.1(m) must be calculated. The relationship in G.1 is used:

$$\Delta P = \frac{\rho(\Delta EL)}{144}$$

The elevation change ( $EL$ ) is 7 ft. The density ( $\rho$ ) of the Halon 1301 at the 243 psi (1675 kPa) starting pressure of the section is found to be 83 lb/ft<sup>3</sup> in Figure H.1(g) on the 70 lb/ft<sup>3</sup> fill density curve. The pressure loss due to the 7 ft increase in elevation is

[H.1j]

$$P = \frac{83 \times 7}{144} = 4 \text{ psi}$$

The new starting pressure is  $243 - 4 = 239$  psi.

(6) Determine  $Y_1$  and  $Z_1$  from Table H.1(i). For a starting pressure of 239 psi,

[H.1k]

$$Y_1 = 2819 \text{ and } Z_1 = 0.173$$

(7) Determine  $Y_2$  from the following equation:

[H.1l]

$$\begin{aligned} Y_2 &= Y_1 + \left( \frac{LQ^2}{A} \right) + B(Z_2 - Z_1)Q^2 \\ &= 2819 + \frac{58(8)^2}{1.302} + 6.59(Z_2 - 0.173)(8)^2 \end{aligned}$$

The  $Z$  term is small and can be neglected for an initial solution:

[H.1m]

$$Y_2 = 5670$$

(8) Determine terminal pressure. The terminal pressure of Section 1-2 of Table H.1(m) is approximately 200 psi from Table H.1(i). At this point the  $Z$  factor is about 0.475. Using this value for  $Z_2$ , the last term of the equation becomes 127. Then,

[H.1n]

$$Y_2 = 5670 + 127 = 5797$$

The final terminal pressure of Section 1-2 is then between 198 and 197 psi. Use 197 psi.

(9) Sections 2-3 and 2-4. For the next section,

[H.1o]

$$\begin{aligned} Y_2 &= 5797 + \frac{19(4)^2}{0.366} + 17.3(Z_2 - 0.475)(4)^2 \\ &= 6628 \end{aligned}$$

Terminal pressure = 182 psi

[H.1p]

$$\begin{aligned} Z_2 &= 0.652 \\ Y_2 &= 6628 + 17.3(0.652 - 0.475)(4)^2 \\ &= 6628 + 49 = 6677 \end{aligned}$$

Terminal pressure is between 182 and 181 psi. Use 181 psi.

The solution would then be reiterated until reasonable agreement between the estimated percent in the pipe and the final calculated quantity is obtained. Such reiteration is,

however, time consuming and subject to numerical error when manual calculation means are used. For this reason, the two-phase method is normally used with a programmed computer.

In unbalanced systems, it is important to use the proper orifice size at each nozzle to give the desired flow rate at the calculated terminal pressure. This is based on the flow characteristics of individual nozzles as provided in the manufacturer's design manual. In no case should the nozzle pressure be lower than the listed minimum pressure.

**Table H.1(a) Constants to Determine Percent of Agent in Piping**

| Storage<br>(psi) | Filling<br>Density | $K_1$ | $K_2$ |
|------------------|--------------------|-------|-------|
| 600              | 70                 | 7180  | 46    |
| 600              | 60                 | 7250  | 40    |
| 600              | 50                 | 7320  | 34    |
| 600              | 40                 | 7390  | 28    |
| 360              | 70                 | 6730  | 52    |
| 360              | 60                 | 6770  | 46    |
| 360              | 50                 | 6810  | 40    |
| 360              | 40                 | 6850  | 34    |

**Table H.1(b) Internal Volume of Steel Pipe Cubic Feet per Foot of Length**

| Nominal<br>Pipe<br>Diameter | Schedule 40<br>Inside Diameter |                     | Schedule 80<br>Inside Diameter |                     |
|-----------------------------|--------------------------------|---------------------|--------------------------------|---------------------|
| in.                         | in.                            | ft <sup>3</sup> /ft | in.                            | ft <sup>3</sup> /ft |
| 1/4                         | 0.364                          | 0.0007              | 0.302                          | 0.0005              |
| 3/8                         | 0.493                          | 0.0013              | 0.423                          | 0.0010              |
| 1/2                         | 0.622                          | 0.0021              | 0.546                          | 0.0016              |
| 3/4                         | 0.824                          | 0.0037              | 0.742                          | 0.0030              |
| 1                           | 1.049                          | 0.0060              | 0.957                          | 0.0050              |
| 1 1/4                       | 1.380                          | 0.0104              | 1.278                          | 0.0089              |
| 1 1/2                       | 1.610                          | 0.0141              | 1.500                          | 0.0123              |
| 2                           | 2.067                          | 0.0233              | 1.939                          | 0.0205              |
| 2 1/2                       | 2.469                          | 0.0332              | 2.323                          | 0.0294              |
| 3                           | 3.068                          | 0.0513              | 2.900                          | 0.0459              |
| 3 1/2                       | 3.548                          | 0.0687              | 3.364                          | 0.0617              |
| 4                           | 4.026                          | 0.0884              | 3.826                          | 0.0798              |

Table H.1(c) Internal Volume of Copper Tubing

| Size | Type | Actual Inside Diameter (in.) | Internal Volume (ft <sup>3</sup> /ft) |
|------|------|------------------------------|---------------------------------------|
| ¼    | M    | —                            | —                                     |
|      | L    | 0.315                        | 0.0005                                |
|      | K    | 0.305                        | 0.0005                                |
| ⅜    | M    | 0.450                        | 0.0011                                |
|      | L    | 0.430                        | 0.0010                                |
|      | K    | 0.402                        | 0.0009                                |
| ½    | M    | 0.569                        | 0.0018                                |
|      | L    | 0.545                        | 0.0016                                |
|      | K    | 0.527                        | 0.0015                                |
| ¾    | M    | 0.811                        | 0.0037                                |
|      | L    | 0.785                        | 0.0034                                |
|      | K    | 0.745                        | 0.0030                                |
| 1    | M    | 1.055                        | 0.0061                                |
|      | L    | 1.025                        | 0.0057                                |
|      | K    | 0.995                        | 0.0054                                |
| 1¼   | M    | 1.291                        | 0.0091                                |
|      | L    | 1.265                        | 0.0087                                |
|      | K    | 1.245                        | 0.0085                                |
| 1½   | M    | 1.527                        | 0.0127                                |
|      | L    | 1.505                        | 0.0124                                |
|      | K    | 1.481                        | 0.0120                                |
| 2    | M    | 2.009                        | 0.0220                                |
|      | L    | 1.985                        | 0.0215                                |
|      | K    | 1.959                        | 0.0209                                |
| 2½   | M    | 2.495                        | 0.0340                                |
|      | L    | 2.465                        | 0.0331                                |
|      | K    | 2.435                        | 0.0323                                |
| 3    | M    | 2.981                        | 0.0485                                |
|      | L    | 2.945                        | 0.0473                                |
|      | K    | 2.907                        | 0.0461                                |
| 3½   | M    | 3.459                        | 0.0653                                |
|      | L    | 3.425                        | 0.0640                                |
|      | K    | 3.385                        | 0.0625                                |
| 4    | M    | 3.935                        | 0.0845                                |
|      | L    | 3.905                        | 0.0832                                |
|      | K    | 3.857                        | 0.0811                                |

Table H.1(d) *A* and *B* Factors for Steel Pipe

| Pipe Size Nominal | Schedule 40 |          | Schedule 80 |          |
|-------------------|-------------|----------|-------------|----------|
|                   | <i>A</i>    | <i>B</i> | <i>A</i>    | <i>B</i> |
| ⅜                 | 0.02472     | 135.0    | 0.01106     | 249.0    |
| ½                 | 0.08375     | 53.3     | 0.04225     | 89.7     |
| ¾                 | 0.3666      | 17.3     | 0.2115      | 26.3     |
| 1                 | 1.302       | 6.59     | 0.8043      | 9.51     |
| 1¼                | 5.495       | 2.20     | 3.672       | 2.99     |
| 1½                | 12.34       | 1.19     | 8.513       | 1.58     |
| 2                 | 45.83       | 0.437    | 32.76       | 0.564    |
| 2½                | 115.3       | 0.216    | 84.6        | 0.274    |
| 3                 | 364.4       | 0.090    | 271.1       | 0.113    |
| 4                 | 1518.0      | 0.0304   | 1162.0      | 0.0372   |
| 5                 | 4972.0      | 0.0123   | 3875.0      | 0.0149   |
| 6                 | 13050.0     | 0.00589  | 9959.0      | 0.00724  |

Table H.1(e) Halon 1301 at 600 psi and 70 lb/ft<sup>3</sup> *Y* and *Z* Factors

| psi | <i>Z</i> | <i>Y</i> |       |       |       |       |       |       |       |       |       |
|-----|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |          | 0        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 400 | 0.006    | 290      | 194   | 97    | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 390 | 0.028    | 1243     | 1149  | 1054  | 960   | 865   | 769   | 674   | 578   | 482   | 386   |
| 380 | 0.051    | 2176     | 2084  | 1991  | 1898  | 1806  | 1712  | 1619  | 1525  | 1432  | 1338  |
| 370 | 0.076    | 3086     | 2996  | 2906  | 2816  | 2725  | 2634  | 2543  | 2451  | 2360  | 2268  |
| 360 | 0.102    | 3974     | 3886  | 3798  | 3710  | 3622  | 3533  | 3444  | 3355  | 3266  | 3176  |
| 350 | 0.129    | 4838     | 4753  | 4667  | 4581  | 4495  | 4409  | 4323  | 4236  | 4149  | 4062  |
| 340 | 0.159    | 5678     | 5595  | 5512  | 5428  | 5345  | 5261  | 5177  | 5093  | 5008  | 4923  |
| 330 | 0.191    | 6492     | 6412  | 6331  | 6251  | 6169  | 6088  | 6007  | 5925  | 5843  | 5760  |
| 320 | 0.224    | 7281     | 7203  | 7125  | 7047  | 6968  | 6890  | 6811  | 6731  | 6652  | 6572  |
| 310 | 0.260    | 8042     | 7967  | 7892  | 7816  | 7741  | 7665  | 7588  | 7512  | 7435  | 7358  |
| 300 | 0.298    | 8776     | 8704  | 8631  | 8559  | 8486  | 8413  | 8339  | 8265  | 8191  | 8117  |
| 290 | 0.339    | 9482     | 9412  | 9343  | 9273  | 9203  | 9132  | 9062  | 8991  | 8919  | 8848  |
| 280 | 0.382    | 10158    | 10092 | 10025 | 9958  | 9891  | 9823  | 9756  | 9688  | 9619  | 9551  |
| 270 | 0.429    | 10805    | 10741 | 10678 | 10614 | 10550 | 10485 | 10420 | 10355 | 10290 | 10224 |
| 260 | 0.478    | 11421    | 11361 | 11300 | 11239 | 11178 | 11117 | 11055 | 10993 | 10930 | 10868 |
| 250 | 0.531    | 12007    | 11950 | 11892 | 11834 | 11776 | 11718 | 11659 | 11600 | 11541 | 11481 |
| 240 | 0.588    | 12561    | 12507 | 12453 | 12398 | 12343 | 12288 | 12232 | 12176 | 12120 | 12064 |
| 230 | 0.649    | 13084    | 13033 | 12982 | 12930 | 12878 | 12826 | 12774 | 12721 | 12668 | 12615 |
| 220 | 0.713    | 13575    | 13527 | 13479 | 13431 | 13382 | 13333 | 13284 | 13234 | 13184 | 13134 |
| 210 | 0.782    | 14034    | 13990 | 13945 | 13900 | 13854 | 13808 | 13762 | 13716 | 13669 | 13622 |
| 200 | 0.855    | 14462    | 14421 | 14379 | 14337 | 14295 | 14252 | 14209 | 14166 | 14122 | 14078 |
| 190 | 0.934    | 14859    | 14820 | 14782 | 14743 | 14704 | 14664 | 14624 | 14584 | 14544 | 14503 |
| 180 | 1.017    | 15225    | 15190 | 15154 | 15118 | 15082 | 15046 | 15009 | 14972 | 14934 | 14897 |
| 170 | 1.105    | 15561    | 15528 | 15496 | 15463 | 15430 | 15396 | 15363 | 15329 | 15294 | 15260 |
| 160 | 1.198    | 15868    | 15838 | 15809 | 15779 | 15748 | 15718 | 15687 | 15656 | 15624 | 15593 |
| 150 | 1.297    | 16146    | 16120 | 16093 | 16066 | 16038 | 16010 | 15982 | 15954 | 15926 | 15897 |
| 140 | 1.402    | 16398    | 16374 | 16350 | 16325 | 16301 | 16276 | 16250 | 16225 | 16199 | 16173 |
| 130 | 1.513    | 16624    | 16603 | 16581 | 16559 | 16537 | 16514 | 16491 | 16469 | 16445 | 16422 |
| 120 | 1.631    | 16826    | 16807 | 16787 | 16768 | 16748 | 16728 | 16708 | 16687 | 16666 | 16645 |
| 110 | 1.755    | 17004    | 16987 | 16970 | 16953 | 16935 | 16918 | 16900 | 16882 | 16863 | 16845 |
| 100 | 1.888    | 17161    | 17147 | 17132 | 17116 | 17101 | 17085 | 17070 | 17054 | 17037 | 17021 |
| 90  | 2.029    | 17298    | 17286 | 17273 | 17259 | 17246 | 17232 | 17219 | 17205 | 17190 | 17176 |
| 80  | 2.181    | 17417    | 17406 | 17395 | 17383 | 17372 | 17360 | 17348 | 17336 | 17324 | 17311 |
| 70  | 2.347    | 17518    | 17509 | 17499 | 17489 | 17479 | 17469 | 17459 | 17449 | 17438 | 17428 |
| 60  | 2.530    | 17603    | 17595 | 17587 | 17579 | 17571 | 17562 | 17554 | 17545 | 17536 | 17527 |

Table H.1(f) Halon 1301 at 600 psi and 60 lb/ft<sup>3</sup> Y and Z Factors

| psi | Z     | Y     |       |       |       |       |       |       |       |       |       |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |       | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 420 | 0.019 | 956   | 861   | 766   | 671   | 575   | 480   | 384   | 289   | 193   | 96    |
| 410 | 0.039 | 1893  | 1800  | 1707  | 1614  | 1520  | 1426  | 1333  | 1239  | 1144  | 1050  |
| 400 | 0.060 | 2811  | 2720  | 2629  | 2537  | 2446  | 2354  | 2262  | 2170  | 2078  | 1985  |
| 390 | 0.083 | 3709  | 3620  | 3531  | 3442  | 3352  | 3262  | 3172  | 3082  | 2992  | 2901  |
| 380 | 0.106 | 4587  | 4500  | 4413  | 4325  | 4238  | 4150  | 4062  | 3974  | 3886  | 3798  |
| 370 | 0.132 | 5443  | 5358  | 5273  | 5188  | 5103  | 5017  | 4932  | 4846  | 4760  | 4673  |
| 360 | 0.158 | 6277  | 6195  | 6112  | 6029  | 5946  | 5863  | 5779  | 5696  | 5612  | 5527  |
| 350 | 0.187 | 7089  | 7009  | 6929  | 6848  | 6767  | 6686  | 6605  | 6523  | 6442  | 6360  |
| 340 | 0.217 | 7877  | 7800  | 7722  | 7643  | 7565  | 7486  | 7407  | 7328  | 7249  | 7169  |
| 330 | 0.249 | 8642  | 8566  | 8491  | 8415  | 8339  | 8263  | 8186  | 8109  | 8032  | 7955  |
| 320 | 0.283 | 9381  | 9308  | 9235  | 9162  | 9088  | 9014  | 8940  | 8866  | 8791  | 8717  |
| 310 | 0.319 | 10095 | 10025 | 9954  | 9883  | 9812  | 9741  | 9670  | 9598  | 9526  | 9454  |
| 300 | 0.358 | 10783 | 10715 | 10647 | 10579 | 10511 | 10442 | 10373 | 10304 | 10235 | 10165 |
| 290 | 0.399 | 11444 | 11379 | 11314 | 11248 | 11183 | 11117 | 11050 | 10984 | 10917 | 10850 |
| 280 | 0.442 | 12077 | 12015 | 11953 | 11890 | 11827 | 11764 | 11701 | 11637 | 11573 | 11508 |
| 270 | 0.489 | 12683 | 12624 | 12564 | 12504 | 12444 | 12384 | 12323 | 12262 | 12201 | 12139 |
| 260 | 0.538 | 13261 | 13204 | 13148 | 13090 | 13033 | 12976 | 12918 | 12859 | 12801 | 12742 |
| 250 | 0.591 | 13809 | 13756 | 13702 | 13648 | 13593 | 13539 | 13484 | 13428 | 13373 | 13317 |
| 240 | 0.647 | 14329 | 14278 | 14227 | 14176 | 14125 | 14073 | 14021 | 13968 | 13916 | 13863 |
| 230 | 0.707 | 14820 | 14772 | 14724 | 14675 | 14627 | 14578 | 14529 | 14479 | 14430 | 14379 |
| 220 | 0.770 | 15281 | 15236 | 15191 | 15145 | 15100 | 15054 | 15008 | 14961 | 14914 | 14867 |
| 210 | 0.838 | 15713 | 15671 | 15629 | 15586 | 15543 | 15500 | 15457 | 15413 | 15369 | 15325 |
| 200 | 0.909 | 16116 | 16077 | 16037 | 15998 | 15958 | 15918 | 15877 | 15837 | 15796 | 15754 |
| 190 | 0.985 | 16490 | 16454 | 16417 | 16381 | 16344 | 16306 | 16269 | 16231 | 16193 | 16154 |
| 180 | 1.066 | 16836 | 16802 | 16769 | 16735 | 16701 | 16666 | 16632 | 16597 | 16561 | 16526 |
| 170 | 1.152 | 17154 | 17123 | 17093 | 17061 | 17030 | 16998 | 16966 | 16934 | 16902 | 16869 |
| 160 | 1.243 | 17445 | 17418 | 17389 | 17361 | 17332 | 17303 | 17274 | 17244 | 17214 | 17184 |
| 150 | 1.339 | 17711 | 17685 | 17660 | 17634 | 17608 | 17581 | 17555 | 17528 | 17501 | 17473 |
| 140 | 1.441 | 17951 | 17928 | 17905 | 17882 | 17858 | 17834 | 17810 | 17786 | 17761 | 17736 |
| 130 | 1.549 | 18168 | 18147 | 18126 | 18105 | 18084 | 18062 | 18041 | 18019 | 17996 | 17974 |
| 120 | 1.664 | 18361 | 18343 | 18324 | 18306 | 18287 | 18267 | 18248 | 18228 | 18208 | 18188 |
| 110 | 1.785 | 18534 | 18517 | 18501 | 18484 | 18467 | 18450 | 18433 | 18415 | 18398 | 18380 |
| 100 | 1.914 | 18686 | 18671 | 18657 | 18642 | 18627 | 18612 | 18597 | 18581 | 18566 | 18550 |
| 90  | 2.052 | 18818 | 18806 | 18793 | 18781 | 18767 | 18754 | 18741 | 18727 | 18714 | 18700 |
| 80  | 2.201 | 18934 | 18923 | 18912 | 18901 | 18890 | 18878 | 18867 | 18855 | 18843 | 18831 |
| 70  | 2.363 | 19032 | 19023 | 19014 | 19004 | 18995 | 18985 | 18975 | 18965 | 18955 | 18944 |
| 60  | 2.543 | 19116 | 19108 | 19100 | 19092 | 19084 | 19076 | 19068 | 19059 | 19050 | 19041 |

Table H.1(g) Halon 1301 at 600 psi and 50 lb/ft<sup>3</sup> *Y* and *Z* Factors

| psi | <i>Z</i> | <i>Y</i> |       |       |       |       |       |       |       |       |       |
|-----|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |          | 0        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 450 | 0.012    | 667      | 573   | 478   | 382   | 287   | 192   | 96    | 0     | 0     | 0     |
| 440 | 0.030    | 1607     | 1513  | 1420  | 1327  | 1233  | 1139  | 1045  | 951   | 857   | 762   |
| 430 | 0.049    | 2529     | 2437  | 2346  | 2254  | 2162  | 2070  | 1978  | 1885  | 1792  | 1700  |
| 420 | 0.068    | 3434     | 3344  | 3254  | 3164  | 3074  | 2984  | 2893  | 2802  | 2711  | 2620  |
| 410 | 0.089    | 4321     | 4233  | 4145  | 4056  | 3968  | 3879  | 3791  | 3702  | 3613  | 3523  |
| 400 | 0.111    | 5189     | 5103  | 5017  | 4930  | 4844  | 4757  | 4670  | 4583  | 4496  | 4408  |
| 390 | 0.134    | 6038     | 5954  | 5870  | 5785  | 5701  | 5616  | 5531  | 5446  | 5360  | 5275  |
| 380 | 0.158    | 6867     | 6785  | 6702  | 6620  | 6538  | 6455  | 6372  | 6289  | 6205  | 6122  |
| 370 | 0.184    | 7675     | 7595  | 7515  | 7435  | 7354  | 7273  | 7192  | 7111  | 7030  | 6948  |
| 360 | 0.212    | 8462     | 8384  | 8306  | 8228  | 8150  | 8071  | 7992  | 7913  | 7834  | 7755  |
| 350 | 0.241    | 9227     | 9151  | 9076  | 9000  | 8924  | 8847  | 8771  | 8694  | 8617  | 8539  |
| 340 | 0.272    | 9970     | 9896  | 9823  | 9749  | 9675  | 9601  | 9527  | 9452  | 9377  | 9302  |
| 330 | 0.304    | 10689    | 10618 | 10547 | 10476 | 10404 | 10332 | 10260 | 10188 | 10115 | 10043 |
| 320 | 0.339    | 11385    | 11316 | 11247 | 11178 | 11109 | 11040 | 10970 | 10900 | 10830 | 10760 |
| 310 | 0.375    | 12056    | 11990 | 11924 | 11857 | 11790 | 11723 | 11656 | 11589 | 11521 | 11453 |
| 300 | 0.414    | 12702    | 12639 | 12575 | 12511 | 12447 | 12382 | 12318 | 12252 | 12187 | 12122 |
| 290 | 0.455    | 13324    | 13263 | 13201 | 13140 | 13078 | 13016 | 12954 | 12891 | 12829 | 12766 |
| 280 | 0.499    | 13919    | 13861 | 13802 | 13743 | 13684 | 13625 | 13565 | 13505 | 13445 | 13384 |
| 270 | 0.546    | 14488    | 14432 | 14376 | 14320 | 14264 | 14207 | 14150 | 14092 | 14035 | 13977 |
| 260 | 0.595    | 15031    | 14978 | 14924 | 14871 | 14817 | 14763 | 14708 | 14654 | 14599 | 14544 |
| 250 | 0.647    | 15546    | 15496 | 15445 | 15394 | 15343 | 15292 | 15240 | 15188 | 15136 | 15083 |
| 240 | 0.703    | 16035    | 15987 | 15939 | 15891 | 15842 | 15794 | 15745 | 15696 | 15646 | 15596 |
| 230 | 0.762    | 16496    | 16451 | 16406 | 16360 | 16315 | 16269 | 16222 | 16176 | 16129 | 16082 |
| 220 | 0.825    | 16930    | 16888 | 16845 | 16802 | 16759 | 16716 | 16673 | 16629 | 16585 | 16540 |
| 210 | 0.892    | 17337    | 17297 | 17257 | 17217 | 17177 | 17137 | 17096 | 17055 | 17013 | 16972 |
| 200 | 0.962    | 17716    | 17680 | 17642 | 17605 | 17568 | 17530 | 17492 | 17453 | 17415 | 17376 |
| 190 | 1.037    | 18069    | 18035 | 18001 | 17966 | 17931 | 17896 | 17861 | 17825 | 17789 | 17753 |
| 180 | 1.117    | 18396    | 18365 | 18333 | 18301 | 18269 | 18236 | 18203 | 17170 | 18137 | 18103 |
| 170 | 1.201    | 18698    | 18669 | 18639 | 18610 | 18580 | 18550 | 18520 | 18489 | 18459 | 18428 |
| 160 | 1.290    | 18974    | 18947 | 18921 | 18894 | 18866 | 18839 | 18811 | 18783 | 18755 | 18726 |
| 150 | 1.384    | 19226    | 19202 | 19178 | 19153 | 19128 | 19103 | 19078 | 19052 | 19026 | 19000 |
| 140 | 1.484    | 19455    | 19433 | 19411 | 19389 | 19366 | 19343 | 19320 | 19297 | 19274 | 19250 |
| 130 | 1.589    | 19662    | 19642 | 19622 | 19602 | 19582 | 19561 | 19540 | 19519 | 19498 | 19477 |
| 120 | 1.701    | 19847    | 19829 | 19811 | 19793 | 19775 | 19757 | 19738 | 19719 | 19700 | 19681 |
| 110 | 1.820    | 20012    | 19996 | 19981 | 19965 | 19948 | 19932 | 19915 | 19898 | 19881 | 19864 |
| 100 | 1.947    | 20158    | 20144 | 20130 | 20116 | 20102 | 20087 | 20073 | 20058 | 20043 | 20027 |
| 90  | 2.083    | 20286    | 20274 | 20262 | 20249 | 20237 | 20224 | 20211 | 20198 | 20185 | 20172 |
| 80  | 2.229    | 20397    | 20387 | 20376 | 20366 | 20355 | 20344 | 20333 | 20321 | 20310 | 20298 |
| 70  | 2.385    | 20493    | 20484 | 20475 | 20466 | 20457 | 20447 | 20437 | 20428 | 20418 | 20408 |
| 60  | 2.555    | 20574    | 20567 | 20559 | 20551 | 20543 | 20535 | 20527 | 20519 | 20510 | 20502 |

Table H.1(h) Halon 1301 at 600 psi and 40 lb/ft<sup>3</sup> *Y* and *Z* Factors

| psi | <i>Z</i> | <i>Y</i> |       |       |       |       |       |       |       |       |       |
|-----|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |          | 0        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 480 | 0.008    | 475      | 380   | 285   | 190   | 95    | 0     | 0     | 0     | 0     | 0     |
| 470 | 0.024    | 1414     | 1321  | 1227  | 1134  | 1040  | 9469  | 852   | 758   | 664   | 570   |
| 460 | 0.041    | 2337     | 2246  | 2154  | 2062  | 1970  | 1878  | 1785  | 1692  | 1600  | 1507  |
| 450 | 0.058    | 3245     | 3155  | 3065  | 2975  | 2884  | 2793  | 2702  | 2611  | 2520  | 2429  |
| 440 | 0.076    | 4137     | 4049  | 3960  | 3871  | 3782  | 3693  | 3604  | 3515  | 3425  | 3335  |
| 430 | 0.096    | 5012     | 4926  | 4839  | 4752  | 4664  | 4577  | 4489  | 4402  | 4314  | 4225  |
| 420 | 0.116    | 5871     | 5785  | 5700  | 5615  | 5529  | 5444  | 5358  | 5272  | 5185  | 5099  |
| 410 | 0.137    | 6711     | 6628  | 6544  | 6461  | 6377  | 6293  | 6209  | 6125  | 6040  | 5955  |
| 400 | 0.160    | 7533     | 7452  | 7370  | 7288  | 7206  | 7124  | 7042  | 6959  | 6877  | 6794  |
| 390 | 0.184    | 8336     | 8257  | 8177  | 8097  | 8017  | 7937  | 7856  | 7776  | 7695  | 7614  |
| 380 | 0.209    | 9120     | 9042  | 8965  | 8887  | 8809  | 8730  | 8652  | 8573  | 8494  | 8415  |
| 370 | 0.236    | 9883     | 9808  | 9732  | 9656  | 9580  | 9504  | 9428  | 9351  | 9274  | 9197  |
| 360 | 0.264    | 10627    | 10553 | 10480 | 10406 | 10332 | 10258 | 10183 | 10109 | 10034 | 9959  |
| 350 | 0.293    | 11348    | 11277 | 11206 | 11134 | 11062 | 10990 | 10918 | 10845 | 10773 | 10700 |
| 340 | 0.325    | 12049    | 11980 | 11910 | 11841 | 11771 | 11701 | 11631 | 11561 | 11490 | 11419 |
| 330 | 0.358    | 12727    | 12660 | 12593 | 12526 | 12458 | 12391 | 12323 | 12254 | 12186 | 12118 |
| 320 | 0.393    | 13382    | 13318 | 13253 | 13188 | 13123 | 13057 | 12992 | 12926 | 12860 | 12793 |
| 310 | 0.430    | 14014    | 13952 | 13890 | 13827 | 13764 | 13701 | 13638 | 13574 | 13510 | 13446 |
| 300 | 0.469    | 14623    | 14563 | 14503 | 14443 | 14382 | 14321 | 14260 | 14199 | 14138 | 14076 |
| 290 | 0.511    | 15207    | 15150 | 15092 | 15034 | 14976 | 14918 | 14859 | 14800 | 14741 | 14682 |
| 280 | 0.555    | 15767    | 15712 | 15657 | 15601 | 15546 | 15490 | 15434 | 15378 | 15321 | 15264 |
| 270 | 0.602    | 16302    | 16250 | 16197 | 16144 | 16091 | 16038 | 15984 | 15930 | 15876 | 15821 |
| 260 | 0.651    | 16812    | 16762 | 16712 | 16662 | 16611 | 16560 | 16509 | 16458 | 16406 | 16354 |
| 250 | 0.704    | 17296    | 17249 | 17202 | 17154 | 17106 | 17057 | 17009 | 16960 | 16911 | 16861 |
| 240 | 0.759    | 17756    | 17711 | 17666 | 17621 | 17575 | 17529 | 17483 | 17437 | 17390 | 17344 |
| 230 | 0.818    | 18189    | 18147 | 18105 | 18062 | 18019 | 17976 | 17932 | 17888 | 17844 | 17800 |
| 220 | 0.880    | 18597    | 18558 | 18518 | 18478 | 18437 | 18397 | 18356 | 18314 | 18273 | 18231 |
| 210 | 0.946    | 18980    | 18943 | 18906 | 18868 | 18830 | 18792 | 18754 | 18715 | 18676 | 18637 |
| 200 | 1.016    | 19338    | 19303 | 19268 | 19233 | 19198 | 19162 | 19126 | 19090 | 19054 | 19017 |
| 190 | 1.090    | 19671    | 19639 | 19606 | 19574 | 19541 | 19508 | 19474 | 19440 | 19407 | 19372 |
| 180 | 1.168    | 19979    | 19950 | 19920 | 19889 | 19859 | 19828 | 19797 | 19766 | 19735 | 19703 |
| 170 | 1.251    | 20264    | 20237 | 20209 | 20181 | 20153 | 20125 | 20096 | 20067 | 20038 | 20009 |
| 160 | 1.339    | 20526    | 20500 | 20475 | 20449 | 20424 | 20398 | 20371 | 20345 | 20318 | 20291 |
| 150 | 1.431    | 20764    | 20742 | 20718 | 20695 | 20672 | 20648 | 20624 | 20600 | 20575 | 20550 |
| 140 | 1.529    | 20982    | 20961 | 20940 | 20919 | 20897 | 20876 | 20854 | 20832 | 20810 | 20787 |
| 130 | 1.633    | 21178    | 21159 | 21140 | 21121 | 21102 | 21082 | 21063 | 21043 | 21023 | 21002 |
| 120 | 1.744    | 21354    | 21338 | 21321 | 21304 | 21286 | 21269 | 21251 | 21233 | 21215 | 21197 |
| 110 | 1.861    | 21512    | 21497 | 21482 | 21467 | 21451 | 21435 | 21420 | 21404 | 21387 | 21371 |
| 100 | 1.986    | 21651    | 21638 | 21625 | 21611 | 21598 | 21584 | 21570 | 21556 | 21541 | 21527 |
| 90  | 2.120    | 21774    | 21763 | 21751 | 21739 | 21727 | 21715 | 21702 | 21690 | 21677 | 21664 |
| 80  | 2.264    | 21881    | 21871 | 21861 | 21850 | 21840 | 21829 | 21819 | 21808 | 21797 | 21785 |
| 70  | 2.420    | 21973    | 21964 | 21955 | 21947 | 21938 | 21929 | 21919 | 21910 | 21900 | 21891 |
| 60  | 2.591    | 22051    | 22044 | 22036 | 22029 | 22021 | 22013 | 22006 | 21998 | 21989 | 21981 |

**Table H.1(i) Halon 1301 at 360 psi and 70 lb/ft<sup>3</sup> Y and Z Factors**

| psi        | Z     | Y    |      |      |      |      |      |      |      |      |      |
|------------|-------|------|------|------|------|------|------|------|------|------|------|
|            |       | 0    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
| <b>260</b> | 0.050 | 962  | 868  | 773  | 678  | 583  | 487  | 391  | 294  | 196  | 98   |
| <b>250</b> | 0.105 | 1874 | 1785 | 1696 | 1606 | 1515 | 1424 | 1333 | 1241 | 1148 | 1055 |
| <b>240</b> | 0.166 | 2735 | 2652 | 2567 | 2483 | 2397 | 2311 | 2225 | 2138 | 2051 | 1963 |
| <b>230</b> | 0.233 | 3543 | 3465 | 3386 | 3307 | 3227 | 3146 | 3065 | 2984 | 2901 | 2819 |
| <b>220</b> | 0.307 | 4297 | 4224 | 4150 | 4076 | 4002 | 3927 | 3851 | 3775 | 3698 | 3621 |
| <b>210</b> | 0.387 | 4994 | 4927 | 4859 | 4791 | 4722 | 4652 | 4582 | 4512 | 4441 | 4369 |
| <b>200</b> | 0.475 | 5635 | 5573 | 5511 | 5449 | 5385 | 5322 | 5257 | 5192 | 5127 | 5061 |
| <b>190</b> | 0.570 | 6220 | 6164 | 6107 | 6050 | 5993 | 5935 | 5876 | 5816 | 5757 | 5696 |
| <b>180</b> | 0.673 | 6750 | 6699 | 6648 | 6597 | 6544 | 6492 | 6439 | 6385 | 6330 | 6275 |
| <b>170</b> | 0.783 | 7227 | 7181 | 7135 | 7089 | 7042 | 6995 | 6947 | 6898 | 6849 | 6800 |
| <b>160</b> | 0.899 | 7652 | 7612 | 7571 | 7530 | 7488 | 7446 | 7403 | 7359 | 7316 | 7271 |
| <b>150</b> | 1.021 | 8030 | 7994 | 7958 | 7922 | 7885 | 7847 | 7809 | 7771 | 7732 | 7692 |
| <b>140</b> | 1.149 | 8364 | 8332 | 8300 | 8268 | 8235 | 8202 | 8169 | 8135 | 8100 | 8066 |
| <b>130</b> | 1.282 | 8656 | 8629 | 8601 | 8573 | 8544 | 8515 | 8486 | 8456 | 8425 | 8395 |
| <b>120</b> | 1.422 | 8912 | 8888 | 8864 | 8839 | 8814 | 8789 | 8763 | 8737 | 8710 | 8684 |
| <b>110</b> | 1.567 | 9133 | 9113 | 9092 | 9070 | 9049 | 9027 | 9004 | 8982 | 8959 | 8935 |
| <b>100</b> | 1.719 | 9324 | 9306 | 9288 | 9270 | 9251 | 9232 | 9213 | 9194 | 9174 | 9154 |
| <b>90</b>  | 1.879 | 9488 | 9472 | 9457 | 9441 | 9425 | 9409 | 9393 | 9376 | 9359 | 9342 |
| <b>80</b>  | 2.047 | 9626 | 9614 | 9600 | 9587 | 9574 | 9560 | 9546 | 9532 | 9517 | 9503 |
| <b>70</b>  | 2.225 | 9743 | 9732 | 9721 | 9710 | 9699 | 9687 | 9676 | 9664 | 9651 | 9639 |
| <b>60</b>  | 2.417 | 9840 | 9831 | 9822 | 9813 | 9804 | 9794 | 9784 | 9774 | 9764 | 9754 |

Table H.1(j) Halon 1301 at 360 psi and 60 lb/ft<sup>3</sup> Y and Z Factors

| psi | Z     | Y     |       |       |       |       |       |       |       |       |       |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |       | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 280 | 0.004 | 98    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 270 | 0.051 | 1056  | 962   | 868   | 774   | 678   | 583   | 487   | 390   | 293   | 196   |
| 260 | 0.102 | 1969  | 1880  | 1790  | 1700  | 1609  | 1518  | 1427  | 1335  | 1242  | 1150  |
| 250 | 0.158 | 2834  | 2750  | 2665  | 2579  | 2494  | 2407  | 2321  | 2233  | 2146  | 2057  |
| 240 | 0.219 | 3650  | 3571  | 3491  | 3410  | 3330  | 3248  | 3166  | 3084  | 3001  | 2918  |
| 230 | 0.286 | 4415  | 4341  | 4266  | 4191  | 4115  | 4039  | 3962  | 3885  | 3807  | 3729  |
| 220 | 0.360 | 5129  | 5060  | 4990  | 4920  | 4850  | 4779  | 4707  | 4635  | 4562  | 4489  |
| 210 | 0.440 | 5789  | 5726  | 5662  | 5597  | 5532  | 5466  | 5399  | 5333  | 5265  | 5197  |
| 200 | 0.527 | 6397  | 6339  | 6280  | 6220  | 6160  | 6100  | 6039  | 5977  | 5915  | 5853  |
| 190 | 0.621 | 6952  | 6899  | 6845  | 6791  | 6736  | 6681  | 6625  | 6569  | 6512  | 6455  |
| 180 | 0.722 | 7456  | 7408  | 7359  | 7310  | 7260  | 7210  | 7160  | 7108  | 7057  | 7005  |
| 170 | 0.829 | 7910  | 7866  | 7823  | 7778  | 7734  | 7689  | 7643  | 7597  | 7550  | 7503  |
| 160 | 0.942 | 8316  | 8278  | 8239  | 8199  | 8159  | 8119  | 8078  | 8036  | 7995  | 7952  |
| 150 | 1.062 | 8678  | 8644  | 8609  | 8574  | 8538  | 8503  | 8466  | 8429  | 8392  | 8354  |
| 140 | 1.187 | 8998  | 8968  | 8937  | 8906  | 8875  | 8843  | 8811  | 8778  | 8745  | 8712  |
| 130 | 1.318 | 9280  | 9254  | 9227  | 9199  | 9172  | 9144  | 9115  | 9087  | 9058  | 9028  |
| 120 | 1.455 | 9527  | 9503  | 9480  | 9456  | 9432  | 9408  | 9383  | 9358  | 9332  | 9306  |
| 110 | 1.598 | 9741  | 9721  | 9700  | 9680  | 9659  | 9638  | 9616  | 9594  | 9572  | 9549  |
| 100 | 1.748 | 9926  | 9909  | 9891  | 9873  | 9855  | 9837  | 9818  | 9799  | 9780  | 9761  |
| 90  | 1.905 | 10085 | 10070 | 10055 | 10040 | 10024 | 10009 | 9993  | 9976  | 9960  | 9943  |
| 80  | 2.071 | 10220 | 10207 | 10195 | 10182 | 10169 | 10155 | 10142 | 10128 | 10114 | 10099 |
| 70  | 2.248 | 10334 | 10323 | 10313 | 10302 | 10291 | 10279 | 10268 | 10256 | 10244 | 10232 |
| 60  | 2.437 | 10429 | 10420 | 10411 | 10402 | 10393 | 10384 | 10374 | 10364 | 10354 | 10344 |

Table H.1(k) Halon 1301 at 360 psi and 50 lb/ft<sup>3</sup> *Y* and *Z* Factors

| psi | <i>Z</i> | <i>Y</i> |       |       |       |       |       |       |       |       |       |
|-----|----------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |          | 0        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 290 | 0.008    | 195      | 98    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 280 | 0.051    | 1148     | 1055  | 961   | 867   | 772   | 677   | 581   | 485   | 389   | 292   |
| 270 | 0.098    | 2059     | 1970  | 1880  | 1790  | 1700  | 1609  | 1518  | 1426  | 1334  | 1241  |
| 260 | 0.150    | 2926     | 2841  | 2756  | 2670  | 2584  | 2498  | 2411  | 2324  | 2236  | 2148  |
| 250 | 0.206    | 3747     | 3667  | 3586  | 3505  | 3424  | 3342  | 3260  | 3177  | 3094  | 3010  |
| 240 | 0.268    | 4521     | 4446  | 4370  | 4294  | 4217  | 4140  | 4062  | 3984  | 3906  | 3827  |
| 230 | 0.335    | 5247     | 5177  | 5106  | 5035  | 4963  | 4890  | 4818  | 4744  | 4670  | 4596  |
| 220 | 0.408    | 5925     | 5859  | 5793  | 5727  | 5660  | 5592  | 5524  | 5456  | 5387  | 5317  |
| 210 | 0.487    | 6552     | 6491  | 6430  | 6369  | 6307  | 6244  | 6181  | 6118  | 6054  | 5989  |
| 200 | 0.573    | 7129     | 7074  | 7018  | 6961  | 6904  | 6847  | 6789  | 6730  | 6671  | 6612  |
| 190 | 0.666    | 7658     | 7607  | 7556  | 7504  | 7452  | 7400  | 7347  | 7293  | 7239  | 7184  |
| 180 | 0.764    | 8138     | 8092  | 8046  | 7999  | 7952  | 7904  | 7856  | 7807  | 7758  | 7708  |
| 170 | 0.870    | 8572     | 8530  | 8489  | 8446  | 8404  | 8361  | 8317  | 8273  | 8228  | 8183  |
| 160 | 0.981    | 8961     | 8924  | 8887  | 8849  | 8810  | 8772  | 8733  | 8693  | 8653  | 8613  |
| 150 | 1.097    | 9308     | 9275  | 9242  | 9208  | 9174  | 9140  | 9105  | 9069  | 9034  | 8998  |
| 140 | 1.220    | 9617     | 9587  | 9558  | 9528  | 9498  | 9467  | 9436  | 9405  | 9373  | 9341  |
| 130 | 1.348    | 9889     | 9863  | 9837  | 9811  | 9784  | 9757  | 9730  | 9702  | 9674  | 9645  |
| 120 | 1.482    | 10127    | 10105 | 10082 | 10059 | 10036 | 10012 | 9988  | 9963  | 9939  | 9914  |
| 110 | 1.623    | 10335    | 10316 | 10296 | 10276 | 10255 | 10235 | 10214 | 10193 | 10171 | 10149 |
| 100 | 1.770    | 10515    | 10498 | 10481 | 10464 | 10446 | 10428 | 10410 | 10392 | 10373 | 10354 |
| 90  | 1.926    | 10670    | 10656 | 10641 | 10626 | 10611 | 10596 | 10580 | 10564 | 10548 | 10532 |
| 80  | 2.090    | 10802    | 10790 | 10777 | 10765 | 10752 | 10739 | 10725 | 10712 | 10698 | 10684 |
| 70  | 2.264    | 10913    | 10903 | 10893 | 10882 | 10871 | 10860 | 10849 | 10837 | 10826 | 10814 |
| 60  | 2.454    | 11006    | 10998 | 10989 | 10980 | 10971 | 10962 | 10953 | 10943 | 10933 | 10923 |

Table H.1(l) Halon 1301 at 360 psi and 40 lb/ft<sup>3</sup> Y and Z Factors

| psi | Z     | Y     |       |       |       |       |       |       |       |       |       |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     |       | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
| 300 | 0.011 | 292   | 195   | 98    | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 290 | 0.051 | 1239  | 1146  | 1053  | 959   | 865   | 770   | 675   | 580   | 484   | 388   |
| 280 | 0.094 | 2149  | 2060  | 1970  | 1880  | 1790  | 1669  | 1608  | 1516  | 1425  | 1332  |
| 270 | 0.142 | 3017  | 2932  | 2847  | 2761  | 2675  | 2588  | 2501  | 2414  | 2326  | 2237  |
| 260 | 0.194 | 3843  | 3763  | 3682  | 3600  | 3518  | 3436  | 3353  | 3270  | 3186  | 3102  |
| 250 | 0.251 | 4626  | 4550  | 4473  | 4396  | 4318  | 4240  | 4162  | 4083  | 4003  | 3924  |
| 240 | 0.313 | 5363  | 5292  | 5219  | 5147  | 5074  | 5000  | 4926  | 4852  | 4777  | 4702  |
| 230 | 0.380 | 6055  | 5988  | 5920  | 5852  | 5784  | 5715  | 5646  | 5576  | 5505  | 5435  |
| 220 | 0.453 | 6700  | 6637  | 6574  | 6511  | 6447  | 6383  | 6318  | 6253  | 6188  | 6121  |
| 210 | 0.532 | 7297  | 7240  | 7182  | 7123  | 7064  | 7004  | 6944  | 6884  | 6823  | 6762  |
| 200 | 0.616 | 7848  | 7795  | 7742  | 7688  | 7634  | 7579  | 7523  | 7468  | 7411  | 7355  |
| 190 | 0.707 | 8353  | 8304  | 8256  | 8206  | 8156  | 8106  | 8056  | 8004  | 7953  | 7901  |
| 180 | 0.805 | 8812  | 8768  | 8724  | 8679  | 8634  | 8588  | 8542  | 8495  | 8448  | 8401  |
| 170 | 0.908 | 9228  | 9188  | 9148  | 9107  | 9066  | 9025  | 8983  | 8941  | 8899  | 8856  |
| 160 | 1.016 | 9601  | 9566  | 9530  | 9493  | 9457  | 9420  | 9382  | 9344  | 9306  | 9267  |
| 150 | 1.131 | 9936  | 9904  | 9872  | 9839  | 9807  | 9773  | 9740  | 9706  | 9671  | 9637  |
| 140 | 1.251 | 10233 | 10205 | 10176 | 10148 | 10118 | 10089 | 10059 | 10029 | 9998  | 9967  |
| 130 | 1.377 | 10496 | 10471 | 10446 | 10421 | 10395 | 10369 | 10342 | 10315 | 10288 | 10261 |
| 120 | 1.508 | 10727 | 10705 | 10683 | 10661 | 10638 | 10615 | 10592 | 10569 | 10545 | 10521 |
| 110 | 1.646 | 10929 | 10910 | 10891 | 10872 | 10852 | 10832 | 10811 | 10791 | 10770 | 10749 |
| 100 | 1.792 | 11105 | 11088 | 11072 | 11055 | 11038 | 11020 | 11003 | 10985 | 10966 | 10948 |
| 90  | 1.945 | 11256 | 11242 | 11227 | 11213 | 11198 | 11183 | 11168 | 11153 | 11137 | 11121 |
| 80  | 2.107 | 11385 | 11373 | 11361 | 11348 | 11336 | 11323 | 11310 | 11297 | 11283 | 11270 |
| 70  | 2.280 | 11494 | 11484 | 11474 | 11463 | 11453 | 11442 | 11431 | 11420 | 11408 | 11397 |
| 60  | 2.465 | 11586 | 11577 | 11569 | 11560 | 11551 | 11542 | 11533 | 11523 | 11514 | 11504 |

Table H.1(m) Two-Phase Solution

| Section | Pipe             | L<br>(ft) | EQL<br>(ft) | Elevation<br>(ft) | Rate<br>(lb/sec) | Start<br>(psi) | End<br>(psi) |
|---------|------------------|-----------|-------------|-------------------|------------------|----------------|--------------|
| 1-2     | 1 in.<br>Sch. 40 | 27        | 58          | 7                 | 8                | 243            | 197          |
| 2-3     | ¾ in.<br>Sch. 40 | 15        | 19          | 0                 | 4                | 197            | 181          |
| 2-4     | ¾ in.<br>Sch. 40 | 15        | 19          | 0                 | 4                | 197            | 181          |