NFPA 12A

Standard on

Halon 1301 Fire Extinguishing Systems

2004 Edition

This edition of NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, was prepared by the Technical Committee on Halogenated Fire Extinguishing Systems and acted on by NFPA at its November Association Technical Meeting held November 15–19, 2003, in Reno, NV. It was issued by the Standards Council on January 16, 2004, with an effective date of February 5, 2004, and supersedes all previous editions.

This edition of NFPA 12A was approved as an American National Standard on January 16, 2004.

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 1967.

The standard was submitted and adopted at the 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 Annual Meeting of NFPA held 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 revision to more clearly state the requirements 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 this revision was decommissioning and removal of systems.

The standard was updated to the MOS for this revision.

Foreword

Halon 1301 (bromotrifluoromethane or $CBrF_3$) 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 U.S.) have enacted further rules regulating the production, use, handling, and deposition 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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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fixed fire extinguishing systems utilizing bromotrifluoromethane and other similar halogenated extinguishing agents, covering the installation, maintenance, and use of systems.

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Halon 1301 Fire Extinguishing Systems
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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.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

Information on referenced 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.

Table 1.3.1 Metric Conversion Factors

Name of Unit	Unit	Conversion Factor
Liter	L	1 gal = 3.785 L
Cubic decimeter	dm^3	1 gal = 3.785 dm^3
Pascal	Pa	1 psi = 6894.757 Pa
Bar	bar	1 psi = 0.0689 bar
Bar	bar	1 bar = 10^5 Pa

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.

1.4.5 Halon 1301 shall only be used in enclosures where ambient temperatures are between -70°F and 900°F (-57°C and 482°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 C-2, *National Electrical Safety Code*

(2) NFPA 70, *National Electrical Code*

(3) Title 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.

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®,* 2002 edition.

NFPA 72®, *National Fire Alarm Code®,* 2002 edition.

2.3 Other Publications.

2.3.1 ANSI Publications.

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

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

ANSI C-2, *National Electrical Safety Code,* 1997.

2.3.2 ASME Publications.

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

ASME *Boiler and Pressure Vessel Code,* Section VIII and IX, 1998.

ASME B31.1, *Power Piping Code,* 1998.

2.3.3 ASTM Publications.

American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 120, *Specifications for Welded and Seamless Steel Pipe,* 1984.

ASTM E S24, *Emergency Standard Specification for Halon 1301, Bromotrifluoromethane* (CF_3Br)*,* 1993.

2.3.4 CGA Publication.

Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders,* 1993.

2.3.5 CTC Publication.

Canadian Transport Commission, Queen's Printer, Ottawa, Ontario.

Regulations for Transportation of Dangerous Commodities by Rail.

2.3.6 ULC Publications.

Underwriters' Laboratories of Canada, 7 Underwriter's Road, Toronto, Ontario M1R 3B4, Canada.

ULC S524-M86, *Standard for the Installation of Fire Alarm Systems.*

ULC S529-M87, *Smoke Detectors for Fire Alarm Systems.*

2.3.7 U.S. Government Publications.

Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Code of Federal Regulations, Title 29.

Code of Federal Regulations, Title 49.

2.3.8 Other Publication.

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

Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

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.

3.3 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.

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. The Halon 1301 shall comply with the requirements of either Table 4.1.2 or ASTM E S24, *Emergency Standard Specification for Halon 1301, Bromotrifluoromethane* *(CF_3Br)*.

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 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.

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. Containers shall not be charged to a filling density greater than 70 lb/ft^3 (1121 kg/m^3). They shall be superpressurized with dry nitrogen to 360 psig ± 5 percent or 600 psig ± 5 percent total pressure at 70°F (2482 kPa ± 5 percent or 4137 kPa ± 5 percent total pressure at 21°C).

Exception: Listed pre-engineered systems shall be permitted to have different pressurization levels per Section 1.2.

4.1.4.2 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.

4.1.4.3 The Halon 1301 containers used in these systems shall be designed to meet the requirements of the U.S. Department of Transportation in Subpart C, Section 178.36 through 178.68 of Title 49, "Transportation," of the CFR 170-190, or the Canadian Transport Commission's *Regulations for Transportation of Dangerous Commodities by Rail*, if used as shipping containers. If not a shipping container, it shall be designed, fabricated, inspected, certified, and stamped in accordance with ASME *Boiler and Pressure Code*. Section VIII, "Rules for Construction of Pressure Vessels," independent inspection and certification is recommended. The design pressure shall be suitable for the maximum pressure developed at 130°F (55°C) or at the maximum controlled temperature limit.

4.1.4.4 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.

4.1.4.5 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.

4.1.4.6 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.

4.1.4.7 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^3 (1121 kg/m^3) density shall be assumed], but in no case shall be less than the following:

(1) For 360 psig (2482 kPa) charging pressure, an internal pressure of 620 psi (4274 kPa) (130°F) (55°C)

(2) For 600 psig (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 A 120, *Specifications for Welded and Seamless Steel Pipe,* 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 ANSI B1.20.1, *Standard for Pipe Threads, General Purpose*. 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, *National Electrical Code*, and *NFPA 72*, *National Fire Alarm Code*. In Canada refer to ULC S524-M86, *Standard for the Installation of Fire Alarm Systems*, and ULC S529-M87, *Smoke Detectors for Fire Alarm Systems*.

4.3.1.1 Automatic detection and automatic actuation shall be used.

Exception: Manual-only actuation shall be permitted to be used 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 lb (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.

5.3.1 In the design of total flooding systems, the characteristics of the enclosure shall be considered as follows.

5.3.1.1 For all types of fires, the area of unclosable openings shall be kept to a minimum. The authority having jurisdiction can require tests to ensure proper performance as defined by this standard.

5.3.1.2* To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures. Where reasonable confinement of agent is not practicable, protection shall be extended to include the adjacent connected hazards or work areas.

5.3.1.3 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 two 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.

Table 5.4.1.1.1 Halon 1301 Design Concentrations for Inerting

Fuel	Minimum Conc. % by Volume[1]
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

Table 5.4.1.1.1 Halon 1301 Design Concentrations for Inerting

Fuel	Minimum Conc. % by Volume[1]

[1]Coll, John P., "Inerting Characteristics of Halon 1301 and 1211 with Various Combustibles," Fenwal Inc., Report PSR 661, July 16, 1976.
Note: Includes a safety factor of 10 percent added to experimental values.

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

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

5.4.1.3 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:

(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^3 (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 (lb)

$s = 0.14781 + 0.000567t$

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

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

C = Halon 1301 concentration, percent by volume

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 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.

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

6.1.5 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.

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

6.2 Container Test.

6.2.1 DOT, CTC, or similar design Halon 1301 cylinders shall not be recharged without a retest if more than 5 years have elapsed since the date of the last test and inspection. The retest shall be permitted to consist of a complete visual inspection as described in the CFR, Title 49, "Transportation," Parts 170–190 and Subpart C, Section 173.34(e)(10), and Section 178.36 through 178.68. In Canada, the corresponding information is set forth in the Canadian Transport Commission's *Regulations for the Transportation of Dangerous Commodities by Rail.*

6.2.2 Cylinders continuously in service without discharging shall be given a complete external visual inspection every 5 years, in accordance with Compressed Gas Association pamphlet C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, Section 3, 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 coastdown 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 150 psig (1034 kPa). At the end of 10 minutes, the pressure drop shall not exceed 20 percent of the test pressure. When pressurizing the piping, pressure shall be increased in

50 psi (3.5 bar) increments.

> **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.

Exception: 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.

6.7.2.1.13 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. 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 E 380, *Standard Practice for Use of the International System of Units (SI): The Modernized Metric System*. In Canada refer to *Canadian Metric Practice Guide,* CSA Standard CAN3-Z234.1.

A.1.4.3 See NFPA 77, *Recommended Practice on Static Electricity*.

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 aisleways 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.)*

Also consult equipment manufacturer representative for specific recommendations.

Further information can be found in *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.

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, 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 documents in a broad manner, since 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, which do not change ownership, does not require recycling or quality testing. All other design features should comply with this standard.

For test procedures associated with Table 4.1.2, refer to MIL-M-12218C, *Monobromotrifluoromethane (Liquefied) Technical Grade Fire Extinguisher*, available from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

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 either be applied 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).]*

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

Steel Pipe — Threaded Connections	
ASTM A 106 Seamless, Grade C	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 Furnace Weld Class F	Schedule 40 — ⅛ in. through 1½ in. NPS Schedule 80 — 2 in. through 8 in. NPS
Steel Pipe — Welded or Rolled Groove Connections	
ASTM A 106 Seamless, Grade C	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 Furnace Weld Class F	Schedule 40 — ⅛ in. through 6 in. NPS •
Steel Pipe — Cut Groove Connections	
ASTM A 106 Seamless, Grade C	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade A	Schedule 40 — ⅛ in. through 5 in. NPS Schedule 80 — 6 in. through 8 in. NPS
ASTM A 53 Furnace Weld Class F	Schedule 40 — ⅛ in. through 3 in. NPS Schedule 80 — 4 in. through 8 in. NPS
Copper Tubing — Compression Fittings	
ASTM B 88 Seamless, Drawn	Type K ¼ in. through 8 in.
ASTM B 88 Seamless, Drawn	Type L ¼ in. through 3 in.
ASTM B 88 Seamless, Drawn	Type M ¼ in. through 1½ in.
ASTM B 88 Seamless, Annealed	Type K ¼ in. through 1 in.
ASTM B 88 Seamless, Annealed	Type L ¼ in. through ¾ in.
ASTM B 88 Seamless, Annealed	Type M ¼ in. ONLY

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

Steel Pipe — Threaded Connections	
ASTM A 106 Seamless, Grade C	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade B	Schedule 40 — ⅛ in. through 5 in. NPS
	Schedule 80 — 6 in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade A	Schedule 40 — ⅛ in. through 2½ in. NPS
	Schedule 80 — 3 in. through 8 in. NPS
ASTM A 53 ERW Grade B	Schedule 40 — ½ in. through 3 in. NPS
	Schedule 80 — 4 in. through 8 in. NPS
ASTM A 53 ERW Grade A	Schedule 40 — ⅛ in. through 1¼ in. NPS
	Schedule 80 — 1½ in. through 8 in. NPS
ASTM A 53 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
Steel Pipe — Welded Connections	
ASTM A 106 Seamless, Grade C	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 106/A 53 Seamless, Grade A	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade B	Schedule 40 — ⅛ in. through 8 in. NPS
ASTM A 53 ERW Grade A	Schedule 40 — ⅛ in. through 6 in. NPS
	Schedule 80 — 8 in. NPS
ASTM A 53 Furnace Weld Class F	Schedule 40 — ⅛ in. through 3 in. NPS
	Schedule 80 — 4 in. through 6 in. NPS •
Copper Tubing — Compression Fittings	
ASTM B 88 Seamless, Drawn	Type K ¼ in. through 1¼ in.
ASTM B 88 Seamless, Drawn	Type L ¼ in. through ¾ in.
ASTM B 88 Seamless, Drawn	Type M ¼ in. through ⅜ in.
ASTM B 88 Seamless, Annealed	Type K ¼ in. through ⅜ in.
ASTM B 88 Seamless, Annealed	Type L DO NOT USE
ASTM B 88 Seamless, Annealed	Type M DO NOT USE

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.

A.5.3.1.2 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, *Standard on Explosion Prevention Systems*, 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, *Guide for Venting of Deflagrations*, and NFPA 69, *Standard on Explosion Prevention Systems*, 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 will depend 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.)*

In order 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 above. For those instances, the reciprocal of the appropriate correction factor in Table A.5.6

egress times longer than 1 minute. *(See 5.2.6 and 5.2.7.)*

In order 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 above. For those instances, the reciprocal of the appropriate correction factor in Table A.5.6 should be used.

Table A.5.6 Correction Factors for Altitude

Altitude		
ft	**m**	**Correction Factor**
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

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.

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*, *National Fire Alarm Code*, 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 only be relied upon 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 E 779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization,* and CAN/CGSB-149.10-M, *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 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 ±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 ±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 8 Pa, 10 Pa, 12 Pa, 15 Pa, 20 Pa, and 40 Pa measured by both ascending and descending pressures (minimum)

(4) Fan calibration at a minimum of three leakage areas (approximate): 0.5 m^2, 0.25 m^2, and 0.05 m^2 measured at a pressure of 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 if 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 ⅛ in. thickness (free of any penetrations) in an unused blower port or other convenient enclosure opening large enough to accept an approximately 0.01 m^2 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 0.05 m^2, 0.1 m^2, and 0.2 m^2, 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 ±15 percent of the hole area cut in the rigid material. If the difference in ELA values is greater than ±15 percent, the door fan apparatus should be recalibrated according to the manufacturer's recommendations and either ASTM E 779 or CAN/CGSB-149.10-M.

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 if 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 leakage 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 Runup 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-M 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:

(1)

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

where:

P_c = pressure due to the halon column (Pa)

g = acceleration due to gravity (9.81 m/sec^2)

H_o = height of protected enclosure (m)

r_m = halon/air mixture density (kg/m^3; see equation 9)

r_a = air density (1.202 kg/m^3)

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 now 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 upwards, 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 ¼ in. of the openings. If neutralization is not possible at all locations, ensure that either smoke 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 either smoke 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 undampered 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-M. 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:

(2)

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

where:

Q_c = corrected flow (m³/sec)

Q_u = uncorrected flow (m³/sec)

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

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

NOTE: When depressurizing, $T_L = T_O$, $T_F = T_I$. When pressurizing, $T_L = T_I$, $T_F = T_O$.

B.2.6.3.4 For equation 2, 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 2 is not used, then the following applies:

$$Q_c = Q_u$$

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/m³ and the discharge coefficient for a hole in a flat plate (door fan) is 0.61. The equation is as follows:

(3)

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

where:

A = area of leaks (m^2)

Q_c = door fan flow, corrected (m^3/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 3 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:

(4)

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

where:

A_d = leakage area (depressurization)

A_p = leakage area (pressurization)

(5)

$$A_T = 0.61(\mathrm{ELA})$$

where:

A_T = total leakage area (m^2)

ELA = equivalent leakage area (m^2)

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 6 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, then equation 7 applies instead. These equations are as follows:

(6)

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

(7)

$$= 0.61(BCLA)$$

where:

A_{LL} = lower leakage area (m^2)

$BCLA$ = below ceiling leakage area (m^2)

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

(8)

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

where:

F_A = lower leak fraction

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:

(9)

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

where:

r_m = halon/air mixture density (kg/m^3)

r_a = air density (1.202 kg/m^3)

c = Halon 1301 concentration (%)

B.2.7.1.5 Static Pressure. Determine the correct value for (P_{SH}) to be used in equation 12; 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:

(10)

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

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%, $H = 5/7 \times 4$ 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:

(11)

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

(12)

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

(13)

$$t = 2A_R\left(\frac{\sqrt{C_3H_o + C_4} - \sqrt{C_3H + C_4}}{C_3F_AA_T}\right)$$

where:

t = time (sec)

C_3 = constant for equation simplification

C_4 = constant for equation simplification

A_R = room floor area (m^2)

g = acceleration due to gravity (9.81 m/sec^2)

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^3

(3) Height of halon-protected enclosure (H_o): 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_{ST}): -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:

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

B.2.7.3.3.2 Calculate the column pressure in the halon-protected enclosure (P_c) using equation 1 *(per B.2.6.1.3)*. Equation 1 requires that the halon/air mixture density (r_m) be known. Thus, the halon/air mixture density (r_m) is first calculated using equation 9 *(per B.2.7.1.4)* as follows:

(9)

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

(1)

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

$P_c < 10$ 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:

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

(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:

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

(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 2, this correction is as follows:

(a) For depressurization,

(2a)

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

(b) For pressurization,

(2b)

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

(4) Calculate the leakage area (A) from the door fan measurements *(per B.2.6.3.5)*. Using equation 3, the calculations are as follows:

(a) For depressurization,

(3a)

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

(b) For pressurization,

(3b)

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

(c) The average is as follows:

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

B.2.7.3.4.2 Retention Calculation.

(1) Calculate the total leakage area (A_T) using equation 5 *(per B.2.7.1.1)* as follows:

(5)

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

(2) Calculate the lower leak area (A_{LL}) using equation 6 *(per B.2.7.1.2)* as follows:

(6)

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

(3) Calculate the leak fraction (F_A) using equation 8 *(per B.2.7.1.3)* as follows:

(8)

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

(4) Calculate the constants for equation simplification (C_3 and C_4) using equations 11 and 12 *(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:

(11)

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

(12)

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

(5) Calculate the minimum time (t) that the enclosure is expected to maintain the descending interface using equation 13 *(per B.2.7.1.7)* as follows:

(13)

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

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

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

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:

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

(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:

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

(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:

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

(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 2, this correction is as follows:

(a) For depressurization,

(2a)

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

(b) For pressurization,

(2b)

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

(5) Calculate the leakage area (A) from the door fan measurements *(per B.2.6.3.5)*. Using equation 3, the calculations are as follows:

(a) For depressurization,

(3a)

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

(b) For pressurization,

(3b)

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

(c) The average is as follows:

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

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

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 5 *(per B.2.7.1.1)* as follows:

(5)

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

(2) Calculate the lower leakage area (A_{LL}) using equation 7 *(per B.2.7.1.2)* as follows:

(7)

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

(3) Calculate the leak fraction (F_A) using equation 8 *(per B.2.7.1.3)* as follows:

(8)

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

(4) Calculate the constants for equation simplification (C_3 and C_4) using equations 11 and 12 *(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:

(11)

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

(12)

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

(5) Calculate the minimum time (t) that the enclosure is expected to maintain the descending interface using equation 13 *(per B.2.7.1.7)* as follows:

(13)

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

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

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

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 assure 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, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, or NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*, 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 printouts

(5) Descriptions of any special techniques utilized by test technician (i.e., use of optional ceiling neutralization and temporary sealing of suspended ceiling)

(6) In 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

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 (CH_4) or ethane (CH_3CH_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 (CF_4), also a gas, is chemically inert, nonflammable, and extremely low in toxicity. Carbon tetrachloride (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 (CBr_4) and carbon tetraiodide (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, CH_2BrCl

(2) Halon 1211, bromochlorodifluoromethane, $CBrClF_2$

(3) Halon 1202, dibromodifluoromethane, CBr_2F_2

(4) Halon 1301, bromotrifluoromethane, $CBrF_3$

(5) Halon 2402, dibromotetrafluoroethane, $CBrF_2CBrF_2$

C.2 Halon Nomenclature System.

The halon system for naming halogenated hydrocarbons was devised by the U.S. 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, $CBrF_3$. 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°F (-167.8°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°F (67°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.

Table C.2.1.1 Physical Properties of Halon 1301

Physical Properties	U.S. Customary	SI
Molecular weight	148.93	148.93
Boiling point at 1 atm	-71.95°F	-57.75°C
Freezing point	-270°F	-168°C
Critical temperature	152.6°F	67.0°C
Critical pressure	575 psia	39.6 bar

Table C.2.1.1 Physical Properties of Halon 1301

Physical Properties	U.S. Customary	SI
Critical volume	0.0215 ft^3/lb	0.000 276 m^3/k
Critical density	46.5 lb/ft^3	745 kg/m^3
Specific heat, liquid, at 77°F (25°C)	0.208 Btu/lb-°F	870 J/kg-°C
Specific heat, vapor, at constant pressure (1 atm) and 77°F (25°C)	0.112 Btu/lb-°F	469 J/kg-°C
Heat of vaporization at boiling point	51.08 Btu/lb	118.8 kJ/kg
Thermal conductivity of liquid at 77°F (25°C)	0.024 Btu/hr-ft-°F	0.85 W/m-K
Viscosity, liquid, at 77°F (25°C)	1.01×10^{-4} lb/ft-sec	1.59×10^{-4} Centip
Viscosity, vapor, at 77°F (25°C)	1.08×10^{-5} lb/ft-sec	1.63×10^{-5} Centip
Surface tension at 77°F (25°C)	4 dynes/cm	0.004 N/m
Refractive index of liquid at 77°F (25°C)	1.238	1.238
Relative dielectric strength at 1 atm, 77°F (25°C) (nitrogen = 1.00)	1.83	1.83
Solubility of Halon 1301 in water at 1 atm 77°F (25°C)	0.03% by weight	0.03% by weigh
Solubility of water in Halon 1301 at 70°F (21°C)	0.0095% by weight	0.0095% by weig

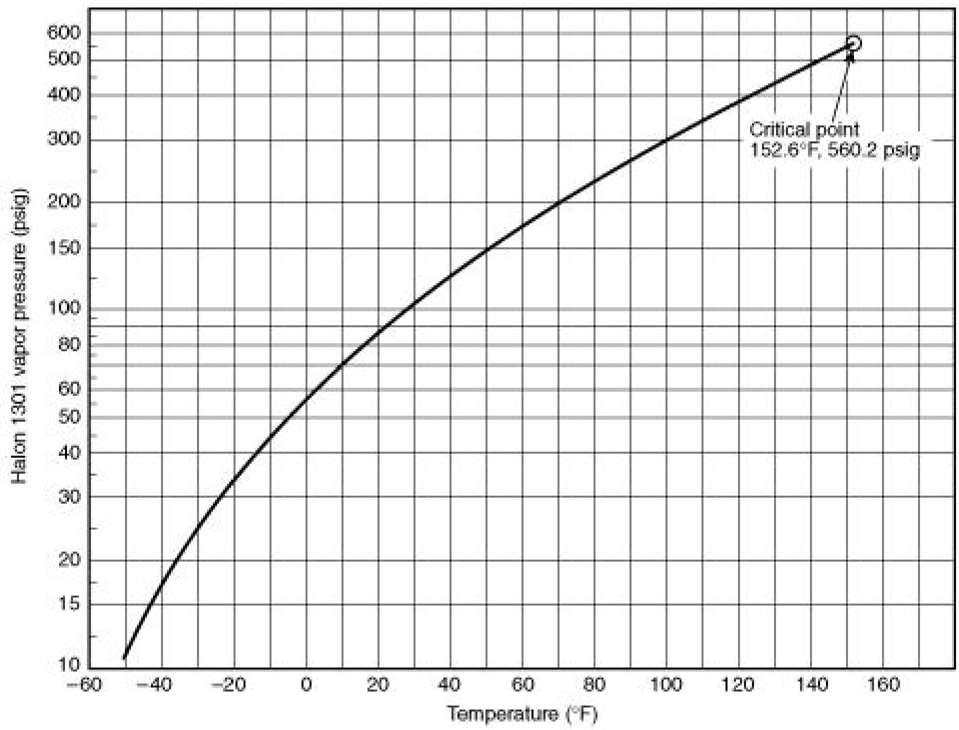

FIGURE C.2.1.1(a) Vapor Pressure of Halon 1301 vs. Temperature.

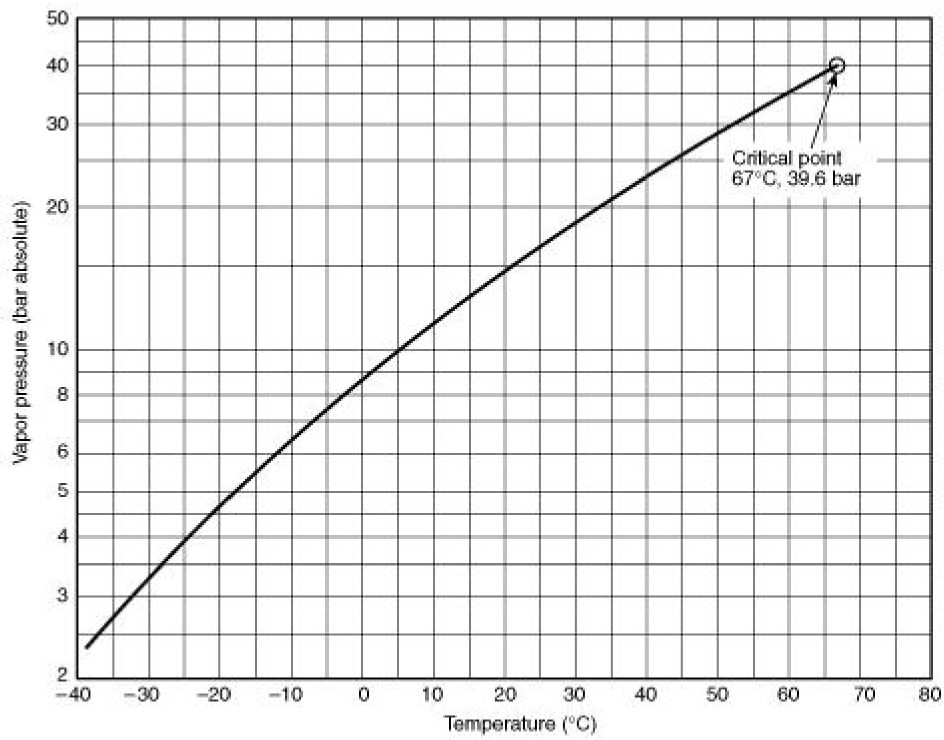

FIGURE C.2.1.1(b) (Metric).

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, gunpowder, and so forth.

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:

$$CBrF_3 \rightarrow CF_3 + Br$$

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,

$$R - H + Br\bullet \rightarrow R\bullet + HBr$$

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

$$HBr + OH\bullet \rightarrow H_2O + Br\bullet$$

The bromide radical again reacts with more fuel, and so on, with the result that active H•, OH•, and O: radicals are removed, and less reactive alkyl radicals are produced.

The “ionic” theory supposes that the uninhibited combustion process includes a step in which 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 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, *Standard for Portable Fire Extinguishers*.

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 will have 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_2 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_2) with small amounts of carbonyl halides (COF_2, $COBr_2$).

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, then 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^2 (2.3 m^2) heptane fire in a 10,000 ft^3 (283 m^3) 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 U.S. Department of Transportation requirements will be used. Manifolded 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:

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

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 Pa = partial pressure of agent vapor.

By ideal solution law

(3) $P_a = P_v X_a$

where

(4) P_v = vapor pressure of agent

(5) X_a = liquid mole fraction of agent

(6) $X_a = 1 - X_n$, where X_n is liquid mole fraction of nitrogen

From (2), (3), (6) we get

(7) $P = P_n + (1 - X_n)P_v$, 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^3 (1566 kg/m^3) 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^3 (1121 kg/m^3) 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.

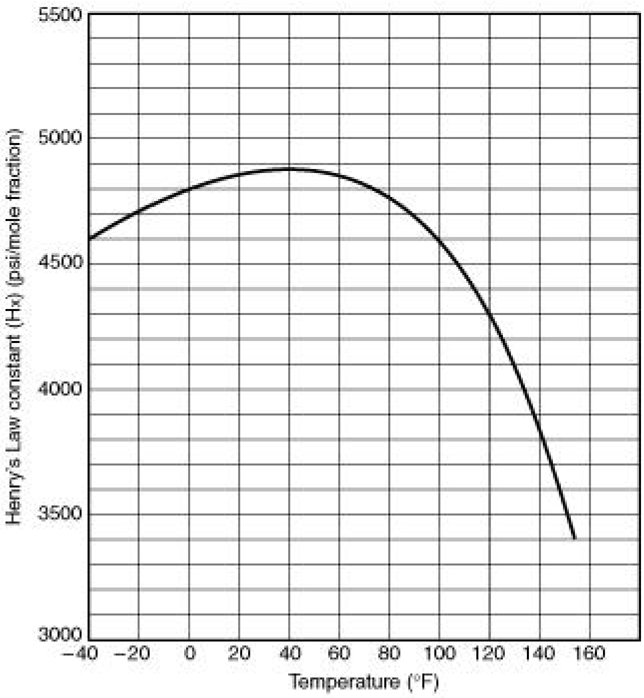

FIGURE E.1.1(a) Henry's Law Constant for Nitrogen Solubility in Liquid Halon 1301.

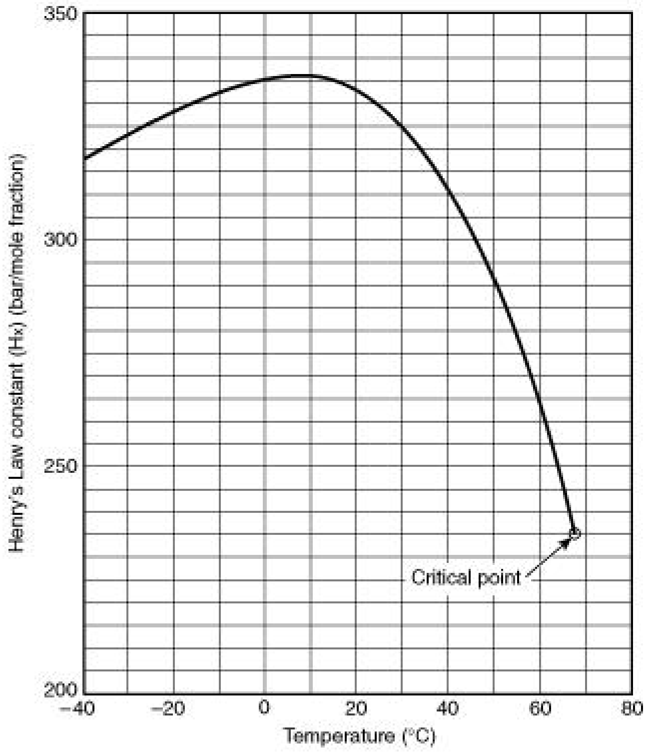

FIGURE E.1.1(b) (Metric).

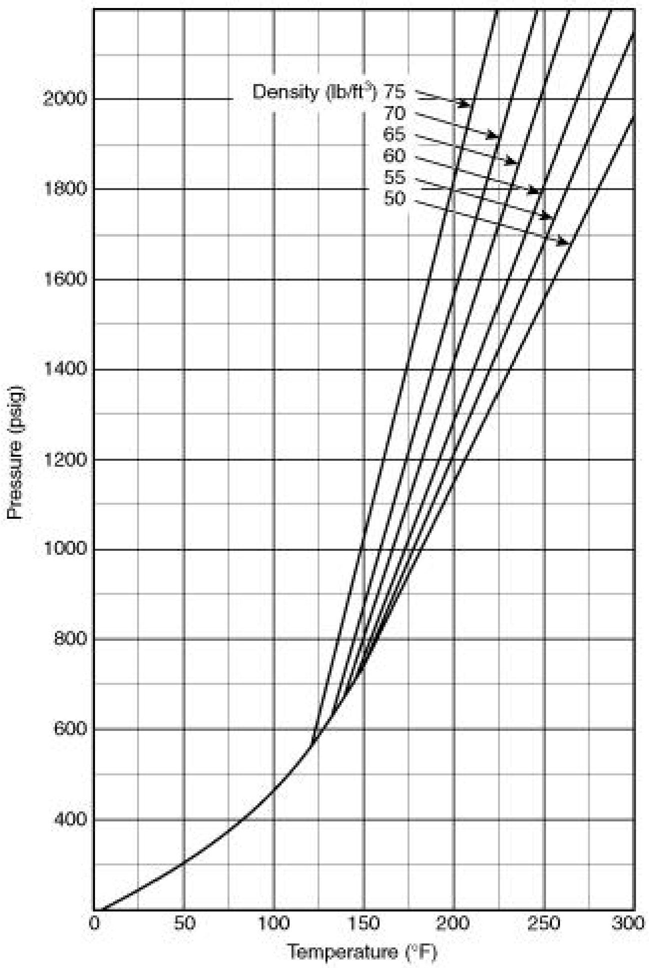

FIGURE E.1.1(c) Isometric Diagram. Halon 1301 Pressurized to 360 psig at 70°F.

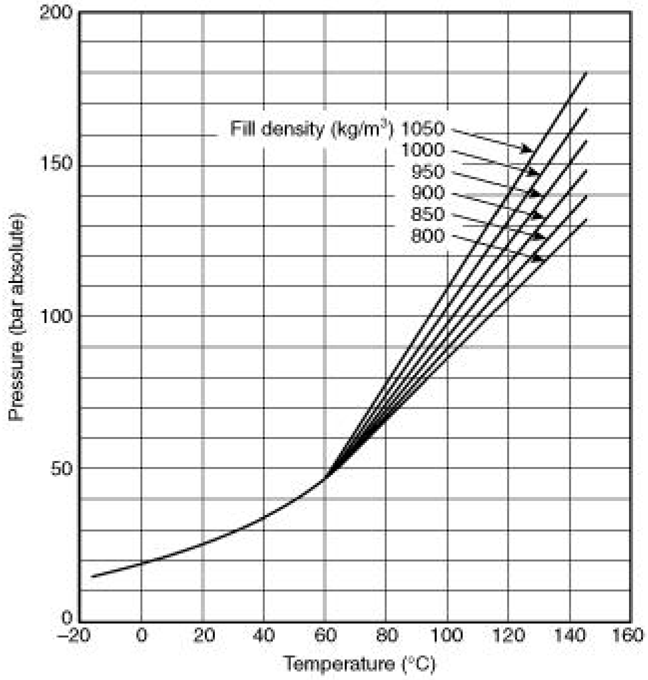

FIGURE E.1.1(d) (Metric).

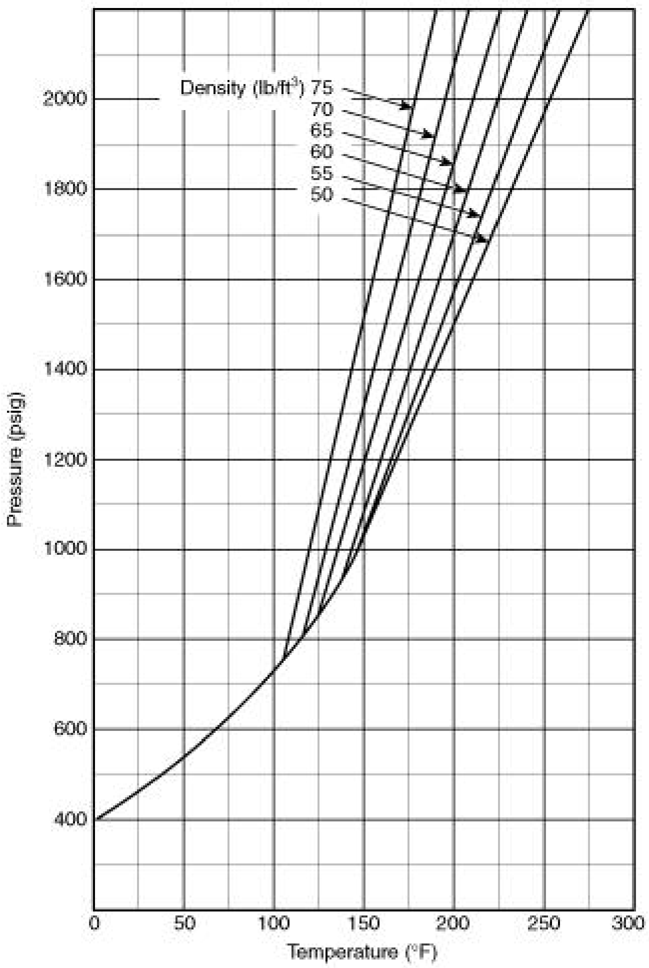

FIGURE E.1.1(e) Isometric Diagram. Halon 1301 Pressurized to 600 psig at 70°F.

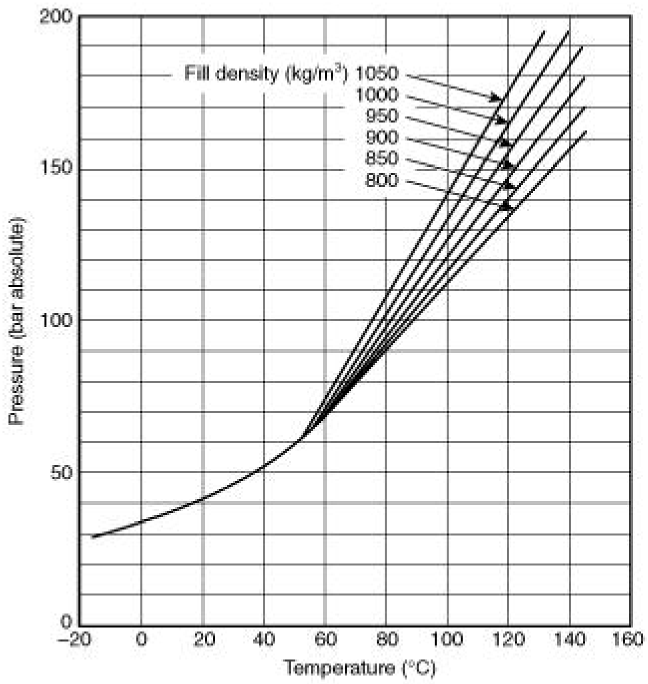

FIGURE E.1.1(f) (Metric).

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

The following 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. Paragraph 4.2.1.1 requires that "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.

F.2 Minimum Piping Requirements for Halon 1301 Systems.

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, tensile strength of the material, yield strength of the material, and temperature limitations of the material

(3) Joining methods (i.e., threaded, welded, grooved, etc.)

(4) Pipe construction method [i.e., seamless, ERW (electric resistance welded), furnace welded, etc.]

(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 A 53, *Standard Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded Seamless*, or ASTM A 106, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service*, and copper tubing conforming to ASTM B 88, *Specifications 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:

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

where:

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

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 ¼ of the tensile strength of the piping material or $\frac{2}{3}$ 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 following listing gives values for *SE* as taken from Appendix A of ASME B31, *Code for Pressure Piping*. Identical values are given in ASME B31.1, *Power Piping Code,* and ASME B31.9, *Building Services Piping*.

	Document	***SE* Value**
Grade C Seamless Pipe	ASTM A 106	17500 psi (120662 kPa)
Grade B Seamless Pipe	ASTM A 53	15000 psi (103425 kPa)
Grade B Seamless Pipe	ASTM A 106	15000 psi (103425 kPa)
Grade A Seamless Pipe	ASTM A 53	12000 psi (82740 kPa)
Grade A Seamless Pipe	ASTM A 106	12000 psi (82740 kPa)
Grade B ERW Pipe	ASTM A 53	12800 psi (88256 kPa)
Grade A ERW Pipe	ASTM A 53	10200 psi (70329 kPa)
Class F Furnace Welded Pipe	ASTM A 53	7200 psi (49608 kPa)
Seamless Copper Tubing (Annealed)	ASTM B 88	5100 psi (35164 kPa)
Seamless Copper Tubing (Drawn)	ASTM B 88	9000 psi (62055 kPa)

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

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

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 the *Power Piping Code* (ASME B31.1) 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 of any 24-hour period. Since the halon piping is normally unpressurized, the system discharge period 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 outlined in Paragraph 4 (per Appendix A of the *Power Piping Code*). The specific values for maximum allowable stress used in these calculations are as follows:

	Document	***SE* Value**
Grade C Seamless Pipe	ASTM A 106	21000 psi (144795 kPa)
Grade B Seamless Pipe	ASTM A 53	18000 psi (124110 kPa)
Grade B Seamless Pipe	ASTM A 106	18000 psi (124110 kPa)
Grade A Seamless Pipe	ASTM A 53	14400 psi (99288 kPa)
Grade A Seamless Pipe	ASTM A 106	14400 psi (99288 kPa)
Grade B ERW	ASTM A 53	15360 psi (105907 kPa)
Grade A ERW Pipe	ASTM A 53	12240 psi (84395 kPa)
Class F Furnace Welded Pipe	ASTM A 53	8640 psi (59573 kPa)
Seamless Copper Tubing (Annealed)	ASTM B 88	6120 psi (42197 kPa)
Seamless Copper Tubing (Drawn)	ASTM B 88	10800 psi (74466 kPa)

NOTE 1: When using rolled groove connections, or welded connections with internal projections (backup rings, etc.), the hydraulic calculations should consider these factors.

NOTE 2: Pipe supplied as dual stenciled A 120/A 53 Class F meets the requirements of Class F furnace welded pipe ASTM A 53 as listed above. Ordinary cast-iron pipe, steel pipe conforming to ASTM A 120, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service,* or nonmetallic pipe should not be used.

NOTE 3: All grooved couplings/fittings should be listed/approved for use with Halon 1301 extinguishing systems.

NOTE 4: These calculations do not apply to extended discharge exceeding 14.4 minutes.

NOTE 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].

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

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. Equivalent 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:

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

where:

ΔP = pressure drop (psi)

ρ = pipeline density of agent at point of elevation change (lb/ft^3)

ΔEL = 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).

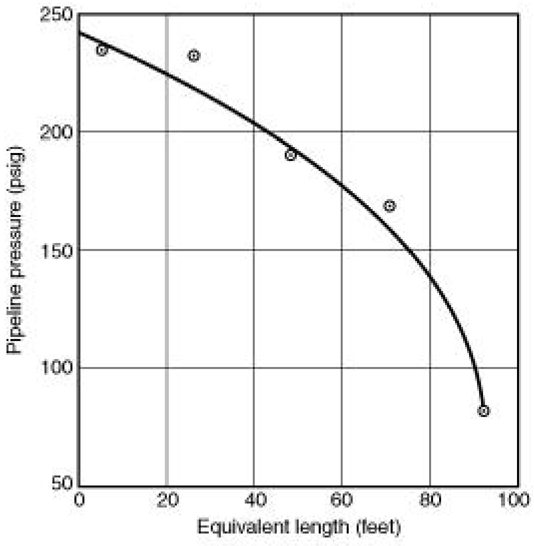

FIGURE G.1 Comparison of Test Data with Calculated Pressure Drop Using Two-Phase Flow Equation.

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
⅜	0.6	1.3	0.8	2.7	0.3
½	0.8	1.7	1.0	3.4	0.4
¾	1.0	2.2	1.4	4.5	0.5
1	1.3	2.8	1.8	5.7	0.6
1¼	1.7	3.7	2.3	7.5	0.8
1½	2.0	4.3	2.7	8.7	0.9
2	2.6	5.5	3.5	11.2	1.2
2½	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°	Tee Thru Flow	Tee Side	Coupling or Gate Valve

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
⅜	0.2	0.7	0.5	1.6	0.3
½	0.3	0.8	0.7	2.1	0.4
¾	0.4	1.1	0.9	2.8	0.5
1	0.5	1.4	1.1	3.5	0.6
1¼	0.7	1.8	1.5	4.6	0.8
1½	0.8	2.1	1.7	5.4	0.9
2	1.0	2.8	2.2	6.9	1.2
2½	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)
⅛	0.20	0.11
¼	0.34	0.24
⅜	0.68	0.48
½	1.0	0.79
¾	2.0	1.9
1	3.4	2.8
1¼	5.8	4.8
1½	8.4	7.5
2	13	13
2½	19.5	17
3	33	26
4	58	48
5	95	81
6	127	109

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)

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

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

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.

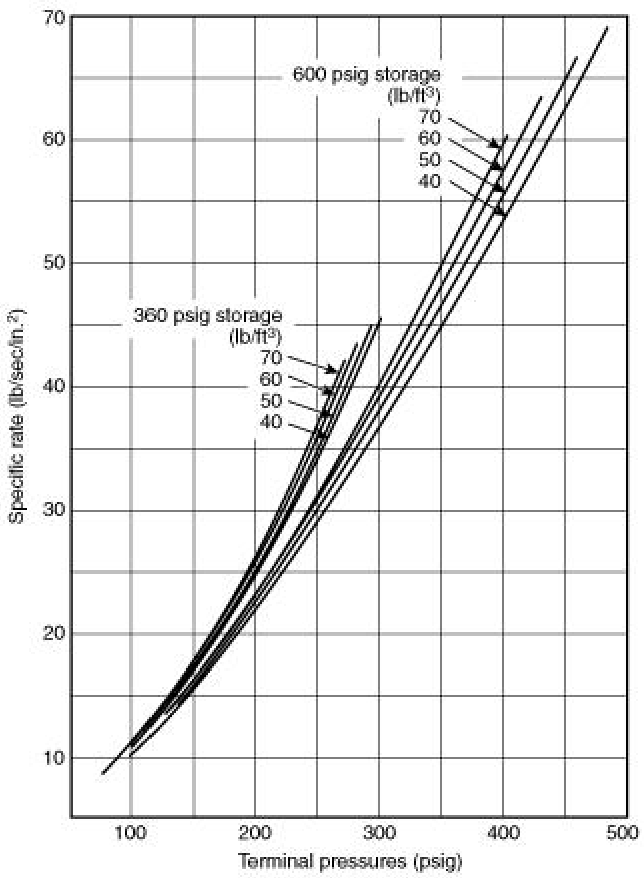

FIGURE H.1(a) Calculated Maximum Open-End Pipe Specific Flow Rate versus Total Terminal Pressure.

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:

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

where:

Q = nozzle rate (lb/sec)

ρ = density (lb/ft³) 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.

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

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

where:

Σ = summation of (Vp) (ρ) values for all pipeline sections

Vp = internal volume of each section of piping (ft^3)

ρ = average pipeline density of agent for each section of piping (lb/ft^3)

W = initial charge weight of Halon 1301 (lb)

NOTE: Internal volume figures for steel pipe and tubing are given in Table H.1(a), Table H.1(b), and Table H.1(c).

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 psig (4137 and 2482 kPa) storage is plotted on 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.

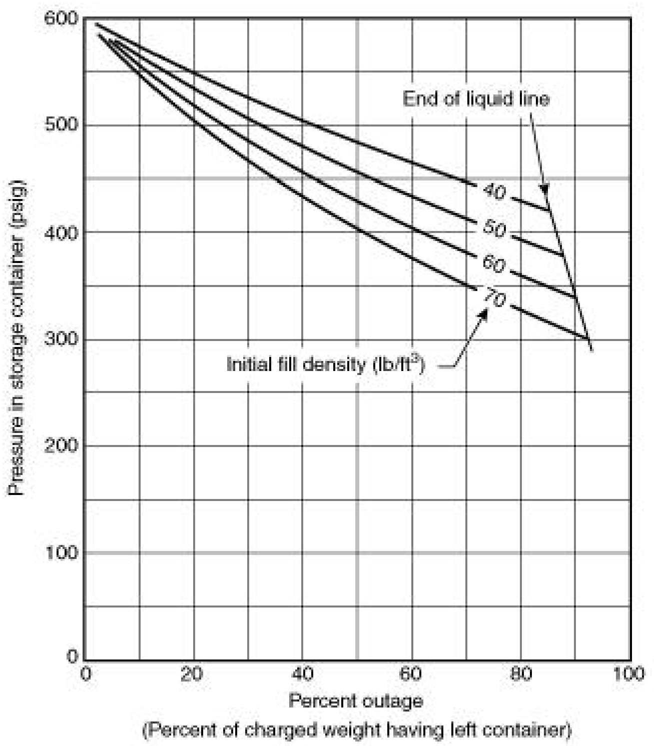

FIGURE H.1(b) Calculated Pressure Recession for 600 psig Storage.

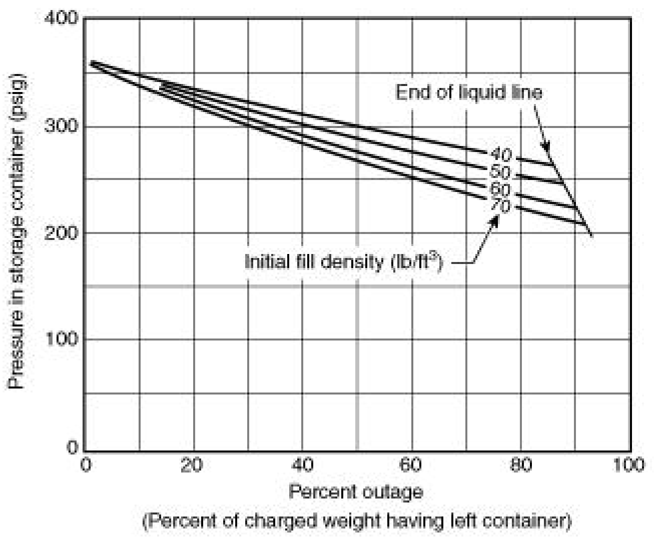

FIGURE H.1(c) Calculated Pressure Recession for 360 psig Storage.

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 psig (4137 kPa) system with initial filling density of 70 lb/ft^3 (1121 kg/m^3) is reduced from a maximum of 403 psig (2779 kPa) to 355 psig (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 quantity of agent in the piping system during discharge is a function of the actual volume of the piping times the average density of the agent. The average density cannot be accurately determined until after the terminal pressure has been calculated. The problem does not have a direct solution; however, the following equation 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.

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

where:

W = initial charge weight of Halon 1301 (lb)

V_p = internal pipe volume (ft^3)

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

An alternative solution of the percent in piping after terminal pressures have been calculated is to use the percent in piping equation. Average density values can be obtained from Figure H.1(f) for the 600 psig (4137 kPa) systems and from Figure H.1(g) for the 360 psig (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.

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

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

In no case should the nozzle pressure be lower than the listed pressure.

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

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

Storage (psig)	Filling 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

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

Storage (psig)	Filling Density	K_1	K_2
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 Pipe Diameter	Schedule 40 Inside Diameter		Schedule 80 Inside Diameter	
in.	in.	ft^3/ft	in.	ft^3/ft
¼	0.364	0.0007	0.302	0.0005
⅜	0.493	0.0013	0.423	0.0010
½	0.622	0.0021	0.546	0.0016
¾	0.824	0.0037	0.742	0.0030
1	1.049	0.0060	0.957	0.0050
1¼	1.380	0.0104	1.278	0.0089
1½	1.610	0.0141	1.500	0.0123
2	2.067	0.0233	1.939	0.0205
2½	2.469	0.0332	2.323	0.0294
3	3.068	0.0513	2.900	0.0459
3½	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^3/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

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

Size	Type	Actual Inside Diameter (in.)	Internal Volume (ft^3/ft)
	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) Precalculated *A* and *B* Factors for Steel Pipe

Pipe Size	Schedule 40		Schedule 80	
Nominal	*A*	*B*	*A*	*B*
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(d) Precalculated *A* and *B* Factors for Steel Pipe

Pipe Size	Schedule 40		Schedule 80	
Nominal	*A*	*B*	*A*	*B*

Table H.1(e) Halon 1301 at 600 psig and 70 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
400	0.006	290	194	97	0	0	0	0	0
390	0.028	1243	1149	1054	960	865	769	674	578
380	0.051	2176	2084	1991	1898	1806	1712	1619	1525
370	0.076	3086	2996	2906	2816	2725	2634	2543	2451
360	0.102	3974	3886	3798	3710	3622	3533	3444	3355
350	0.129	4838	4753	4667	4581	4495	4409	4323	4236
340	0.159	5678	5595	5512	5428	5345	5261	5177	5093
330	0.191	6492	6412	6331	6251	6169	6088	6007	5925
320	0.224	7281	7203	7125	7047	6968	6890	6811	6731
310	0.260	8042	7967	7892	7816	7741	7665	7588	7512
300	0.298	8776	8704	8631	8559	8486	8413	8339	8265
290	0.339	9482	9412	9343	9273	9203	9132	9062	8991
280	0.382	10158	10092	10025	9958	9891	9823	9756	9688
270	0.429	10805	10741	10678	10614	10550	10485	10420	10355
260	0.478	11421	11361	11300	11239	11178	11117	11055	10993
250	0.531	12007	11950	11892	11834	11776	11718	11659	11600
240	0.588	12561	12507	12453	12398	12343	12288	12232	12176
230	0.649	13084	13033	12982	12930	12878	12826	12774	12721
220	0.713	13575	13527	13479	13431	13382	13333	13284	13234
210	0.782	14034	13990	13945	13900	13854	13808	13762	13716
200	0.855	14462	14421	14379	14337	14295	14252	14209	14166
190	0.934	14859	14820	14782	14743	14704	14664	14624	14584
180	1.017	15225	15190	15154	15118	15082	15046	15009	14972
170	1.105	15561	15528	15496	15463	15430	15396	15363	15329

Table H.1(e) Halon 1301 at 600 psig and 70 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
130	1.513	16624	16603	16581	16559	16537	16514	16491	16469
120	1.631	16826	16807	16787	16768	16748	16728	16708	16687
110	1.755	17004	16987	16970	16953	16935	16918	16900	16882
100	1.888	17161	17147	17132	17116	17101	17085	17070	17054
90	2.029	17298	17286	17273	17259	17246	17232	17219	17205
80	2.181	17417	17406	17395	17383	17372	17360	17348	17336
70	2.347	17518	17509	17499	17489	17479	17469	17459	17449
60	2.530	17603	17595	17587	17579	17571	17562	17554	17545

Table H.1(f) Halon 1301 at 600 psig and 60 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
420	0.019	956	861	766	671	575	480	384	289	
410	0.039	1893	1800	1707	1614	1520	1426	1333	1239	1
400	0.060	2811	2720	2629	2537	2446	2354	2262	2170	2
390	0.083	3709	3620	3531	3442	3352	3262	3172	3082	2
380	0.106	4587	4500	4413	4325	4238	4150	4062	3974	3
370	0.132	5443	5358	5273	5188	5103	5017	4932	4846	4
360	0.158	6277	6195	6112	6029	5946	5863	5779	5696	5
350	0.187	7089	7009	6929	6848	6767	6686	6605	6523	6
340	0.217	7877	7800	7722	7643	7565	7486	7407	7328	7
330	0.249	8642	8566	8491	8415	8339	8263	8186	8109	8
320	0.283	9381	9308	9235	9162	9088	9014	8940	8866	8
310	0.319	10095	10025	9954	9883	9812	9741	9670	9598	9
300	0.358	10783	10715	10647	10579	10511	10442	10373	10304	1
290	0.399	11444	11379	11314	11248	11183	11117	11050	10984	1
280	0.442	12077	12015	11953	11890	11827	11764	11701	11637	1
270	0.489	12683	12624	12564	12504	12444	12384	12323	12262	1
260	0.538	13261	13204	13148	13090	13033	12976	12918	12859	1

Table H.1(f) Halon 1301 at 600 psig and 60 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
250	0.591	13809	13756	13702	13648	13593	13539	13484	13428	1
240	0.647	14329	14278	14227	14176	14125	14073	14021	13968	1
230	0.707	14820	14772	14724	14675	14627	14578	14529	14479	1
220	0.770	15281	15236	15191	15145	15100	15054	15008	14961	1
210	0.838	15713	15671	15629	15586	15543	15500	15457	15413	1
200	0.909	16116	16077	16037	15998	15958	15918	15877	15837	1
190	0.985	16490	16454	16417	16381	16344	16306	16269	16231	1
180	1.066	16836	16802	16769	16735	16701	16666	16632	16597	1
170	1.152	17154	17123	17093	17061	17030	16998	16966	16934	1
160	1.243	17445	17418	17389	17361	17332	17303	17274	17244	1
150	1.339	17711	17685	17660	17634	17608	17581	17555	17528	1
140	1.441	17951	17928	17905	17882	17858	17834	17810	17786	1
130	1.549	18168	18147	18126	18105	18084	18062	18041	18019	1
120	1.664	18361	18343	18324	18306	18287	18267	18248	18228	1
110	1.785	18534	18517	18501	18484	18467	18450	18433	18415	1
100	1.914	18686	18671	18657	18642	18627	18612	18597	18581	1
90	2.052	18818	18806	18793	18781	18767	18754	18741	18727	1
80	2.201	18934	18923	18912	18901	18890	18878	18867	18855	1
70	2.363	19032	19023	19014	19004	18995	18985	18975	18965	1
60	2.543	19116	19108	19100	19092	19084	19076	19068	19059	1

Table H.1(g) Halon 1301 at 600 psig and 50 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
450	0.012	667	573	478	382	287	192	96	0	0
440	0.030	1607	1513	1420	1327	1233	1139	1045	951	857
430	0.049	2529	2437	2346	2254	2162	2070	1978	1885	1792
420	0.068	3434	3344	3254	3164	3074	2984	2893	2802	2711

Table H.1(g) Halon 1301 at 600 psig and 50 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
410	0.089	4321	4233	4145	4056	3968	3879	3791	3702	3613
400	0.111	5189	5103	5017	4930	4844	4757	4670	4583	4496
390	0.134	6038	5954	5870	5785	5701	5616	5531	5446	5360
380	0.158	6867	6785	6702	6620	6538	6455	6372	6289	6205
370	0.184	7675	7595	7515	7435	7354	7273	7192	7111	7030
360	0.212	8462	8384	8306	8228	8150	8071	7992	7913	7834
350	0.241	9227	9151	9076	9000	8924	8847	8771	8694	8617
340	0.272	9970	9896	9823	9749	9675	9601	9527	9452	9377
330	0.304	10689	10618	10547	10476	10404	10332	10260	10188	10115
320	0.339	11385	11316	11247	11178	11109	11040	10970	10900	10830
310	0.375	12056	11990	11924	11857	11790	11723	11656	11589	11521
300	0.414	12702	12639	12575	12511	12447	12382	12318	12252	12187
290	0.455	13324	13263	13201	13140	13078	13016	12954	12891	12829
280	0.499	13919	13861	13802	13743	13684	13625	13565	13505	13445
270	0.546	14488	14432	14376	14320	14264	14207	14150	14092	14035
260	0.595	15031	14978	14924	14871	14817	14763	14708	14654	14599
250	0.647	15546	15496	15445	15394	15343	15292	15240	15188	15136
240	0.703	16035	15987	15939	15891	15842	15794	15745	15696	15646
230	0.762	16496	16451	16406	16360	16315	16269	16222	16176	16129
220	0.825	16930	16888	16845	16802	16759	16716	16673	16629	16585
210	0.892	17337	17297	17257	17217	17177	17137	17096	17055	17013
200	0.962	17716	17680	17642	17605	17568	17530	17492	17453	17415
190	1.037	18069	18035	18001	17966	17931	17896	17861	17825	17789
180	1.117	18396	18365	18333	18301	18269	18236	18203	17170	18137
170	1.201	18698	18669	18639	18610	18580	18550	18520	18489	18459
160	1.290	18974	18947	18921	18894	18866	18839	18811	18783	18755
150	1.384	19226	19202	19178	19153	19128	19103	19078	19052	19026
140	1.484	19455	19433	19411	19389	19366	19343	19320	19297	19274
130	1.589	19662	19642	19622	19602	19582	19561	19540	19519	19498

Table H.1(g) Halon 1301 at 600 psig and 50 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
120	1.701	19847	19829	19811	19793	19775	19757	19738	19719	19700
110	1.820	20012	19996	19981	19965	19948	19932	19915	19898	19881
100	1.947	20158	20144	20130	20116	20102	20087	20073	20058	20043
90	2.083	20286	20274	20262	20249	20237	20224	20211	20198	20185
80	2.229	20397	20387	20376	20366	20355	20344	20333	20321	20310
70	2.385	20493	20484	20475	20466	20457	20447	20437	20428	20418
60	2.555	20574	20567	20559	20551	20543	20535	20527	20519	20510

Table H.1(h) Halon 1301 at 600 psig and 40 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
480	0.008	475	380	285	190	95	0	0	0	
470	0.024	1414	1321	1227	1134	1040	9469	852	758	
460	0.041	2337	2246	2154	2062	1970	1878	1785	1692	
450	0.058	3245	3155	3065	2975	2884	2793	2702	2611	[illegible]
440	0.076	4137	4049	3960	3871	3782	3693	3604	3515	[illegible]
430	0.096	5012	4926	4839	4752	4664	4577	4489	4402	[illegible]
420	0.116	5871	5785	5700	5615	5529	5444	5358	5272	[illegible]
410	0.137	6711	6628	6544	6461	6377	6293	6209	6125	[illegible]
400	0.160	7533	7452	7370	7288	7206	7124	7042	6959	[illegible]
390	0.184	8336	8257	8177	8097	8017	7937	7856	7776	[illegible]
380	0.209	9120	9042	8965	8887	8809	8730	8652	8573	[illegible]
370	0.236	9883	9808	9732	9656	9580	9504	9428	9351	[illegible]
360	0.264	10627	10553	10480	10406	10332	10258	10183	10109	1
350	0.293	11348	11277	11206	11134	11062	10990	10918	10845	1
340	0.325	12049	11980	11910	11841	11771	11701	11631	11561	1
330	0.358	12727	12660	12593	12526	12458	12391	12323	12254	1
320	0.393	13382	13318	13253	13188	13123	13057	12992	12926	1

Table H.1(h) Halon 1301 at 600 psig and 40 lb/ft³ *Y* and *Z* Factors

		Y								
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
310	0.430	14014	13952	13890	13827	13764	13701	13638	13574	1
300	0.469	14623	14563	14503	14443	14382	14321	14260	14199	1
290	0.511	15207	15150	15092	15034	14976	14918	14859	14800	1
280	0.555	15767	15712	15657	15601	15546	15490	15434	15378	1
270	0.602	16302	16250	16197	16144	16091	16038	15984	15930	1
260	0.651	16812	16762	16712	16662	16611	16560	16509	16458	1
250	0.704	17296	17249	17202	17154	17106	17057	17009	16960	1
240	0.759	17756	17711	17666	17621	17575	17529	17483	17437	1
230	0.818	18189	18147	18105	18062	18019	17976	17932	17888	1
220	0.880	18597	18558	18518	18478	18437	18397	18356	18314	1
210	0.946	18980	18943	18906	18868	18830	18792	18754	18715	1
200	1.016	19338	19303	19268	19233	19198	19162	19126	19090	1
190	1.090	19671	19639	19606	19574	19541	19508	19474	19440	1
180	1.168	19979	19950	19920	19889	19859	19828	19797	19766	1
170	1.251	20264	20237	20209	20181	20153	20125	20096	20067	2
160	1.339	20526	20500	20475	20449	20424	20398	20371	20345	2
150	1.431	20764	20742	20718	20695	20672	20648	20624	20600	2
140	1.529	20982	20961	20940	20919	20897	20876	20854	20832	2
130	1.633	21178	21159	21140	21121	21102	21082	21063	21043	2
120	1.744	21354	21338	21321	21304	21286	21269	21251	21233	2
110	1.861	21512	21497	21482	21467	21451	21435	21420	21404	2
100	1.986	21651	21638	21625	21611	21598	21584	21570	21556	2
90	2.120	21774	21763	21751	21739	21727	21715	21702	21690	2
80	2.264	21881	21871	21861	21850	21840	21829	21819	21808	2
70	2.420	21973	21964	21955	21947	21938	21929	21919	21910	2
60	2.591	22051	22044	22036	22029	22021	22013	22006	21998	2

Table H.1(i) Halon 1301 at 360 psig and 70 lb/ft³ *Y* and *Z* Factors

Table H.1(i) Halon 1301 at 360 psig and 70 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
260	0.050	962	868	773	678	583	487	391	294
250	0.105	1874	1785	1696	1606	1515	1424	1333	1241
240	0.166	2735	2652	2567	2483	2397	2311	2225	2138
230	0.233	3543	3465	3386	3307	3227	3146	3065	2984
220	0.307	4297	4224	4150	4076	4002	3927	3851	3775
210	0.387	4994	4927	4859	4791	4722	4652	4582	4512
200	0.475	5635	5573	5511	5449	5385	5322	5257	5192
190	0.570	6220	6164	6107	6050	5993	5935	5876	5816
180	0.673	6750	6699	6648	6597	6544	6492	6439	6385
170	0.783	7227	7181	7135	7089	7042	6995	6947	6898
160	0.899	7652	7612	7571	7530	7488	7446	7403	7359
150	1.021	8030	7994	7958	7922	7885	7847	7809	7771
140	1.149	8364	8332	8300	8268	8235	8202	8169	8135
130	1.282	8656	8629	8601	8573	8544	8515	8486	8456
120	1.422	8912	8888	8864	8839	8814	8789	8763	8737
110	1.567	9133	9113	9092	9070	9049	9027	9004	8982
100	1.719	9324	9306	9288	9270	9251	9232	9213	9194
90	1.879	9488	9472	9457	9441	9425	9409	9393	9376
80	2.047	9626	9614	9600	9587	9574	9560	9546	9532
70	2.225	9743	9732	9721	9710	9699	9687	9676	9664
60	2.417	9840	9831	9822	9813	9804	9794	9784	9774

Table H.1(j) Halon 1301 at 360 psig and 60 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
280	0.004	98	0	0	0	0	0	0	0
270	0.051	1056	962	868	774	678	583	487	39

Table H.1(j) Halon 1301 at 360 psig and 60 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
260	0.102	1969	1880	1790	1700	1609	1518	1427	13
250	0.158	2834	2750	2665	2579	2494	2407	2321	22
240	0.219	3650	3571	3491	3410	3330	3248	3166	30
230	0.286	4415	4341	4266	4191	4115	4039	3962	38
220	0.360	5129	5060	4990	4920	4850	4779	4707	46
210	0.440	5789	5726	5662	5597	5532	5466	5399	53
200	0.527	6397	6339	6280	6220	6160	6100	6039	59
190	0.621	6952	6899	6845	6791	6736	6681	6625	65
180	0.722	7456	7408	7359	7310	7260	7210	7160	71
170	0.829	7910	7866	7823	7778	7734	7689	7643	75
160	0.942	8316	8278	8239	8199	8159	8119	8078	80
150	1.062	8678	8644	8609	8574	8538	8503	8466	84
140	1.187	8998	8968	8937	8906	8875	8843	8811	87
130	1.318	9280	9254	9227	9199	9172	9144	9115	90
120	1.455	9527	9503	9480	9456	9432	9408	9383	93
110	1.598	9741	9721	9700	9680	9659	9638	9616	95
100	1.748	9926	9909	9891	9873	9855	9837	9818	97
90	1.905	10085	10070	10055	10040	10024	10009	9993	99
80	2.071	10220	10207	10195	10182	10169	10155	10142	101
70	2.248	10334	10323	10313	10302	10291	10279	10268	102
60	2.437	10429	10420	10411	10402	10393	10384	10374	103

Table H.1(k) Halon 1301 at 360 psig and 50 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
290	0.008	195	98	0	0	0	0	0	0
280	0.051	1148	1055	961	867	772	677	581	48
270	0.098	2059	1970	1880	1790	1700	1609	1518	14

Table H.1(k) Halon 1301 at 360 psig and 50 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
260	0.150	2926	2841	2756	2670	2584	2498	2411	23
250	0.206	3747	3667	3586	3505	3424	3342	3260	31
240	0.268	4521	4446	4370	4294	4217	4140	4062	39
230	0.335	5247	5177	5106	5035	4963	4890	4818	47
220	0.408	5925	5859	5793	5727	5660	5592	5524	54
210	0.487	6552	6491	6430	6369	6307	6244	6181	61
200	0.573	7129	7074	7018	6961	6904	6847	6789	67
190	0.666	7658	7607	7556	7504	7452	7400	7347	72
180	0.764	8138	8092	8046	7999	7952	7904	7856	78
170	0.870	8572	8530	8489	8446	8404	8361	8317	82
160	0.981	8961	8924	8887	8849	8810	8772	8733	86
150	1.097	9308	9275	9242	9208	9174	9140	9105	90
140	1.220	9617	9587	9558	9528	9498	9467	9436	94
130	1.348	9889	9863	9837	9811	9784	9757	9730	97
120	1.482	10127	10105	10082	10059	10036	10012	9988	99
110	1.623	10335	10316	10296	10276	10255	10235	10214	101
100	1.770	10515	10498	10481	10464	10446	10428	10410	103
90	1.926	10670	10656	10641	10626	10611	10596	10580	105
80	2.090	10802	10790	10777	10765	10752	10739	10725	107
70	2.264	10913	10903	10893	10882	10871	10860	10849	108
60	2.454	11006	10998	10989	10980	10971	10962	10953	109

Table H.1(l) Halon 1301 at 360 psig and 40 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
300	0.011	292	195	98	0	0	0	0	0
290	0.051	1239	1146	1053	959	865	770	675	58
280	0.094	2149	2060	1970	1880	1790	1669	1608	15
270	0.142	3017	2932	2847	2761	2675	2588	2501	24
260	0.194	3843	3763	3682	3600	3518	3436	3353	32
250	0.251	4626	4550	4473	4396	4318	4240	4162	40

Table H.1(l) Halon 1301 at 360 psig and 40 lb/ft³ *Y* and *Z* Factors

		Y							
psig	***Z***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
240	0.313	5363	5292	5219	5147	5074	5000	4926	48
230	0.380	6055	5988	5920	5852	5784	5715	5646	55
220	0.453	6700	6637	6574	6511	6447	6383	6318	62
210	0.532	7297	7240	7182	7123	7064	7004	6944	68
200	0.616	7848	7795	7742	7688	7634	7579	7523	74
190	0.707	8353	8304	8256	8206	8156	8106	8056	80
180	0.805	8812	8768	8724	8679	8634	8588	8542	84
170	0.908	9228	9188	9148	9107	9066	9025	8983	89
160	1.016	9601	9566	9530	9493	9457	9420	9382	93
150	1.131	9936	9904	9872	9839	9807	9773	9740	97
140	1.251	10233	10205	10176	10148	10118	10089	10059	100
130	1.377	10496	10471	10446	10421	10395	10369	10342	103
120	1.508	10727	10705	10683	10661	10638	10615	10592	105
110	1.646	10929	10910	10891	10872	10852	10832	10811	107
100	1.792	11105	11088	11072	11055	11038	11020	11003	109
90	1.945	11256	11242	11227	11213	11198	11183	11168	111
80	2.107	11385	11373	11361	11348	11336	11323	11310	112
70	2.280	11494	11484	11474	11463	11453	11442	11431	114
60	2.465	11586	11577	11569	11560	11551	11542	11533	115

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 psig (2482 kPa) and has a filling density of 70 lb/ft³ (1121 kg/m³).

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:

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

$$Z = \ln \frac{\rho_1}{\rho}$$

where:

P_1 = storage pressure (psia)

P = pipeline pressure (psia)

ρ_1 = density at pressure P_1 (lb/ft³)

ρ = density at pressure P (lb/ft³)

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:

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.

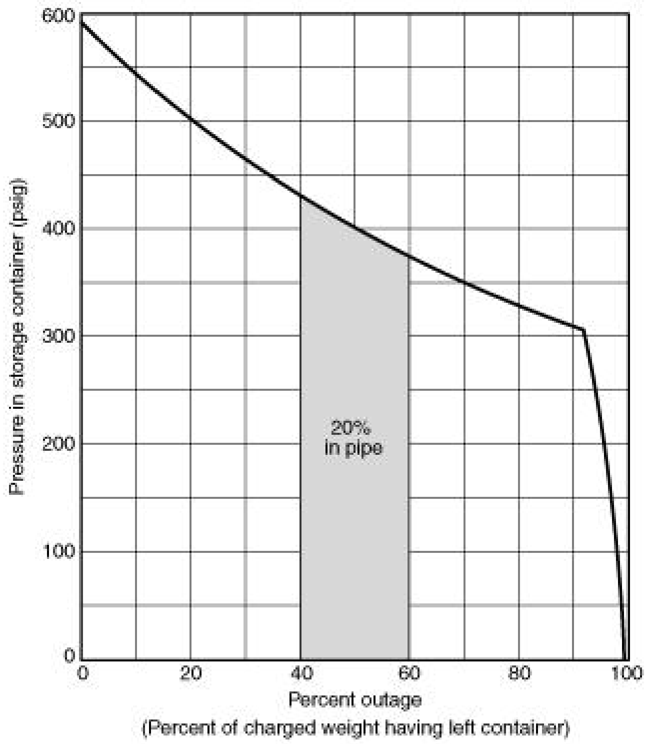

FIGURE H.1(d) Percent Outage.

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(d) provides precalculated A and B factors for steel pipe. Table H.1(e) through Table H.1(h) are for the 600 psig (4137 kPa) systems with filling densities of 70, 60, 50, and 40 lb/ft^3. Table H.1(i) through Table H.1(l) are for the 360 psig (2482 kPa) systems with the same filling densities. Table H.1(m) shows the two-phase solution.

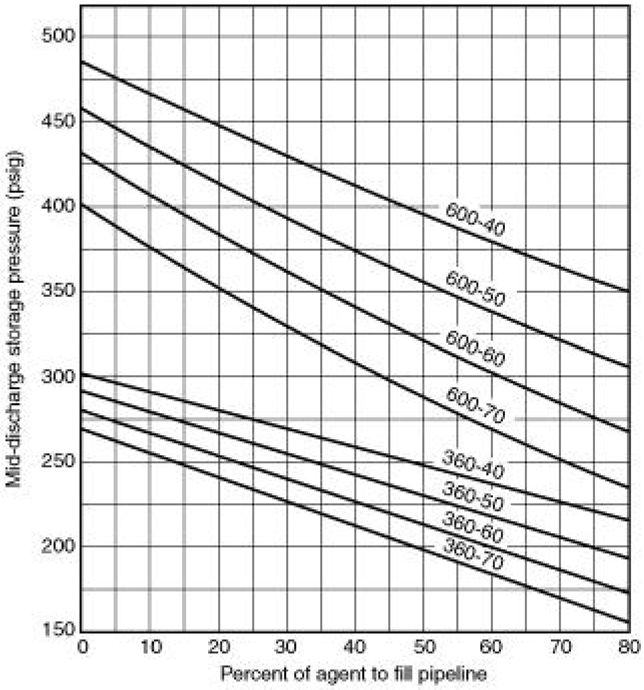

FIGURE H.1(e) Percent of Agent to Fill Pipeline.

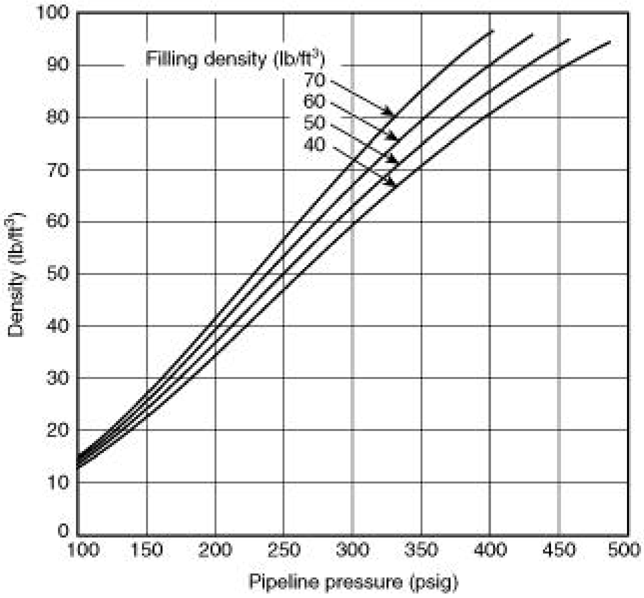

FIGURE H.1(f) Pipeline Density for 600 psig Systems Based on Constant Enthalpy Expansion.

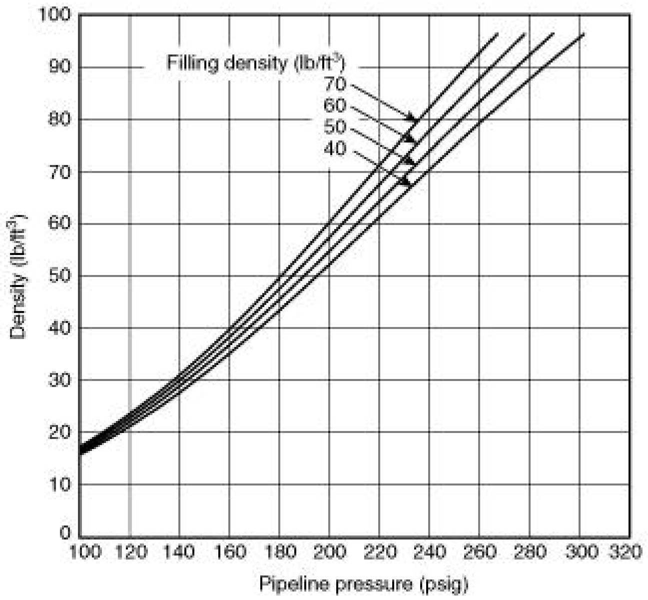

FIGURE H.1(g) Pipeline Density for 360 psig Systems Based on Constant Enthalpy Expansion.

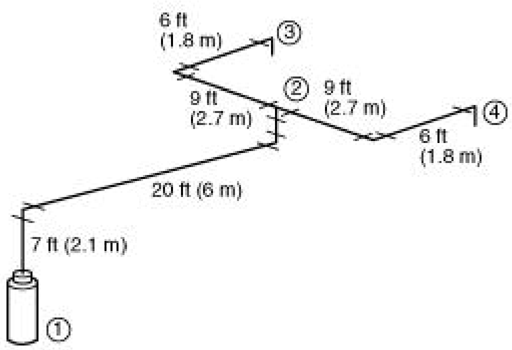

FIGURE H.1(h) Calculated Solution.

Table H.1(m) Two-Phase Solution

Section	Pipe	L (ft)	EQL (ft)	Elevation (ft)	Rate	Start (psig)	End (psig)
1-2	1 in. Sch. 40	27	58	7	8	243	197
2-3	¾ in. Sch. 40	15	19	0	4	197	181
2-4	¾ in. Sch. 40	15	19	0	4	197	181

(1) Calculate *A* and *B*.

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

For ¾ in. pipe, A = 0.3666 and B = 17.3.

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

(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(d), based on the estimated 19.5 percent in piping the average storage container pressure in 243 psig (1675 kPa).

(5) Elevation correction. Before calculating pressure drop due to friction, the pressure change due to elevation in Section 1-2 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 (ρ) of the Halon 1301 at the 243 psig (1675 kPa) starting pressure of the section is found to be 83 lb/ft³ in Figure H.1(f) on the 70 lb/ft³ fill density curve. The pressure loss due to the 7 ft increase in elevation is

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

The new starting psig is 243 – 4 = 239.

(6) Determine Y_1 and Z_1 from Table H.1(i).

For a starting pressure of 239 psig,

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

(7) Determine Y_2 from the following equation:

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

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

$$Y_2 = 5670$$

(8) Determine terminal pressure.

The terminal pressure of Section 1-2 is 200 psig 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,

$$Y_2 = 5670 + 127 = 5797$$

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

(9) Section 4-3.

For the next section,

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

Terminal pressure = 182 psig

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

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

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.

Annex I Fire Extinguishment

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

I.1

Halon 1301, like other halogenated hydrocarbons, chemically inhibits the propagation of flame. However, although the presence of Halon 1301 in the vicinity of a deep-seated fire will extinguish the flame, thereby greatly reducing the rate of burning, the quantity of agent required for complete extinction of all embers is difficult to assess. It depends on the nature of the fuel, its state of comminution, its distribution within the enclosure, the length of time it has been burning, the ratio of the area of the burning surface to the volume of the enclosure, and the degree of ventilation in the enclosure. It is usually difficult or impractical to maintain an adequate concentration for a sufficient time to ensure the complete extinction of a deep-seated fire. However, the concentration should be maintained for the time period required to obtain response by emergency personnel.

Fires in Solid Materials. Two types of fires can occur in solid fuels: one in which volatile gases resulting from heating or decomposition of the fuel surface are the source of combustion; and another in which oxidation occurs at the surface of, or within, the mass of fuel. The former is commonly referred to as "flaming" combustion, while the latter is often called “smoldering” or “glowing” combustion. The two types of fires frequently occur concurrently, although one type of burning can precede the other. For example, a wood fire can start as flaming combustion and become smoldering as burning progresses. Conversely, spontaneous ignition in a pile of oily rags can begin as a smoldering fire and break into flames at some later point. Flaming combustion, because it occurs in the vapor phase, is promptly extinguished with low levels of Halon 1301. In the absence of smoldering combustion, it will stay out.

Smoldering combustion is not subject to immediate extinguishment as is flaming combustion. Characteristic of this type of combustion is the slow rate of heat losses from the reaction zone. Thus, the fuel remains hot enough to react with oxygen, even though the rate of reaction, which is controlled by diffusion processes, is extremely slow. Smoldering fires can continue to burn for many weeks, for example, in bales of cotton and jute and within heaps of sawdust. A smoldering fire ceases to burn only when either all of the available oxygen or fuel has been consumed or when the fuel surface is at too low a temperature to react. These fires are usually extinguished by reducing the fuel temperature, either directly by application of a heat absorbing medium, such as water, or by blanketing with an inert gas. The inert gas slows the reaction rate to the point where heat generated by oxidation is less than heat losses to surroundings. This causes the temperature to fall below the level necessary for spontaneous ignition after removal of the inert atmosphere.

For the purposes of this standard, smoldering fires are divided into two classes: (1) where the smoldering is not “deep seated” and (2) deep-seated fires. The difference is only a matter of degree, and the distinction is a functional one: if a 5 percent concentration of Halon 1301 will not extinguish it within 10 minutes of application, it is considered to be deep seated. In practice, experiments have shown a rather sharp dividing line between the two. Deep-seated fires usually require much higher concentrations than 10 percent and much longer soaking times than 10 minutes.

Whether a fire will become deep seated depends, in part, on the length of time it has been burning before application of the extinguishing agent. This time is usually called the “preburn” time. Underwriters Laboratories’ wood crib fires (1A) and stacks of wood pallets have been readily extinguished with less than 5 percent Halon 1301 maintained for less than 10 minutes following discharge. *(See UL 711, Rating and Fire Testing of Fire Extinguishers.)* In these tests, a 10-minute preburn was allowed. Charcoal, the ultimate product of a wood fire, required over 30 minutes for complete extinguishment in a 5 percent Halon 1301 concentration. In charcoal fires, higher agent concentrations were found to reduce the soaking times. At a 10 percent concentration, a 20-minute soaking time was required, and at 20 percent, the soaking time was reduced below 15 minutes.

Another important variable is the fuel configuration. While wood cribs and pallets are easily extinguished with 5 percent Halon 1301, vertical wood panels closely spaced and parallel require about 25 percent concentrations for 30 to 40 minutes for extinguishment. Fires in boxes of excelsior and in piles of shredded paper also required about 20 percent Halon 1301 for extinguishment. In these situations, heat tends to be retained in the fuel array rather than being dissipated to the surroundings. Radiation is an important mechanism for heat removal from smoldering fires.

Experiments with a similar agent, Halon 1211, have shown that the ratio of the burning surface area to the enclosure volume can affect the concentration-soaking time requirements for some deep-seated fires. Low area/volume ratios required higher agent concentrations and longer soaking times than higher ratios did. In other words, small fires in large enclosures were more difficult to extinguish than the contrary situation. This suggested that oxygen depletion is important in the extinguishment of deep-seated fires.

To date, no firm basis has been developed to predict the agent requirements for a deep-seated fire. In a practical sense, however, the use of a Halon 1301 system for control or extinguishment of a deep-seated fire is usually unattractive. Long soaking times are usually difficult to maintain without an extended agent discharge, and at high agent concentrations these systems become rather expensive. The use of Halon 1301 systems will generally be limited to solid combustibles that do not become deep seated.

The deep-seated potential of a solid material in a given situation can be established positively only by experiment. The information given in this standard can assist the authority having jurisdiction in deciding whether such experimentation is necessary. Table I.1(a) provides the quantity of fuel required to achieve ½ of lower explosive limit in air at 1.0 atm and 70°F (21°C). Table I.1(b) provides information on the development of Halon 1301 design concentrations for flame extinguishment for certain fuels.

Table I.1(a) Quantity of Fuel Required to Achieve ½ of Lower Explosive Limit in Air at 1.0 atm and 70°F (21°C)

	Fuel Quantity (per enclosed volume)	
Material	**lb/ft^3**	**kg/m^3**
n-Butane	0.0014	0.0224
Isobutane	0.0016	0.0256
Carbon disulfide	0.00099	0.0159
Carbon monoxide	0.0045	0.0721
Ethane	0.0012	0.0192
Ethyl alcohol	0.0018	0.0288
Ethylene	0.0020	0.0320
n-Heptane	0.0016	0.0256
Hydrogen	0.00011	0.0018
Methane	0.0011	0.0176
Propane	0.0013	0.0256

Table I.1(b) Development of Halon 1301 Design Concentrations for Flame Extinguishment

Concentration in Air in Volume Percent

Table I.1(b) Development of Halon 1301 Design Concentrations for Flame Extinguishment

Fuel	Concentration in Air in Volume Percent: Average[1]	Safety Factor	Total	Design[2]	Reference
Acetone	3.3	+0.7	=4.0	5.0	1, 2, 3
Benzene	3.3	+0.7	=4.0	5.0	1, 2, 3
Ethanol	3.8	+0.8	=4.6	5.0	1, 2, 3
Ethylene	6.8	+1.4	=8.2	8.2	1, 2, 3
Methane	3.1	+0.7	=3.8	5.0	1, 2, 3
n-Heptane	4.1	+0.8	=4.9	5.0	1, 2, 3
Propane	4.3	+0.9	=5.2	5.2	1, 2, 3

Notes:
[1]Average of values reported in references measured at elevated temperature conditions.
[2]Measured extinguishing concentration plus safety factor are increased to a minimum 5 percent for design concentrations.

References:
1. Bajpai, S. N., "Extinction of Diffusion Flames by Halons," FMRC Serial No. 22545, Report No. 76-T-59, July 1976.
2. Riley, J. F. and K. R. Olson, "Determination of Halon 1301/1211 Threshold Extinguishment Concentrations Using the Cup Burner Method," Ansul Report AL-530A, July 1, 1976.
3. Data on file at NFPA.

Annex J Surface Fires

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

J.1

Most materials that develop deep-seated fires do so after exposure to flaming combustion for a certain length of time, which varies with the material. In others, the fire can begin as deep seated through internal ignition, such as spontaneous heating.

Surface fires associated with the burning of solid materials are also quickly extinguished by Halon 1301. In many solid materials, smoldering combustion can continue at the surface of the fuel after extinguishment of the flames. These surface embers will normally be extinguished by low concentrations of Halon 1301 maintained for short periods of time.

Deep-seated fires can become established beneath the surface of a fibrous or particulate material. This situation can result from flaming combustion at the surface or from ignition within the mass of fuel. Smoldering combustion then progresses slowly through the mass. A fire of this kind is referred to in this standard as a deep-seated fire. The burning rate of these fires can be reduced by the presence of Halon 1301, and they can be extinguished if a high concentration can be maintained for an adequate soaking time. However, it is not normally practical to maintain a sufficient concentration of Halon 1301 for a sufficient time to extinguish a deep-seated fire.

J.2 Solid Surface Fires.

Almost all flammable solids begin burning on the surface. In many materials, such as plastics without filler materials, surface combustion is the only type that occurs. These fires are readily extinguished with a 5 percent concentration of Halon 1301. Although glowing embers can remain at the surface of the fuel following extinguishment of flames, these embers will usually be completely extinguished within 10 minutes, provided the Halon 1301 concentration is maintained around the fuel for this period of time. It is appropriate to consider maintaining the agent concentration around the fuel until response by emergency personnel can be achieved.

J.2.1 Halon 1301 Requirements for Surface Fires. The following two basic types of extinguishment data have been obtained for Halon 1301:

(1) Flame extinguishment data, which determine the agent concentration necessary to extinguish a flame of a particular fuel

(2) Inerting data, which determine the minimum premixed agent concentration to suppress propagation of a flame front at the “flammability peak,” or stoichiometric fuel/air composition

Flame extinguishment data generally relate closest to the concentration actually required in a fire extinguishing system. The test recommended for these measurements is the cup burner method similar to that described in Bajpai, 1976, Booth et al., 1976, and Riley et al., 1976. Liquid fuels are examined at the following two temperatures:

(1) *Ambient:* 25°C, or approximately 5°C above ASTM open-cup flash point of the fuel, whichever is higher

(2) *Elevated:* approximately 5°C below the boiling point of the fuel, or 200°C, whichever is lower

Gaseous fuels are examined at two temperatures, 25°C and 150°C. A 20 percent safety factor is added to experimental threshold concentrations. Design concentrations less than 5 percent Halon 1301 are not used for flame extinguishment. Measured flame extinguishment data plus safety factor that are less than 5 percent should be increased to a 5 percent minimum because the potential array of fuels likely to be involved in every real fire requires the higher concentration.

The cup burner test method has been shown to compare well with other test methods and with tests at larger scale. Data produced by the cup burner are somewhat more conservative than those of tests using conventional total flooding techniques. *(See M.1.2.8.)*

In inerting measurements, a fuel/air mixture is contained in a test chamber, and an ignition source is activated. If the mixture cannot support a flame front, the mixture is considered to be nonflammable. Typical results can be plotted as shown in Figure J.2.1.

The normal flammability range that exists when no agent is present is shown at the left-hand side of the graph. As Halon 1301 is added to the system, the flammability range is reduced until it finally disappears entirely. The agent concentration at which this occurs is called the “flammability peak” concentration. All fuel/air mixtures containing concentrations of agent equal to or greater than the flammability-peak value are nonflammable, hence the term “inert.” The results in Table 5.4.2(a) were measured using a spherical vessel described in Dalzell, 1975.

The choice between using the flame extinguishing concentration or the inerting concentration for a given fuel depends on (1) the volatility characteristics of the fuel, (2) the quantity of fuel present, and (3) the conditions of use in the hazard. Applying Halon 1301 at the flame extinguishment concentration to actual fires will effectively extinguish the fire without sacrificing the reliability of the system. It is desirable to use this lower concentration when possible because of the following advantages:

(1) The cost of the system will be correspondingly lower.

(2) The concentration to which personnel will be (inadvertently) exposed will be lower.

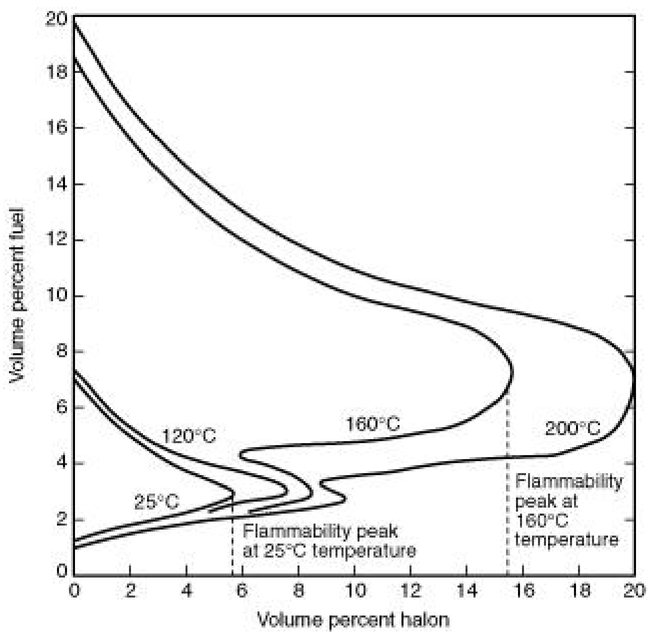

FIGURE J.2.1 Typical Flammability-Peak Concentration.

The danger in supplying this lower concentration is that, at some time after extinguishment, a flammable concentration of fuel, air, and agent could possibly be attained through release or vaporization of additional fuel. This is more likely with highly volatile liquid fuels, gaseous fuels, or fuels heated to near their flash point than it is with high flash point liquids or solid fuels. In addition, stratification of the evolved fuel vapors, the size and possible duration of the fire, and other materials that can become heated or involved in the fire must be taken into account. If the volatility of the fuel can be shown to be sufficiently low, and the detection-plus-extinguishment time is short enough to prevent the volatility of the fuel from reaching its flash point as a result of the fire, the use of flame extinguishment data is adequate.

In addition, the extinguishing concentration can be used if the amount of fuel present in the hazard is too low to permit attainment of the lower flammable limit of the fuel. The minimum fuel quantity required to achieve the lower explosive limit is as follows:

$$\frac{\text{pounds of fuel quantity}}{100\ \text{ft}^3\ \text{of enclosed volume}} = \frac{(LFL)(MW)(1.37)}{T + 460}$$

where:

LFL = lower flammable limit of fuel in air, % (vol)

MW = molecular weight of fuel

T = temperature (°F)

For SI units:

$$\text{fuel quantity}\left(\text{kg/m}^3\right) = \frac{(LFL)(MW)(4.75)}{K}$$

where:

K = Kelvin = °C + 273.15

To account for possible stratification effects that might create localized explosive pockets, the fuel quantity as determined above should be divided by an appropriate safety factor. Table I.1(a) lists quantities for several fuels, to which an arbitrary safety factor of 2 has been applied. Greater safety factors can be required by individual situations.

Annex K Total Flooding Quantity

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

K.1 Total Flooding Quantity.

The volume of Halon 1301 required to develop a given concentration will be greater than the final volume remaining in the enclosure.

In most cases, Halon 1301 must be applied in a manner that promotes progressive mixing of the atmosphere. As Halon 1301 is injected, the displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents. Some Halon 1301 is therefore lost with the vented atmosphere, and the higher the concentration, the greater the loss of halon.

For the purposes of this standard, it is assumed that the Halon 1301/air mixture lost in this manner contains the final design concentration of Halon 1301. This represents the worst case from a theoretical standpoint and provides a built-in safety factor to compensate for non-ideal discharge arrangements.

Table K.1(a) and Table K.1(b) show a tabulation of the Halon 1301 weight per cubic foot of hazard volume required to produce the specified concentration of various hazard temperature conditions.

The initial discharge is to be completed within the limits specified in 5.7.1.2. *[See Figure K.1(a) and Figure K.1(b) (Metric).]*

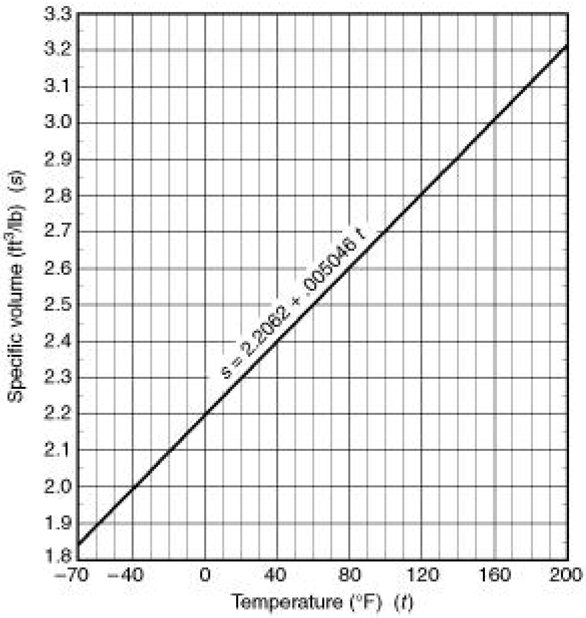

FIGURE K.1(a) Specific Volume of Superheated Halon 1301 Vapor (at 1 atmosphere).

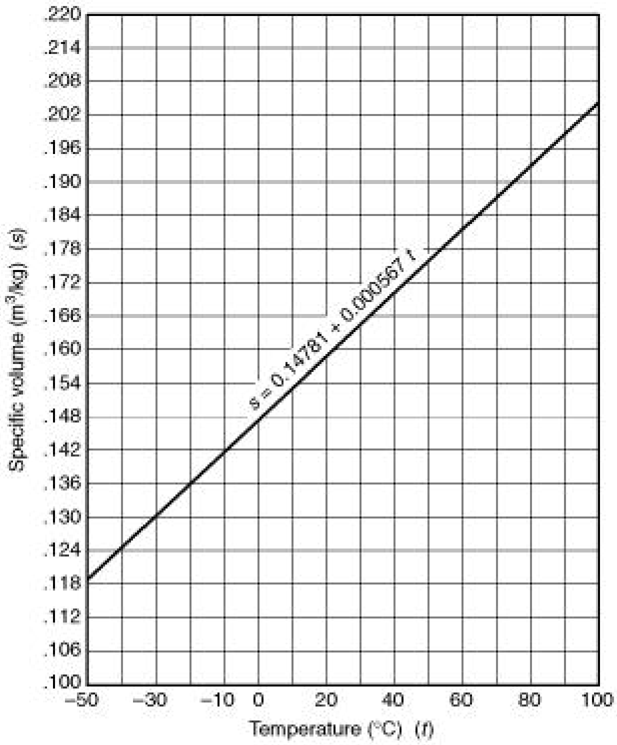

FIGURE K.1(b) (Metric). Specific Volume of Superheated Halon 1301 Vapor (at 1 atmosphere).

Table K.1(a) Halon 1301 Total Flooding Quantity

Temperature (t)	Halon 1301 Specific Vapor Volume(s)	Halon 1301 Weight Requirements of Hazard Volume (W/V) [lb						
		Halon 1301 Concentration (C) [% by Volume]						
[°F]	[ft^3/lb]	3	4	5	6	7	8	
-70	1.8468	0.0167	0.0225	0.0285	0.0345	0.0407	0.0471	0.
-60	1.8986	0.0163	0.0219	0.0277	0.0336	0.0396	0.0458	0.
-50	1.9502	0.0158	0.0213	0.0270	0.0327	0.0386	0.0446	0.
-40	2.0016	0.0154	0.0208	0.0263	0.0319	0.0376	0.0434	0.
-30	2.0530	0.0151	0.0203	0.0256	0.0311	0.0366	0.0423	0.
-20	2.1042	0.0147	0.0198	0.0250	0.0303	0.0357	0.0413	0.
-10	2.1552	0.0143	0.0193	0.0244	0.0296	0.0349	0.0403	0.
0	2.2062	0.0140	0.0189	0.0239	0.0289	0.0341	0.0394	0.
10	2.2571	0.0137	0.0185	0.0233	0.0283	0.0334	0.0385	0.
20	2.3078	0.0134	0.0181	0.0228	0.0277	0.0326	0.0377	0.
30	2.3585	0.0131	0.0177	0.0223	0.0271	0.0319	0.0369	0.
40	2.4091	0.0128	0.0173	0.0218	0.0265	0.0312	0.0361	0.
50	2.4597	0.0126	0.0169	0.0214	0.0260	0.0306	0.0354	0.
60	2.5101	0.0123	0.0166	0.0210	0.0254	0.0300	0.0346	0.

Table K.1(a) Halon 1301 Total Flooding Quantity

Temperature (t)	Halon 1301 Specific Vapor Volume(s)	Halon 1301 Weight Requirements of Hazard Volume (W/V) [lb						
		Halon 1301 Concentration (C) [% by Volume]						
[°F]	[ft^3/lb]	3	4	5	6	7	8	
70	2.5605	0.0121	0.0163	0.0206	0.0249	0.0294	0.0340	0.
80	2.6109	0.0118	0.0160	0.0202	0.0244	0.0288	0.0333	0.
90	2.6612	0.0116	0.0156	0.0198	0.0240	0.0283	0.0327	0.
100	2.7114	0.0114	0.0154	0.0194	0.0235	0.0277	0.0320	0.
110	2.7616	0.0112	0.0151	0.0190	0.0231	0.0272	0.0315	0.
120	2.8118	0.0110	0.0148	0.0187	0.0227	0.0267	0.0309	0.
130	2.8619	0.0108	0.0145	0.0184	0.0223	0.0263	0.0303	0.
140	2.9119	0.0106	0.0143	0.0181	0.0219	0.0258	0.0298	0.
150	2.9620	0.0104	0.0140	0.0178	0.0215	0.0254	0.0293	0.
160	3.0120	0.0103	0.0138	0.0175	0.0212	0.0250	0.0289	0.
170	3.0169	0.0101	0.0136	0.0172	0.0208	0.0246	0.0284	0.
180	3.1119	0.0099	0.0134	0.0169	0.0205	0.0242	0.0280	0.
190	3.1618	0.0098	0.0132	0.0166	0.0202	0.0238	0.0275	0.
200	3.2116	0.0096	0.0130	0.0164	0.0199	0.0234	0.0271	0.

Note:
W/V [agent weight requirements (lb/ft^3)] = pounds of agent required per cubic foot of protected volume to prod
concentration at temperature specified:

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

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft^3/lb)] = specific volume of superheated Halon 1301 vapor approximated by the formula:
$s = 2.2062 + 0.005046t$
where:
t = temperature (°F)
C [concentration (%)] = volumetric concentration of Halon 1301 in air at the temperature indicated

Table K.1(b) (Metric) Halon 1301 Total Flooding Quantity

Temperature (t)	Halon 1301 Specific Vapor Volume(s)	Halon 1301 Weight Requirements of Hazard Volume (W/V) [k					
		Halon 1301 Concentration (C) [% by Volume]					
[°C]	[m^3/kg]	3	4	5	6	7	8
-50	0.11946	0.2589	0.3488	0.4406	0.5343	0.6301	0.7279
-45	0.12230	0.2529	0.3407	0.4304	0.5219	0.6155	0.7110
-40	0.12513	0.2472	0.3330	0.4206	0.5101	0.6015	0.6949
-35	0.12797	0.2417	0.3256	0.4113	0.4988	0.5882	0.6795

Table K.1(b) (Metric) Halon 1301 Total Flooding Quantity

Temperature (t)	Halon 1301 Specific Vapor Volume(s)	Halon 1301 Weight Requirements of Hazard Volume (W/V) [k					
		Halon 1301 Concentration (C) [% by Volume]					
[°C]	[m³/kg]	3	4	5	6	7	8
-30	0.13080	0.2364	0.3185	0.4024	0.4880	0.5754	0.6648
-25	0.13364	0.2314	0.3118	0.3938	0.4776	0.5632	0.6507
-20	0.13647	0.2266	0.3053	0.3857	0.4677	0.5515	0.6372
-15	0.13931	0.2220	0.2991	0.3778	0.4582	0.5403	0.6242
-10	0.14214	0.2176	0.2931	0.3703	0.4491	0.5295	0.6118
-5	0.14498	0.2133	0.2874	0.3630	0.4403	0.5192	0.5998
0	0.14781	0.2092	0.2819	0.3561	0.4318	0.5092	0.5883
5	0.15065	0.2053	0.2766	0.3494	0.4237	0.4996	0.5772
10	0.15348	0.2015	0.2715	0.3429	0.4159	0.4904	0.5666
15	0.15632	0.1979	0.2666	0.3367	0.4083	0.4815	0.5563
20	0.15915	0.1943	0.2618	0.3307	0.4011	0.4729	0.5464
25	0.16199	0.1909	0.2572	0.3249	0.3940	0.4647	0.5368
30	0.16482	0.1876	0.2528	0.3193	0.3873	0.4567	0.5276
35	0.16766	0.1845	0.2485	0.3139	0.3807	0.4489	0.5187
40	0.17049	0.1814	0.2444	0.3087	0.3744	0.4415	0.5100
45	0.17333	0.1784	0.2404	0.3037	0.3683	0.4343	0.5017
50	0.17616	0.1756	0.2365	0.2988	0.3623	0.4273	0.4936
55	0.17900	0.1728	0.2328	0.2940	0.3566	0.4205	0.4858
60	0.18183	0.1701	0.2291	0.2895	0.3510	0.4139	0.4782
65	0.18467	0.1675	0.2256	0.2850	0.3456	0.4076	0.4709
70	0.18750	0.1649	0.2222	0.2807	0.3404	0.4014	0.4638
75	0.19034	0.1625	0.2189	0.2765	0.3353	0.3954	0.4569
80	0.19317	0.1601	0.2157	0.2725	0.3304	0.3896	0.4501
85	0.19601	0.1578	0.2126	0.2685	0.3256	0.3840	0.4436
90	0.19884	0.1555	0.2095	0.2647	0.3210	0.3785	0.4373
95	0.20168	0.1534	0.2066	0.2610	0.3165	0.3732	0.4312

Table K.1(b) (Metric) Halon 1301 Total Flooding Quantity

Temperature (t)	Halon 1301 Specific Vapor Volume(s)	Halon 1301 Weight Requirements of Hazard Volume (W/V) [k					
		Halon 1301 Concentration (C) [% by Volume]					
[°C]	[m^3/kg]	3	4	5	6	7	8

Note:
W/V [agent weight requirements (kg/m^3)] = kilograms of agent required per cubic meter of protected volume t
concentration at temperature specified:

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

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated Halon 1301 vapor can be approximated by the fo
$s = 0.14781 + 0.000567t$
where:
t = temperature (°C)
C [concentration (%)] = volumetric concentration of Halon 1301 in air at the temperature indicated

Annex L Approval of Installations

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

L.1

Where circumstances exist that require a discharge test, test agents sulfur hexafluoride or Halon 121 can be used. These agents have been identified as having characteristics similar to Halon 1301. The discharge test is not a substitute for any of the approval tests required in Section 6.7, except for the "puff" test [*see 6.7.2.1.13*].

(1) *Planning for a Discharge Test.*

(a) A date and time should be set well in advance of the test to ensure that proper preparations are made.

(b) To ensure that the testing objectives are met, an evaluation team should be set up, including the following: the user, the installer, and the authority having jurisdiction.

(2) *Preparing for a Discharge Test.*

(a) All members of the testing evaluating team should meet and make sure all items on the pretest inspection have been resolved.

(b) Before conducting an actual system test, read and perform all appropriate steps in the above predischarge checklist. (Disregard if the steps in the predischarge test have resulted in failures to pass tests.)

(c) The following equipment will be required for the test:

i. An accurate concentration meter capable of providing both direct readout and printout. Multiple recorders can be required for large installations.

ii. A stopwatch.

iii. Portable exhaust fans, if needed for post-test ventilation.

(3) *Test Preparation.*

(a) Use of Halon 1301 as a test agent further reduces availability for fire extinguishing purposes. Therefore, this standard recommends that Halon 1301 not be used as a test agent.

(b) When using sulfur hexafluoride the following information should be used for guidance.

i. Enclosure leakage rate of sulfur hexafluoride dispersed in air is nearly identical to Halon 1301. The vapor densities of the two materials are almost the same.

ii. Distribution in balanced piping systems is similar to that expected with Halon 1301. THIS SUBSTANCE MIGHT NOT BE SUITABLE FOR TESTING HYDRAULICALLY COMPLEX SYSTEMS. Tests to determine suitability for testing hydraulically complex systems are ongoing.

iii. Sulfur hexafluoride is compatible with Halon 1301 systems hardware.

iv. The toxicity of sulfur hexafluoride is no greater than that of Halon 1301.

v. The dynamic loads exerted on the piping network will be similar to that of Halon 1301.

vi. The test cylinder should be filled to 98 percent of the Halon 1301 weight to achieve the same volume percent concentration. Cylinders with a DOT CTC rating of 500 psig (3447 kPa) [typically used in 360 psig (2482 kPa) applications] will not meet DOT regulations for shipping when filled with sulfur hexafluoride. However, these cylinders can be filled with sulfur hexafluoride and safely used and/or stored at the job site provided the temperature of the cylinders is not allowed to go above 100°F (37.8°C).

vii. Test meters used for Halon 1301 are suitable for use with sulfur hexafluoride. It is recommended that test thermoconductivity meters be calibrated with a sample sulfur hexafluoride in air. If desired, calibration with Halon 1301 can be done, but percent concentration values must be multiplied by a factor of 2.

viii. Sulfur hexafluoride is not a fire extinguishing agent.

ix. Sulfur hexafluoride ozone depletion is zero and not regulated by the Montreal Protocol.

(c) When using Halon 121 the following information should be used for guidance:

i. Because of its lower vapor density, the enclosure leakage rate of Halon 121 is slower than that for Halon 1301.

ii. Distribution in balanced systems is similar to Halon 1301. Hydraulically complex systems might not be suitable for testing with this agent.

iii. Common materials of construction are satisfactory for use with Halon 121. However, the compatibility with exposed Buna-N seals should be established for the duration of storage.

iv. Self-contained breathing apparatus must be used if personnel enter the protected space while the agent is present. The threshold limit value for Halon 121 is 1000 ppm by volume.

v. The test cylinders should be filled to 58 percent of the Halon 1301 weight to achieve the same volume percent concentration.

vi. The test meter should be calibrated with a sample of Halon 121 in air. Thermoconductivity meters used to measure Halon 1301 concentrations are suitable for this purpose.

vii. The ozone depleting potential of Halon 121 is low (0.050 DP). It is not regulated by the Montreal Protocol of 1987.

viii. The suitability of Halon 121 at minimum cylinder fill densities has not been determined.

ix. Halon 121 is not a recognized fire extinguishing agent.

(d) Replacement 1301 should be on hand, and the replacement containers should be weighed at the site.

(4) *Test Procedure.* The following guidelines are for information purposes only and are not intended to replace or restrict the manufacturer's recommendations. The protected enclosure should be prepared as follows:

(a) The room should be in the normal operating condition. Taping and other nonpermanent methods should not be allowed.

(b) All openings that are to be automatically closed on system actuation should be in their normal open position (doors, fire dampers, etc.).

(c) All ceiling tiles should be installed.

(d) All nozzle locations should be checked for obstructions. All loose papers and light materials that can be moved by the discharge of halon should be removed.

(e) All areas where halon discharge can stir up dust or debris that could damage equipment should be vacuumed clean to minimize potential damage.

(f) Adjacent rooms should be checked to make sure that halon migrating from the room will not trip adjacent halon systems or affect people or equipment.

(g) Provisions should be provided for removal of the halon at the end of the testing.

(h) Experience has shown that the primary cause of discharge test failure is the inability to hold the specified concentration for the entire holding period. Room vacuum/pressurization techniques should be considered for locating unwanted room leakage. These techniques are highly recommended for locating room leakage both immediately prior to a discharge test and on a future periodic basis.

(5) *Test Evaluation.* For total flooding systems, a listed or approved concentration meter should be used and calibrated in strict accordance with the manufacturer's instructions. The meters should be checked for accuracy by means of a known sample. Concentration readings should be taken at the point of the highest combustible being protected or at a level equivalent to 75 percent of the height of the enclosure, whichever is greater. The sampling points should not be located less than 12 in. (305 mm) from the ceiling unless the combustibles being protected extend within the area, in which case special design consideration might be necessary. If more than one space or compartment is being simultaneously protected, a sampling point should be located in each space in accordance with the above criteria. (The minimum design concentration for the hazard should be achieved at all sampling points in the enclosure within 1 minute after the end of the initial discharge.) For flammable liquids and gases, the minimum specified concentration need not be maintained for an extended period. For surface fire hazards other than flammable liquids and gases, 80 percent of the minimum design concentration should be maintained for a period of 10 minutes after the initial discharge or as required by the authority having jurisdiction. Hazards involving deep-seated combustibles require maintenance of the design concentrations for longer periods of time *(see 5.4.2.2)*. Where an inerting concentration is required, a more stringent test could be necessary. Refer to 5.2.6 to determine that concentrations do not exceed the safety limits specified therein. A 110-volt, 60-cycle power source should be available for operating a recordable-type analyzer. The power to the analyzer should remain on when the fire extinguisher system is activated. The following information is provided as guidance when performing a full discharge test:

(a) Halon analyzers should be field calibrated and adjusted, in accordance with the analyzer manufacturer's instructions, prior to each use.

(b) If the system is linked to an alarm circuit providing local and remote fire call, the appropriate party should be notified and advised prior to and at the completion of the test.

(c) Actuate the system for discharge.

(d) Concentration will be reported for the time period that the authority having jurisdiction has determined to be appropriate for that particular occupancy.

CAUTION: There should be no smoking in or around the test area during and after the discharge.

(e) The following items should be complied with to designate the system as acceptable:

i. Liquid discharge should be in accordance with 5.7.1.2.

ii. The system should achieve the specified concentration in the protected volume within 1 minute after the end of the initial discharge.

iii. The specified concentration should be maintained for the specified holding period.

iv. The system should be properly installed and perform as designed without causing unacceptable damage to the protected volume.

(f) Once the requirement for hold time has been completed, ventilation to exhaust the halon from the area should be started and maintained as necessary.

(g) Operation of all auxiliary system functions, horns, lights, local and remote alarms, magnetic releases, and so on, should be confirmed.

(6) *Failure Classification.* Discharge test failure can be classified as one of the following:

(a) *Primary Failure.* The failure of equipment necessary to complete system discharge and achieve initial design concentration (i.e., hydraulic calculations, inoperative containers, control panel malfunction, etc.).

(b) *Secondary Failure.* The failure of ancillary equipment that does not inhibit the system from completing discharge and achieving initial design concentration (i.e., dampers, door closures, bells, dry contact relays, etc.).

(c) *Room Integrity Failure.* The failure of the room to hold the specified concentration for the specified holding period.

(7) *Test Documentation.* The results of the test should be documented in report form for each member of the test team. This report should include, but not necessarily be limited to, the following:

(a) A sketch of the protected area showing the location of sampling points, in plan and elevation.

(b) Copies of clearly identified analyzer chart records showing halon concentration. This should also include analyzer calibration results, and the tapes should be signed by the authority having jurisdiction.

(c) A signoff by each member of the test team.

(8) *Placing System Back in Service.* Place the system back in service. (Refer to the manufacturer's recommendations.) The steps should include, but not necessarily be limited to, the following:

(a) Verify that all detectors and manual pull stations have been reset.

(b) Refurbish or replace agent storage containers with the proper amount of agent. Containers should be weighed to verify the required amount of agent.

(c) Verify that the system control unit is in a normal operating condition free of all fault indication. Normally this is done before arming each agent storage container release mechanism.

(d) Secure the system control unit and lock where applicable.

(e) Verify that the end user has been properly instructed in the use and operation of this system.

(f) Clean the area of any debris that might have resulted during the system installation.

(g) Verify that an emergency telephone number has been left with the end user.

Annex M Informational References

M.1 Referenced Publications.

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

M.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2002 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 2002 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2002 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2000 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 2002 edition.

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*, 2002 edition.

M.1.2 Other Publications.

M.1.2.1 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016.

ASME B31, *Code for Pressure Piping,* 1998.

ASME B31.1, *Power Piping Code,* 1998.

ASME B31.9, *Building Services Piping,* 1991.

M.1.2.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 53, *Standard Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded Seamless,* 1996.

ASTM A 106, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service,* 1995.

ASTM A 120, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service,* 1988.

ASTM B 88, *Specifications for Seamless Copper Water Tube,* 1996.

ASTM E 380, *Standard Practice for Use of the International System of Units (SI): The Modernized Metric System,* 1993.

ASTM E 779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization,* 1987.

M.1.2.3 CGA Publication. Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA P-1, *Safe Handling of Compressed Gas in Containers*, 2000.

M.1.2.4 CSA Publications. Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario L4W 5N6, Canada.

CAN3-Z234.1, *Canadian Metric Practice Guide,* 1979.

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

M.1.2.5 Military Specifications. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

MIL-M-12218C, *Monobromotrifluoromethane (Liquefied) Technical Grade Fire Extinguisher,* 1981.

M.1.2.6 UL Publication. Underwriters Laboratories Inc, 333 Pfingsten Road, Northbrook, IL 60062-2069.

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

M.1.2.7 Toxicology References.

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

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

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

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

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

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

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

M.1.2.8 Flame Extinguishment and Inerting References.

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

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

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

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

M.1.2.9 Additional Reference.

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

M.1.2.10 EPA Publications. United States Environmental Protection Agency, http://www.denix.osd.mil/denix/Public/News/DLA/Halon/hal1.html.

Safety Guide for Decommissioning Halon Systems

M.2 Informational References.

(Reserved)

M.3 References for Extracts.

(Reserved)

Formal Interpretations

NFPA 12A

Halon 1301 Fire Extinguishing Systems

2004 Edition

Reference: 4.1.3.2
F.I.

Question: Are agent storage containers permitted to be located within the hazard area?

Answer: Yes.

Issue Edition: 1973
Reference: 1541
Date: October - November 1974

Formal Interpretation

NFPA 12A

Halon 1301 Fire Extinguishing Systems

2004 Edition

Reference: 4.1.3.3, 4.1.4.7, and 5.5.1
F.I. 85-2

Question 1: Is it the intent of 5.5.1 that the total flooding quantity of Halon 1301 required to achieve design concentration be calculated on the basis of:

a) the design temperature in the hazard area?

Answer: Yes.

b) the minimum anticipated temperature in the hazard area?

Answer: Yes.

c) the minimum anticipated temperature of the storage container?

Answer: No.

Question 2: Does 4.1.4.7 define the phrase "severe weather conditions" in 4.1.3.3 to mean greater than 130°F or less than -20°F?

Answer: No.

Issue Edition: 1985
Reference: 1-9.4.3, 1-9.5.8, 2-5.2
Date: December 1985
Reprinted to correct error: January 1989

Formal Interpretation

NFPA 12A

Halon 1301 Fire Extinguishing Systems

2004 Edition

Reference: 4.3.3.5, 5.5.2
F.I. 80-5

Background: Section 1.5.1 and Annex D address at substantial length the hazards to personnel from the extinguishing agent, its decomposition products produced by a fire, and the effects of agent discharge. However, nowhere does the standard seem to address good practice by assuring total personnel evacuation prior to discharge.

Question 1: Is it the intent of the Technical Committee to allow the installation of manual actuation stations within the hazard enclosure of total flooding systems? (Manual actuation stations being arranged to discharge agent immediately upon activation, thus requiring the occupant to be within the confines of the enclosure during all or portions of the system discharge.)

Answer: Yes.

Question 2: If the answer to Question 1 is "yes," is it the intent of 5.5.2 to require additional agent quantities to compensate for loss, when the occupant exits the hazard enclosure?

Answer: No.

Question 3: If the answer to Question 1 is "no," is it the intent of the Technical Committee to subject the location of the manual actuation stations to the approval/discretion of the authority having jurisdiction?

Answer: N/A.

Issue Edition: 1980
Reference: 1-8.3.5, 2-5.1
Date: February 1985

Formal Interpretation

NFPA 12A

Halon 1301 Fire Extinguishing Systems

2004 Edition

Reference: 4.3.4.1, 4.3.4.2
F.I. 87-1

Question 1: Do the requirements of NFPA 12A, 4.3.4.1 and 4.3.4.2 mean that the detection system control equipment and the halon system actuation devices must be supplied by the same manufacturer?

Answer: No.

Question 2: Can one assume that if both the detection system control equipment and the halon system actuation devices are supplied by the same manufacturer that the requirements of NFPA 12A, 4.3.4.1 and 4.3.4.2 have been implicitly satisfied?

Answer: No.

Question 3: Do 4.3.4.1 and 4.3.4.2 of NFPA 12A require either evaluation by an organization acceptable to the Authority Having Jurisdiction or other means, such as an engineering evaluation satisfactory to the Authority Having Jurisdiction to show compatibility between control equipment and actuation devices, in all cases?

Answer: Yes.

Question 4: Was it the intent of the Committee in drafting 4.3.4.1 and 4.3.4.2 of NFPA 12A to permit the use of a detection system control panel made by one manufacturer and a halon system actuation device made by another manufacturer as long as the compatibility between them is verified in a means acceptable to the Authority Having Jurisdiction?

Answer: Yes.

Issue Edition: 1987
Reference: 1-8.4.1, 1-8.4.2
Date: September 1987

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