ANSI/NFPA 12A An American National Standard August 7, 1989

NFPA 12A
Halon 1301 Fire Extinguishing Systems
1989 Edition

NFPA

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

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NFPA®

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 12A

Standard on

Halon 1301 Fire Extinguishing Systems

1989 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 the National Fire Protection Association, Inc. at its Annual Meeting held May 15-18, 1989 in Washington, D.C. It was issued by the Standards Council on July 14, 1989, with an effective date of August 7, 1989, and supersedes all previous editions.

The 1989 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

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

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Halogenated Fire Extinguishing Systems

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Fred K. Walker, HQ United States Air Force
R. J. Wright, Underwriters Labs of Canada
Thomas J. Wysocki, NF Fire Control Systems
Dennis M. Zallen, NM Engr Research Institute

Alternates

William H. Barlen, Compressed Gas Assn. Inc.
(Alternate to D. J. Parrish)
Kerry M. Bell, Underwriters Laboratories Inc.
(Alternate to W. M. Carey)
Robert L. Darwin, Naval Sea Systems Command
(Alternate to D.H. Kay)
Alfred P. Dougherty, E I du Pont de Nemours & Co. Inc.
(Alternate to D. W. Moore)
David R. Fiedler, Rolf Jensen & Associates Inc.
(Alternate to D. C. Kennedy)
William D. Hard, Hard Suppression Systems
(Alternate to J. P. Hebert)
Richard L. Koehler, American Fire & Electric Industries Inc.
(Alternate to W. A. Eckholm)
Edward D. Leedy, Industrial Risk Insurers
(Alternate to S. A. Chines)
Earl James McCarty, Reynolds Elecl. & Engr. Co. Inc.
(Alternate to P. E. Phillips)
William H. McIntyre, Johnson & Higgins,
(Alternate to Johnson & Higgins Rep.)
James Robert Ryan, Kemper Group
(Alternate to S. L. Rogers)
Howard J. Spice, Underwriters Laboratories of Canada
(Alternate to R. J. Wright)
Robert E. Tapscott, N.M. Engineering Research Institute
(Alternate to D. Zallen)
D. R. Todd, Levitt-Safety Ltd
(Alternate to FEMI Rep.)

Nonvoting

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Rep. Technical Committee on Elec. Computer Systems
Y. Spector, Spectronix Ltd
H. V. Williamson, Roscoe, IL
Rep. NFPA Comm on Carbon Diox.

Mark T. Conroy, NFPA Staff Liaison

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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.

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Standard on

Halon 1301 Fire Extinguishing Systems

1989 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 4 and Appendix C.

Chapter 1 General

1-1 Scope. This standard contains minimum requirements for 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. Portable Halon 1301 extinguishers are covered in NFPA 10, *Standard for Portable Fire Extinguishers.*

Only those skilled in this work are competent to design and install this equipment. It may 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.

1-2 Purpose. This standard is prepared for the use and guidance of those charged with purchasing, designing, installing, testing, inspecting, approving, listing, operating, and maintaining 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.

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 may incorporate special nozzles, flow rates, methods of application, nozzle placement and pressurization levels, which may differ from those detailed elsewhere in this standard. All other requirements of the standard 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 Arrangement. This standard is arranged as follows:

Chapter 1 — General Information and Requirements.

Chapter 2 — Total Flooding Systems.

Chapter 3 — Local Application Systems.

Chapter 4 — Referenced Publications.

Appendix A — Explanatory.

Appendix B — Enclosure Integrity Procedure.

Appendix C — Referenced Publications.

Chapters 1 through 4 constitute the body of the standard and contain the rules and regulations necessary for properly designing, installing, inspecting, testing, approving, operating, and maintaining halogenated agent fire extinguishing systems.

Appendix A contains educational and informative material that will aid in understanding and applying this standard.

Appendix B contains the enclosure integrity procedure for Halon 1301 total flooding fire suppression systems.

1-4 Definitions and Units.

1-4.1 Definitions. For purpose of clarification, the following general terms used with special technical meanings in this standard are defined:

Approved. Acceptable to the "authority having jurisdiction."

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

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" 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, 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 delegated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Listed. Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which 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.

Normally Occupied Area. One that is intended for occupancy.

Shall. Indicates a mandatory requirement.

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

Other terms used with special technical meaning are defined or explained where they occur in the standard.

1-4.2 Units.

1-4.2.1 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 1-4.2 with conversion factors.

1-4.2.2 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

Table 1-4.2
Metric Conversion Factors

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785L
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

For additional conversions and information see ASTM E380, *Standard for Metric Practice.*

In Canada refer to *Canadian Metric Practice Guide*, CSA Standard CAN3-Z234.1-79.

1-5* General Information and Requirements.

1-5.1 The information and requirements in Chapter 1 are generally common to all Halon 1301 (bromotrifluoromethane $CBrF_3$) systems.

1-5.2* Halon 1301.

1-5.2.1 Halon 1301 is a colorless, odorless, electrically nonconductive gas that is an effective medium for extinguishing fires.

1-5.2.2 According to present knowledge, Halon 1301 extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. The extinguishing effect due to cooling or dilution of oxygen or fuel vapor concentration is minor.

1-5.3 Use and Limitations.

1-5.3.1 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. 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, where cleanup of other media presents a problem.

1-5.3.2 Some of the more important types of hazards and equipment that Halon 1301 systems may satisfactorily protect include:

(a) Gaseous and liquid flammable materials.

(b) Electrical hazards such as transformers, oil switches and circuit breakers, and rotating equipment.

(c) Engines utilizing gasoline and other flammable fuels.

(d) Ordinary combustibles such as paper, wood, and textiles.

(e) Hazardous solids.

(f) Electronic computers, data processing equipment, and control rooms.

1-5.3.3 Halon 1301 has not been found effective on the following:

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

(b) Reactive metals such as sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium.

(c) Metal hydrides.

(d) Chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides and hydrazine.

1-5.3.4 Specific limitations are placed on Halon 1301 total flooding systems. (*See 2-1.1.3 and 2-1.1.4.*)

1-5.3.5 Electrostatic charging of nongrounded conductors may occur during the discharge of liquefied gases. These conductors may discharge to other objects, causing an electric arc of sufficient energy to initiate an explosion. (*See NFPA 77, Recommended Practice on Static Electricity.*)

1-5.4 Duration of Protection. 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 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. Water supplies for standard sprinklers, on the other hand, are normally designed to provide protection for one-half to four hours duration, but sprinklers may be less effective in controlling many fires. The designer, the buyer, and the emergency force in particular shall be fully aware of the advantages and limitations of each, the residual risks being assumed, and the proper emergency procedures.

1-5.5 Types of Systems.

1-5.5.1 There are two types of systems recognized in this standard: total flooding systems and local application systems.

1-5.5.2 *A total flooding system* consists of a supply of Halon 1301 arranged to discharge into, and fill to the proper concentration, an enclosed space or enclosure about the hazard.

1-5.5.3 *A local application system* consists of a supply of Halon 1301 arranged to discharge directly on the burning material.

1-5.6 Halon 1301 System. A Halon 1301 system may be used to protect one or more hazards or groups of hazards by means of directional valves. Where two or more hazards may be simultaneously involved in fire by reason of their proximity, each hazard shall be protected with an individual system with the combination arranged to operate simultaneously or shall be protected with a single system that shall be sized and arranged to discharge on all potentially involved hazards simultaneously.

1-6 Safety.

1-6.1* Hazards to Personnel.

1-6.1.1 Experience and testing have shown that personnel may be exposed to Halon 1301 vapors in low concentration for brief periods without serious risk; however, unnecessary exposure is not recommended. (*See 2-1.1.3 and 2-1.1.4.*) Exposure to high concentrations or for prolonged periods may produce dizziness, impaired coordination, and disturbances in cardiac rhythm. Following the extinguishment of a fire with Halon 1301, the atmosphere may also contain combustion and decomposition products in quantities that may be hazardous to personnel. In addition, the effects of the noise, turbulence, high velocity, and low temperature associated with the discharge of the agent shall be considered.

1-6.1.2* Safety Requirements. In any proposed use of Halon 1301 where there is a possibility that people may be trapped in or enter into atmospheres made hazardous, suitable safeguards shall be provided to ensure prompt evacuation of and to prevent entry into such atmospheres and also to provide means for prompt rescue of any trapped personnel. Such safety items as personnel training, warning signs, discharge alarms, and breathing apparatus shall be considered.

1-6.2 Electrical Clearances. All system components shall be located to maintain minimum clearances from live parts as shown in Table 1-6.2.

As used in this standard, "clearance" is the air distance between Halon 1301 equipment, including piping and nozzles, and unenclosed or on uninsulated live electrical components at other than ground potential. The minimum clearances listed in Table 1-6.2 are for the purpose of electrical clearance under normal conditions; they are not intended for use as "safe" distances during fixed Halon 1301 system operation.

The clearances given are for altitudes of 3,300 ft (1000 m) or less. At altitudes in excess of 3,300 ft (1000 m), the clearance shall be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3,300 ft (1000 m).

The clearances are based on minimum general practices related to design Basic Insulation Level (BIL) values. To coordinate the required clearance with the electrical design, the design BIL of the equipment being protected shall be used as a basis, although this is not material at nominal line voltages of 161 kv or less.

Up to electrical system voltages of 161 kv, the design BIL kv and corresponding minimum clearances, phase to ground, have been established through long usage.

At voltages higher than 161 kv, uniformity in the relationship between design BIL kv and the various electrical system voltages has not been established in practice. For these higher system voltages it has become common practice to use BIL levels dependent on the degree of protection to be obtained. For example, in 230-kv systems, BILs of 1050, 900, 825, 750 and 650 kv have been utilized.

Required clearance to ground may also be affected by switching surge duty, a power system design factor that, along with BIL, must correlate with selected minimum clearances. Electrical design engineers may be able to furnish clearances dictated by switching surge duty. Table 1-6.2 deals only with clearances required by design BIL. The selected clearance to ground shall satisfy the greater of switching surge or BIL duty, rather than being based on nominal voltage.

Table 1-6.2
Clearance from Halon 1301 Equipment to Live Uninsulated Electrical Components

Nominal System Voltage (kv)	Maximum System Voltage (kv)	Design BIL (kv)	Minimum* Clearance (in.)	(mm)
To 13.8	14.5	110	7	178
23	24.3	150	10	254
34.5	36.5	200	13	330
46	48.3	250	17	432
69	72.5	350	25	635
115	121	550	42	1067
138	145	650	50	1270
161	169	750	58	1473
230	242	900	76	1930
		1050	84	2134
345	362	1050	84	2134
		1300	104	2642
500	550	1500	124	3150
		1800	144	3658
765	800	2050	167	4242

*For voltages up to 161 kv, the clearances are taken from NFPA 70, *National Electrical Code*®. For voltages of 230 kv and above, the clearances are taken from Table 124 of ANSI C-2, *National Electrical Safety Code*.

In Canada, refer to *Canadian Electrical Code*, Part I, CSA Standard C22.1-1986.

NOTE: BIL values are expressed as kilovolts (kv), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand. For BIL values not listed in the table, clearances may be found by interpolation.

Possible design variations in the clearances required at higher voltages are evident in Table 1-6.2, where a range of BIL values is indicated opposite the various voltages in the high-voltage portion of the table. However, the clearance between uninsulated energized parts of the electrical system equipment and any portion of the Halon 1301 system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

1-6.2.1 When the design 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.

1-7 Specifications, Plans, and Approvals.

1-7.1 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.

1-7.2 Plans.

1-7.2.1 Plans and calculations shall be submitted for approval to the authority having jurisdiction before installation begins. Their preparation shall be entrusted to none but persons fully experienced and qualified in the design of Halon 1301 extinguishing systems.

1-7.2.2 These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so they can be easily reproduced.

1-7.2.3 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.

1-7.2.4 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.

1-7.2.5 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.

1-7.3 Approval of Plans.

1-7.3.1 Plans and calculations shall be submitted for approval before work starts.

1-7.3.2 When field conditions necessitate any material change from approved plans, the change shall be submitted for approval.

1-7.3.3 When such material changes from approved plans are made, corrected "as installed" plans shall be provided.

1-7.4* Approval of Installations.

1-7.4.1 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 following tests shall be performed.

1-7.4.1.1 The piping shall be pneumatically tested in a closed circuit for a period of 10 minutes at 150 psig. At the end of 10 minutes, the pressure drop shall not exceed 10 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 may 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.

1-7.4.1.2 Prior to the pressure test, a physical inspection of the piping, nozzle, and their supports shall determine that the piping and nozzles are restrained so that no unacceptable movement, either vertical or lateral, occurs other than the normal movement anticipated within the restraining device (hanger).

1-7.4.1.3

A. The following mechanical items shall be checked:

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.

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.

3. Piping joints, discharge nozzles, and piping supports shall be securely fastened to prevent agent leakage and hazardous movement during discharge.

4. 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.

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

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

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

(a) Agent shall not be discharged at head high or below, where personnel in the normal work area would be injured by the agent discharge.

(b) 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.

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

9. 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. Refer to NFPA 72E, *Standard on Automatic Fire Detectors*, and the manufacturer's recommended guidelines concerning this area.

10. The detectors shall be installed in a neat, professional manner and in accordance with technical data regarding their installation.

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

12. All manual stations used to release Halon shall be of the dual action type, and shall be properly identified as to their purpose. 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.

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

14. 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.

15. The control unit shall be properly installed and readily accessible.

B. Inspection of Agent and Containers

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

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

3. 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.

4. Adequate quantity of agent to produce the desired specified concentration shall be provided. The actual room volume 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.

C. Electrical Checkout

1. All wiring systems shall be properly installed in compliance with local codes, insuring agencies, and the system drawings.

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. Replace components after measuring.

3. Power shall be supplied to the control unit from a separate dedicated source.

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.

5. All auxiliary functions such as alarm sounding or displaying devices, remote annunciators, air handling shutdown, power shutdown, and so on 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. Silencing of alarms (if desirable) shall not affect other auxiliary functions such as air handling or power-cut off if required in the design specification.

D. Functional Test or Predischarge Test

1. Functional test (predischarge)

(a) If the system is connected to an alarm receiving office, the alarm receiving office shall be notified that the fire 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.

(b) Disable each agent storage container release mechanism so that activation of the release circuit will not release agent. Reconnect the release circuit with a functional device in lieu of each agent storage container release mechanism. For electrically actuated release mechanisms, these devices may include 24-volt lamps, flash bulbs, or circuit breakers. Pneumatically actuated release mechanisms may include pressure gauges. Refer to the manufacturer's recommendations in all cases.

(c) Check each detector for proper response.

(d) Check that polarity has been observed on all polarized alarm devices and auxiliary relays.

(e) Check that all end-of-line resistors have been installed across the detection and alarm bell circuits where required.

2. System functional operational test

(a) Operate detection initiating circuit(s). All alarm functions shall occur according to the design specification.

(b) Operate the necessary circuit to initiate a second alarm circuit. Verify all second alarm functions occur according to design specifications.

(c) Operate manual release. Verify that manual release functions occur according to design specifications.

(d) If supplied, operate abort switch circuit. Verify that abort functions occur according to design specifications. Confirm that visual and audible supervisory signals are received at the control panel.

(e) All automatic valves shall be tested unless testing the valve will release Halon or damage the valve (destructive testing).

(f) Where required, pneumatic equipment shall be checked for integrity to assure proper operation.

3. Testing of remote monitoring operations, if applicable

(a) 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.

(b) Operate each type of alarm condition on each signal circuit and verify receipt of trouble condition at the remote station.

4. Testing of the control panel primary power source

(a) 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.

(b) 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.

5. When all predischarge work is completed, reconnect each agent storage container so that activation of the release circuit will release the agent. System shall be returned to its fully operational design condition.

6. Tests shall be in accordance with the appropriate NFPA or Canadian standards (*see Chapter 4*).

E. Enclosure Integrity Check. All total flooding systems shall have the enclosure examined or 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. 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.

F. To determine that the system has been properly installed and will function as specified, the following additional test shall be performed. A test, such as a "puff" test with compressed air or carbon dioxide, shall be performed to check for continuous and obstruction free piping.

1-8 Detection, Actuation, and Control Systems.

1-8.1 Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with appropriate NFPA protective signaling systems standards (*see NFPA 70, National Electrical Code; NFPA 72A, Standard for the Installation, Maintenance and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm and Supervisory Service; NFPA 72B, Standard for the Installation, Maintenance and Use of Auxiliary Protective Signaling Systems for Fire Alarm Service; NFPA 72C, Standard for the Installation, Maintenance, and Use of Remote Station Protective Signaling Systems; NFPA 72D, Standard for the Installation, Maintenance and Use of Proprietary Signaling Systems, and NFPA 72E, Standard on Automatic Fire Detectors. In Canada refer to CAN/ULC—S524-M86, Standard for the Installation of Fire Alarm Systems, and CAN/ULC—S529-M87, Smoke Detectors for Fire Alarm Systems*).

1-8.1.1 Automatic detection and automatic actuation shall be used.

Exception: Manual-only actuation may be used if acceptable to the authority having jurisdiction where automatic release could result in an increased risk.

1-8.2 Automatic Detection.

1-8.2.1 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.

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

1-8.2.2 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.

1-8.3 Operating Devices.

1-8.3.1 Operating devices shall include Halon 1301 releasing devices or valves, discharge controls, and shutdown equipment necessary for successful peformance of the system.

1-8.3.2 Operation shall be by listed or approved mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

1-8.3.3 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.

1-8.3.4 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.

1-8.3.5 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.

1-8.3.6 A means of emergency release of the system resulting from a single manual operation shall be provided. This may be by means of the normal manual control(s), where the control equipment is provided with an uninterruptable power supply. The emergency release shall also cause simultaneous operation of automatically operated valves controlling agent release and distribution.

1-8.3.7 Manual controls shall not require a pull of more than 40 lb (178 newtons) 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.

1-8.3.8 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.

1-8.3.9 All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation.

1-8.3.10 All manual operating devices shall be identified as to the hazard they protect.

1-8.4 Control Equipment.

1-8.4.1 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.

1-8.4.2 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 to ensure that no loss of integrity will occur. 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.

1-8.5 Operating Alarms and Indicators.

1-8.5.1 Alarms or indicators or both are 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.

1-8.5.2 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.

1-8.5.3* Abort switches are generally not recommended. However, where 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.

1-8.5.4 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.

1-8.5.5 Warning and instruction signs at entrances to and inside protected areas shall be provided.

1-8.5.6 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.

1-8.6 Unwanted System Operation. Accidental discharge has been recognized as a significant factor in unwanted Halon 1301 emissions. Care shall be taken to thoroughly evaluate and correct any factors that may result in unwanted discharges.

1-9 Halon 1301 Supply.

1-9.1 Quantities.

1-9.1.1 The amount of Halon 1301 in the system shall be at least sufficient for the largest single hazard protected or group of hazards which are to be protected simultaneously.

1-9.1.2 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.

1-9.1.3 Where uninterrupted protection is required, both primary and reserve supply shall be permanently connected to the distribution piping and arranged for easy changeover.

1-9.2 Quality. The Halon 1301 shall comply with the requirements of Table 1-9.2.

Table 1-9.2
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 mmHg	-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

NOTE: For test procedures refer to MIL-M-12218C available from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

1-9.3 Storage Container Arrangement.

1-9.3.1 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.

1-9.3.2 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.

1-9.3.3 Storage containers shall not be located to be subject to severe weather conditions or mechanical, chemical, or other damage. When excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

1-9.3.4 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.

1-9.4* Storage Containers.

1-9.4.1 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 per cu ft (1121 kg/m^3). They shall be superpressurized with dry nitrogen to 360 psig ± 5% or 600 psig ± 5% total pressure at 70 °F (25.84 bars ± 5% or 42.38 bars ± 5% total pressure at 21 °C).

Exception: Listed pre-engineered systems may have different pressurization levels per Section 1-2.

1-9.4.2 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 must be returned for recycling or recovery of the agent when no longer needed.

1-9.4.3 The Halon 1301 containers used in these systems shall be designed to meet the requirements of the U.S. Department of Transportation or the Canadian Transport Commission,[1] if used as shipping containers. If not a shipping container, it shall be designed, fabricated, inspected, certified, and stamped in accordance with Section VIII of the ASME *Unfired Pressure Vessel Code*; 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 (*see 1-9.4.8*).

1-9.4.4 A reliable means of indication, other than weighing, shall be provided to determine the pressure in refillable containers. The means of indication shall account for variation of container pressure with temperature.

1-9.4.5 Container Test.

1-9.4.5.1 D.O.T., C.T.C, or similar design Halon 1301 cylinders shall not be recharged without a retest if more than five years have elapsed since the date of the last test and inspection. The retest may consist of a complete visual inspection as described in the *Code of Federal Regulations*, Title 49, Section 173.34(e)(10).

1-9.4.5.2 Cylinders continuously in service without discharging shall be given a complete external visual inspection every five years, in accordance with Compressed Gas Association pamphlet C-6, Section 3; except that the cylinders need not be emptied or stamped while under pressure.[1]

[1]Subpart C, Section 178.36 to and including 178.68 of Title 49, Transportation, *Code of Federal Regulations*, Parts 170-190. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401. In Canada, the corresponding information is set forth in the "Canadian Transport Commission's Regulations for Transportation of Dangerous Commodities by Rail," available from the Queen's Printer, Ottawa, Ontario.

1-9.4.5.3 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.

1-9.4.5.4 Before recharging a container, a visual inspection of its interior shall be performed.

1-9.4.5.5 When manifolded, containers shall be adequately mounted and suitably supported in a rack which 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.

1-9.4.6 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.

1-9.4.7 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. For local application systems, container storage temperatures shall be within a range from +32 °F (0 °C) to +130 °F (55 °C) unless special methods of compensating for changing flow rates are provided. External heating or cooling may be used to keep the temperature within desired ranges.

1-10 Distribution.

1-10.1* Piping.

1-10.1.1* 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 may be required in severely corrosive atmospheres.

(a) Ferrous piping — black or galvanized steel pipe shall be either ASTM A-53 seamless or electric resistance welded, grade A or B, or ASTM A-106, grade A, B, or C. ASTM A-120 and ordinary cast-iron pipe shall not be used. The thickness of the pipe wall shall be calculated in accordance with ANSI 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 per cu ft (1121 kg/m^3) density shall be assumed], but in no case shall be less than the following:

For 360 psig charging pressure, an internal pressure of 620 psi (130 °F);

For 600 psig charging pressure, an internal pressure of 1,000 psi (130 °F).

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.

(b) The above itemized materials do not preclude the use of other materials that satisfy the strength requirements of paragraph (a).

1-10.1.2 Ordinary cast-iron pipe, steel pipe conforming to ASTM A-120, or nonmetallic pipe shall not be used.

1-10.1.3 Flexible piping, tubing, or hoses (including connections) where used shall be of approved materials and pressure ratings.

1-10.2 Piping Joints.

1-10.2.1 The type of piping joint shall be suitable for the design conditions and shall be selected with consideration of joint tightness and mechanical strength. Examples of suitable joints and fittings are screwed, flanged, welded, brazed, flared, and compression.

1-10-2.2* Fittings. Class 150 lb and cast-iron fittings shall not be used.

(a) Fittings for 600 psig charging pressure systems shall have a working pressure of 1,000 psi.

(b) Systems utilizing 360 psig charging pressure shall use fittings having a minimum working pressure of 620 psi.

(c) 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 ANSI B31.1. Where fittings not covered by one of these standards are used, the design recommendations of the manufacturer of the fittings shall not be exceeded.

1-10.2.3 Ordinary cast-iron fittings shall not be used.

1-10.2.4 All threads used in joints and fittings shall conform to ANSI B1.20.1. Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

1-10.2.5 Welding and brazing alloys shall have a melting point above 1000 °F (538 °C).

1-10.2.5.1 Welding shall be performed in accordance with Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators" of the ASME *Boiler and Pressure Vessel Code*.

1-10.2.6 Where copper, stainless steel, or other suitable tubing is joined with flared or compression-type fittings, the pressure-temperature ratings of the manufacturer of the fitting shall not be exceeded.

1-10.3 Arrangement and Installation of Piping and Fittings.

1-10.3.1 Piping shall be installed in accordance with good commercial practice. Care shall be taken to avoid possible restrictions due to foreign matter, faulty fabrication, or improper installation.

1-10.3.2 The piping system shall be securely supported with due allowance for agent thrust forces; thermal expansion and contraction, and shall not be subjected to mechanical, chemical, vibration, or other damage. ANSI B31.1 shall be consulted for guidance on this matter. Where explosions are likely, the piping shall be attached to supports that are least likely to be displaced.

1-10.3.3 Each pipe section shall be cleaned after preparation and before assembly by means of swabbing, utilizing a nonflammable organic solvent. The piping network shall be free of particulate matter and oil residue before installation of nozzles or discharge devices.

1-10.3.4 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. Where pressure-operated container valves are used, a means shall be provided to vent any container leakage from the manifold and prevent loss of the agent when the system operates.

1-10.3.5 All pressure relief devices shall be of such design and so located that the discharge therefrom will not injure personnel or be otherwise objectionable.

1-10.4 Valves.

1-10.4.1 All valves shall be suitable for the intended use, particularly in regard to flow capacity and operation. They shall be used only under temperatures and other conditions for which they are listed.

1-10.4.2 Valves shall be protected against mechanical, chemical, or other damage.

1-10.4.3 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.

1-10.5 Discharge Nozzles.

1-10.5.1 Discharge nozzles shall be listed for the use intended and for discharge characteristics. The discharge nozzle consists of the orifice and any associated horn, shield, or baffle.

1-10.5.2 Discharge orifices shall be of corrosion-resistant metal.

1-10.5.3 Discharge nozzles used in local application systems shall be accurately located and directed in accordance with the system design requirements as covered in Section 3-3. Discharge nozzles used in local application systems shall be so connected and supported that they may not readily be put out of alignment.

1-10.5.4 Discharge nozzles shall be permanently marked to identify the manufacturer as well as the type and size of the nozzle. The type and size of the nozzle can be identified by part number, orifice code, orifice diameter, or other suitable markings. (*See 1-7.2.4.*) The marking shall be readily discernible after installation.

1-10.5.5 Discharge nozzles shall be provided with frangible discs or blow-out caps where clogging by foreign materials is likely. These devices shall provide an unobstructed opening upon system operation and shall be located so they will not injure personnel.

1-10.6* System Flow Calculations.

1-10.6.1 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.

1-10.6.2 The system shall be installed and oriented per the manufacturer's listed limitations to ensure proper system performance.

1-10.6.3* The piping lengths and sizes, as well as the type and size of the fittings, shall be as entered into the flow calculation program. If the final installation varies from the prepared calculations, new calculations representing the "As-Built" installation shall be prepared.

1-10.6.4* Nozzle orifice sizes shall be selected to achieve the designed flow rate. The discharge characteristics of the nozzle shall be provided in the manufacturer's listed design manual.

1-10.6.5* Design flow rates shall be high enough to ensure complete mixing of the liquid and vapor phases in the pipe line.

1-11 Inspection, Maintenance, and Instructions.

1-11.1* Inspection and Tests.

1-11.1.1 At least annually, all systems shall be thoroughly inspected and tested for proper operation by competent personnel.

1-11.1.2 The goal of this inspection and testing shall be to ensure that the system is in full operating condition.

1-11.1.3 Suitable tests shall be made when inspection indicates their advisability.

1-11.1.4 The inspection report with recommendations shall be filed with the owner.

1-11.1.5 Between the annual inspections and tests, the system shall be inspected visually or otherwise by competent personnel, following an approved schedule and procedure.

1-11.1.6 At least semiannually, 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. All halon removed from refillable containers during service or maintenance procedures shall be collected and recycled.

1-11.1.7 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.

1-11.1.8 The weight and pressure of the container shall be recorded on a tag attached to the container.

1-11.1.9 All system hoses shall be examined annually for damage. If visual examination shows any deficiency, the hose shall be immediately replaced or tested as follows:

1-11.1.9.1 All hoses shall be tested at 1500 psi for 600 psi charging pressure systems, and at 900 psi for 360 psi charging pressure systems.

(a) Remove the hose from any attachment.

(b) The hose assembly is then to be placed in a protective enclosure designed to permit visual observation of the test.

(c) The hose must be completely filled with water before testing.

(d) Pressure then is applied at a rate-of-pressure rise to reach the test pressure within a minimum of one minute. The test pressure is to be maintained for one full minute. Observations are then made to note any distortion or leakage.

(e) 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.

(f) 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).

(g) Hose assemblies failing a hydrostatic test must be marked and destroyed. They shall be replaced with new assemblies.

(h) Each hose assembly passing the hydrostatic test shall be marked to show the date of test.

1-11.1.9.2 Testing. All hoses shall be tested every five years in accordance with 1-11.1.9.1.

1-11.2 Maintenance.

1-11.2.1 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.

1-11.2.2 Any troubles or impairments shall be corrected at once by competent personnel.

1-11.3 Instruction. All persons who may be expected to inspect, test, maintain, or operate fire extinguishing systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

Chapter 2 Total Flooding Systems

2-1* General Information.

2-1.1 Uses.

2-1.1.1 This type of system may be used where there is a fixed enclosure about the hazard that is adequate to enable the required concentration to be built up and maintained for the required period of time to ensure the effective extinguishment of the fire in the specific combustible materials involved where the ambient temperature is above −70 °F (−57 °C).

2-1.1.2* Total flooding systems may provide fire protection within rooms, vaults, enclosed machines, ovens, containers, storage tanks, and bins. Where ambient temperatures exceed 900 °F (482 °C), see A-1-6.1.

2-1.1.3* Halon 1301 total flooding systems shall not be used in concentrations greater than 10 percent in normally occupied areas. For the purposes of this standard, a "normally occupied" area is defined as an area intended for occupancy. Areas that may 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 A-1-6.1.*)

2-1.1.4 Halon 1301 total flooding systems utilizing concentrations greater than 10 percent but not exceeding 15 percent may be used in areas not normally occupied, provided egress can be accomplished within 30 seconds. Where egress cannot be accomplished within 30 seconds or concentrations greater than 15 percent must be used, provisions shall be made to prevent inhalation by personnel. (*See A-1-6.1.*)

2-1.2 General Requirements. Total flooding systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements in Chapter 1 and with the additional requirements set forth in this chapter.

2-2 Hazard Specifications.

2-2.1 Types of Fires.

2-2.1.1 Fires that can be extinguished by total flooding methods may be divided into three categories:

(a) Fires involving flammable liquids or gases.

(b) Surface fires involving flammable solids.

(c) Deep-seated fires, such as can occur with certain Class A materials subject to spontaneous heating, smoldering, and high heat retention.

2-2.1.2 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*, shall be referred to when possible flammable concentrations of gases make explosion protection techniques necessary.

2-2.1.3 Surface fires associated with the burning of solid materials are also quickly extinguished by Halon 1301. In many solid materials, smoldering combustion may 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.

2-2.1.4 Deep-seated fires may become established beneath the surface of a fibrous or particulate material. This may 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 may 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.

2-2.2 Enclosure.

2-2.2.1 In the design of total flooding systems, the characteristics of the enclosure shall be considered as follows:

2-2.2.2 For all types of fires, the area of unclosable openings shall be kept to a minimum. The authority having jurisdiction may require tests to assure proper performance as defined by this standard.

2-2.2.3* 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.

2-2.2.4 Forced-air ventilating systems 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.

2-3* Halon 1301 Requirements for Liquid and Gas Fires.

2-3.1 General. The quantity of Halon 1301 for fires involving flammable liquids and gases is based on normal conditions with the extinguishing system meeting the requirements specified herein.

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

2-3.2 Design Concentrations. In the determination of the design concentration of Halon 1301, proper consideration shall be given to the type and quantity of flammable material involved, the conditions under which it normally exists in the hazard, and any special conditions of the hazard itself. For a particular fuel, either of two minimum levels of Halon 1301 concentration may apply, i.e., flame extinguishment or inerting. However, the greater inerting concentrations shall be used where conditions for subsequent reflash or explosion could exist. Specifically, these conditions are when both:

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, and

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 close 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.

2-3.2.1 Inerting. Table 2-3.2.1 gives minimum design concentrations required to inert atmospheres involving several flammable liquids and gases. Design inerting concentrations not given in Table 2-3.2.1 shall be determined by test plus a 10 percent safety factor. The minimum design concentration shall be 5 percent.

Table 2-3.2.1
Halon 1301 Design Concentrations for Inerting

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

*For references, see Reference (4) Appendix C-1.7.

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

2-3.2.2 Flame Extinguishment.

(a) *Applicability of Flame Extinguishment Concentrations.* The minimum design concentration required to extinguish normal fires involving certain flammable gases and liquids at atmospheric pressure are applicable if the conditions in 2-3.2 for reflash or explosion do not exist.

(b) *Temperature Sensitivity.* The flame extinguishing concentration required for some fuels depends on the fuel temperature. All fuels shall be tested at at least two temperatures to determine temperature sensitivity.

(c) *Special Fire Consideration.* Where high temperatures or pressures exist or may result from delayed system activation and for configurations other than simple pool or gas jet fires, added tests specific to the intended application shall be made.

(d) *Typical Design Concentrations.* Table 2-3.2.2 gives minimum design concentrations required to extinguish normal fires involving several flammable liquids and gases. Design flame extinguishment concentrations not given in 2-3.4 shall be obtained by test plus a 20 percent safety factor. Minimum design concentrations shall be 5 percent.

Table 2-3.2.2
Halon 1301 Design Concentrations for Flame Extinguishment
(In 25°C at 1 atm)

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

NOTE: See A-2-3 for basis of this table.

2-3.2.3 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.

2-3.2.4 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 shall be consulted. In particular, extreme caution shall 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.

2-4* Halon 1301 Requirements for Fires in Solid Materials.

2-4.1 General. Flammable solids may be classed as those that do not develop deep-seated fires and those that do. Materials that do not develop deep-seated fires undergo surface combustion only and the resulting fires may be treated much like flammable liquid fires. 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 may begin as deep-seated through internal ignition, such as spontaneous heating.

2-4.2 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 may 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 would be appropriate to consider maintaining the agent concentration around the fuel until response by emergency personnel can be achieved.

2-4.3 Deep-Seated Fires.

2-4.3.1 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 shall be maintained for the time period required to obtain response by emergency personnel (*see A-2-4*).

2-4.3.2 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, provision shall be made to the satisfaction of the authority having jurisdiction for means to effect complete extinguishment of the fire (*see A-2-4*).

2-5 Determination of Halon 1301 Quantity for Total Flooding Systems.

2-5.1 General. The Halon 1301 concentration requirements established in Sections 2-3 and 2-4 are converted into agent weight requirements through mathematical computations considering the volume of the hazard and the specific volume of the superheated Halon 1301 vapor. In addition to the concentration requirements, additional quantities of agent may be required to compensate for any special conditions that would affect the extinguishing efficiency.

2-5.2* Total Flooding Quantity. Figure 2-5.2 depicts the specific volume of superheated Halon 1301 vapor at various temperatures. The amount of Halon 1301 required to achieve the design concentration is calculated from the following formula:

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

W = Weight of Halon 1301 required, lb (kg).
s = Specific volume superheated Halon 1301, cu ft/lb (m^3/ kg).
C = Halon 1301 concentration, percent by volume.
V = Volume of hazard, cu ft (m^3).

This calculation includes an allowance for normal leakage from a "tight" enclosure due to agent expansion. Since the amount of gas and, therefore, the concentration produced by a given weight of Halon 1301 is greatly affected by the temperature it encounters, the specific volume of superheated Halon 1301 vapor for the lower operating minimum anticipated ambient temperature limit shall be used in the design of a Halon 1301 total flooding system. Table 2-5.2 is a tabulation of the Halon 1301 weight per cu ft of hazard volume required to produce the specified concentration of various hazard temperature conditions.

All Halon 1301 total flooding systems shall be capable of producing the required concentration of agent under the conditions of maximum net volume (gross volume of the hazard minus the volume occupied by solid objects), maximum ventilation, and minimum anticipated ambient temperature. In areas where wide variations in net volume are encountered under normal operations such as storage rooms, warehouses, etc., or where wide variations in ambient temperatures are experienced as in unheated rooms, the agent concentration generated under these extremes shall be calculated to determine compliance with 2-1.1.3 and 2-1.1.4.

2-5.3* Special Conditions. The design quantity of Halon 1301 shall be adjusted to compensate for any special conditions, such as openings, forced ventilation, altitudes of more than 3000 ft (1000 m) above or below sea level, and pressures other than atmospheric. It shall be the responsibility of the system designer to show that such conditions have been taken into account in the design of a system.

2-6 Distribution System.

2-6.1 General. The distribution system for applying Halon 1301 to enclosed hazards shall be designed with due consideration for the materials involved, the type of burning expected, and the nature of the enclosure. These factors all may affect the discharge times and rates of application.

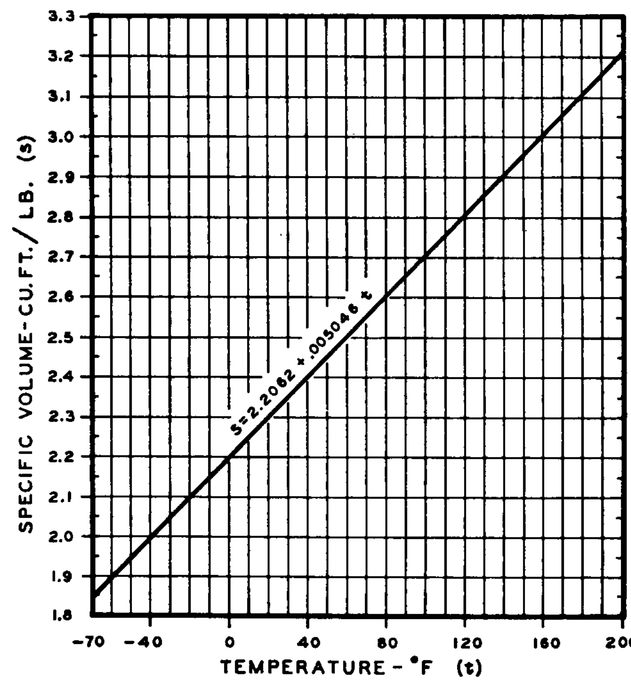


Figure 2-5.2 Specific volume of superheated Halon 1301 vapor (at 1 atmosphere).

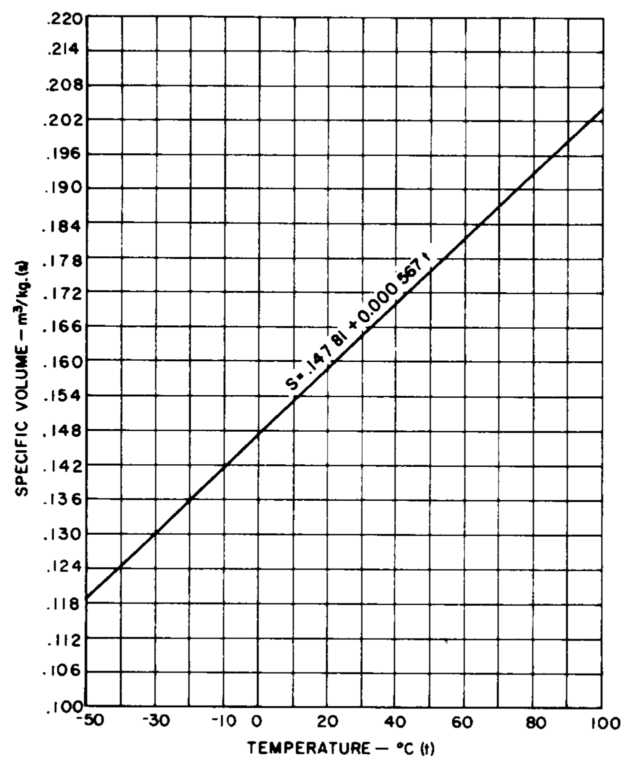


Figure 2-5.2 (Metric) Specific volume of superheated Halon 1301 vapor (at 1 atmosphere).

Table 2-5.2
Halon 1301 Total Flooding Quantity

Temperature -t- [°F] (2)	Halon 1301 Specific Vapor Volume-s- [ft.³/lb.] (3)	Halon 1301 Weight Requirements of Hazard Volume $\frac{W}{V}$ [lb./ft.³] (1) — Halon 1301 Concentration -C- [% By Volume] (4)							
		3	4	5	6	7	8	9	10
— 70	1.8468	.0167	.0225	.0285	.0345	.0407	.0471	.0536	.0602
— 60	1.8986	.0163	.0219	.0277	.0336	.0396	.0458	.0521	.0585
— 50	1.9502	.0158	.0213	.0270	.0327	.0386	.0446	.0507	.0570
— 40	2.0016	.0154	.0208	.0263	.0319	.0376	.0434	.0494	.0555
— 30	2.0530	.0151	.0203	.0256	.0311	.0366	.0423	.0482	.0541
— 20	2.1042	.0147	.0198	.0250	.0303	.0357	.0413	.0470	.0528
— 10	2.1552	.0143	.0193	.0244	.0296	.0349	.0403	.0459	.0515
0	2.2062	.0140	.0189	.0239	.0289	.0341	.0394	.0448	.0504
10	2.2571	.0137	.0185	.0233	.0283	.0334	.0385	.0438	.0492
20	2.3078	.0134	.0181	.0228	.0277	.0326	.0377	.0429	.0481
30	2.3585	.0131	.0177	.0223	.0271	.0319	.0369	.0419	.0471
40	2.4091	.0128	.0173	.0218	.0265	.0312	.0361	.0411	.0461
50	2.4597	.0126	.0169	.0214	.0260	.0306	.0354	.0402	.0452
60	2.5101	.0123	.0166	.0210	.0254	.0300	.0346	.0394	.0443
70	2.5605	.0121	.0163	.0206	.0249	.0294	.0340	.0386	.0434
80	2.6109	.0118	.0160	.0202	.0244	.0288	.0333	.0379	.0426
90	2.6612	.0116	.0156	.0198	.0240	.0283	.0327	.0371	.0417
100	2.7114	.0114	.0154	.0194	.0235	.0277	.0320	.0365	.0410
110	2.7616	.0112	.0151	.0190	.0231	.0272	.0315	.0358	.0402
120	2.8118	.0110	.0148	.0187	.0227	.0267	.0309	.0351	.0395
130	2.8619	.0108	.0145	.0184	.0223	.0263	.0303	.0345	.0388
140	2.9119	.0106	.0143	.0181	.0219	.0258	.0298	.0340	.0382
150	2.9620	.0104	.0140	.0178	.0215	.0254	.0293	.0334	.0375
160	3.0120	.0103	.0138	.0175	.0212	.0250	.0289	.0328	.0369
170	3.0169	.0101	.0136	.0172	.0208	.0246	.0284	.0323	.0363
180	3.1119	.0099	.0134	.0169	.0205	.0242	.0280	.0318	.0357
190	3.1618	.0098	.0132	.0166	.0202	.0238	.0275	.0313	.0351
200	3.2116	.0096	.0130	.0164	.0199	.0234	.0271	.0308	.0346

(1) $\frac{W}{V}$ [Agent Weight Requirements (lb/ft³)] – Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

(2) t [Temperature (°F)] – The design temperature in the hazard area.
(3) s [Specific Volume (ft³/lb)] – Specific volume of superheated Halon 1301 vapor may be approximated by the formula:

$$s = 2.2062 + .005046\, t$$
where t = temperature, °F

(4) C [Concentration (%)] – Volumetric concentration of Halon 1301 in air at the temperature indicated.

2-6.2* Rate of Application.

2-6.2.1 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.

2-6.2.2 Discharge Time. The agent discharge shall be substantially completed in a nominal 10 seconds or as otherwise required by the authority having jurisdiction.

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

2-6.3 Extended Application Rate.

2-6.3.1 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 may be applied at a reduced rate.

2-6.3.2 This type of application is particularly suitable for enclosed rotating electric apparatus, such as generators, motors, and convertors, and also may be needed for total flooding protection of deep-seated fires.

Table 2-5.2 — Metric
Halon 1301 Total Flooding Quantity

Temperature -t- [°C] (2)	Halon 1301 Specific Vapor Volume-s- [m³/kg.] (3)	Halon 1301 Weight Requirements of Hazard Volume $\frac{W}{V}$ [kg/m³] (1) — Halon 1301 Concentration -C- [% By Volume] (4)							
		3	4	5	6	7	8	9	10
−50	0.11946	0.2589	0.3488	0.4406	0.5343	0.6301	0.7279	0.8279	0.9301
−45	0.12230	0.2529	0.3407	0.4304	0.5219	0.6155	0.7110	0.8087	0.9085
−40	0.12513	0.2472	0.3330	0.4206	0.5101	0.6015	0.6949	0.7904	0.8879
−35	0.12797	0.2417	0.3256	0.4113	0.4988	0.5882	0.6795	0.7729	0.8683
−30	0.13080	0.2364	0.3185	0.4024	0.4880	0.5754	0.6648	0.7561	0.8495
−25	0.13364	0.2314	0.3118	0.3938	0.4776	0.5632	0.6507	0.7401	0.8314
−20	0.13647	0.2266	0.3053	0.3857	0.4677	0.5515	0.6372	0.7247	0.8142
−15	0.13931	0.2220	0.2991	0.3778	0.4582	0.5403	0.6242	0.7099	0.7976
−10	0.14214	0.2176	0.2931	0.3703	0.4491	0.5295	0.6118	0.6958	0.7817
− 5	0.14498	0.2133	0.2874	0.3630	0.4403	0.5192	0.5998	0.6822	0.7664
0	0.14781	0.2092	0.2819	0.3561	0.4318	0.5092	0.5883	0.6691	0.7517
5	0.15065	0.2053	0.2766	0.3494	0.4237	0.4996	0.5772	0.6565	0.7376
10	0.15348	0.2015	0.2715	0.3429	0.4159	0.4904	0.5666	0.6444	0.7239
15	0.15632	0.1979	0.2666	0.3367	0.4083	0.4815	0.5563	0.6327	0.7108
20	0.15915	0.1943	0.2618	0.3307	0.4011	0.4729	0.5464	0.6214	0.6981
25	0.16199	0.1909	0.2572	0.3249	0.3940	0.4647	0.5368	0.6105	0.6859
30	0.16482	0.1876	0.2528	0.3193	0.3873	0.4567	0.5276	0.6000	0.6741
35	0.16766	0.1845	0.2485	0.3139	0.3807	0.4489	0.5187	0.5899	0.6627
40	0.17049	0.1814	0.2444	0.3087	0.3744	0.4415	0.5100	0.5801	0.6517
45	0.17333	0.1784	0.2404	0.3037	0.3683	0.4343	0.5017	0.5706	0.6410
50	0.17616	0.1756	0.2365	0.2988	0.3623	0.4273	0.4936	0.5614	0.6307
55	0.17900	0.1728	0.2328	0.2940	0.3566	0.4205	0.4858	0.5525	0.6207
60	0.18183	0.1701	0.2291	0.2895	0.3510	0.4139	0.4782	0.5439	0.6111
65	0.18467	0.1675	0.2256	0.2850	0.3456	0.4076	0.4709	0.5356	0.6017
70	0.18750	0.1649	0.2222	0.2807	0.3404	0.4014	0.4638	0.5275	0.5926
75	0.19034	0.1625	0.2189	0.2765	0.3353	0.3954	0.4569	0.5196	0.5838
80	0.19317	0.1601	0.2157	0.2725	0.3304	0.3896	0.4501	0.5120	0.5752
85	0.19601	0.1578	0.2126	0.2685	0.3256	0.3840	0.4436	0.5046	0.5669
90	0.19884	0.1555	0.2095	0.2647	0.3210	0.3785	0.4373	0.4974	0.5588
95	0.20168	0.1534	0.2066	0.2610	0.3165	0.3732	0.4312	0.4904	0.5509

(1) $\frac{W}{V}$ [Agent Weight Requirements (kg/m³)] – Kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

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

(2) t [Temperature (°C)] – The design temperature in the hazard area.
(3) s [Specific Volume (m³/kg)] – Specific volume of superheated Halon 1301 vapor may be approximated by the formula:

$$s = 0.147\,81 + .000\,567\,t$$

where t = temperature, °C

(4) C [Concentration (%)] – Volumetric concentration of Halon 1301 in air at the temperature indicated.

2-6.3.3 The initial discharge shall be completed within the limits specified in 2-6.2.

2-6.3.4 The rate of extended discharge shall be sufficient to maintain the desired concentration for the duration of application.

2-6.4 Piping and Supply. Piping shall be designed in accordance with the requirements outlined in Chapter 1 to deliver the required rate of application at each nozzle.

2-6.5 Nozzle Choice and Location.

2-6.5.1 Nozzles used with total flooding systems shall be of the type listed for the intended purpose, and shall be located with the geometry of the hazard and enclosure taken into consideration.

2-6.5.2* 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. Nozzles vary in design and discharge characteristics and shall be selected on the basis of their adequacy for the use intended. Nozzles shall be placed within the hazard area in compliance with listed limitations with regard to spacing, floor coverage, and alignment.

Chapter 3 Local Application Systems

3-1* General Information.

3-1.1 Uses.

3-1.1.1 Local application systems are used where there is no fixed enclosure about the hazard or hazards or where there is a fixed enclosure about the hazard that is not adequate to enable an extinguishing concentration to be built up and maintained in the space. Individual hazards within confined spaces may be protected, subject to the limitations of 3-1.1.3. Where deep-seated fires are expected, the total flooding requirements of Chapter 2 shall apply.

3-1.1.2 Examples of hazards that may be successfully protected by local application systems include dip tanks, quench tanks, spray booths, oil-filled electric transformers, vapor vents, and similar types of hazards.

3-1.1.3 For all Halon 1301 local application systems located in normally occupied confined spaces, the calculations described in 2-5.2 shall be performed to determine the volumetric concentration of the agent developed in that volume. The limitations of use shall be governed by the requirements of 2-1.1.3 and 2-1.1.4. Since it is not the object of a local application system to distribute the agent evenly throughout the entire volume, locally high concentrations may be experienced. (*See A-1-6.1.*)

3-1.2 General Requirements. Local application systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements of Chapter 1 and with the additional requirements set forth in this chapter.

3-2 Hazard Specifications.

3-2.1 Extent of Hazard.

3-2.1.1 The hazard shall be so isolated from other hazards or combustibles that fire will not spread outside the protected area. The entire hazard shall be protected. The hazard shall include all areas that are or may become coated by combustible liquids or thin solid coatings such as areas subject to spillage, leakage, dripping, splashing, or condensation, and all associated materials or equipment such as freshly coated stock, drain boards, hoods, ducts, etc., that might extend fire outside or lead fire into the protected area.

3-2.1.2 When a series of interexposed hazards is subdivided into smaller groups or sections, the systems for such hazards shall be designed to provide immediate independent protection to the adjacent groups or sections.

3-2.2 Location of Hazard. The hazard may be indoors or partly sheltered. If the hazard is completely out-of-doors, it is essential that the agent discharge be such that winds or strong air currents do not impair the protection. It shall be the responsibility of the system designer to show that such conditions have been taken into account in the design of a system.

3-3* Halon 1301 Requirements.

3-3.1 General.

3-3.1.1 The quantity of agent required for local application systems shall be based on liquid discharge only and on the total rate of discharge needed to protect the hazard and the time that the discharge shall be maintained to assure complete extinguishment.

3-3.1.2 Since only the liquid portion of the discharge is effective in this application, the computed quantity of agent shall be increased to compensate for the residual agent in the storage container at the end of liquid flow. This additional agent is not required for the total flooding portion of a combined total flooding and local application system.

3-3.1.3* The system shall be designed to compensate for any agent vaporized in the pipelines due to heat absorption from the piping.

3-3.2 Rate of Discharge.

3-3.2.1 Nozzle discharge rates shall be determined as outlined below:

3-3.2.2 If part of the hazard is to be protected by total flooding, the discharge rate for the local application portion of the system shall be maintained for a period not less than the discharge time for the total flooding portion.

3-3.2.3 The minimum design rate (R_d) shall not be less than the optimum rate (R_o) required for extinguishment (*see Figure 3-3.2.3*). The minimum design quantity (Q_d) shall be no less than 1.5 times the minimum quantity (Q_m) required for extinguishment at any selected design rate

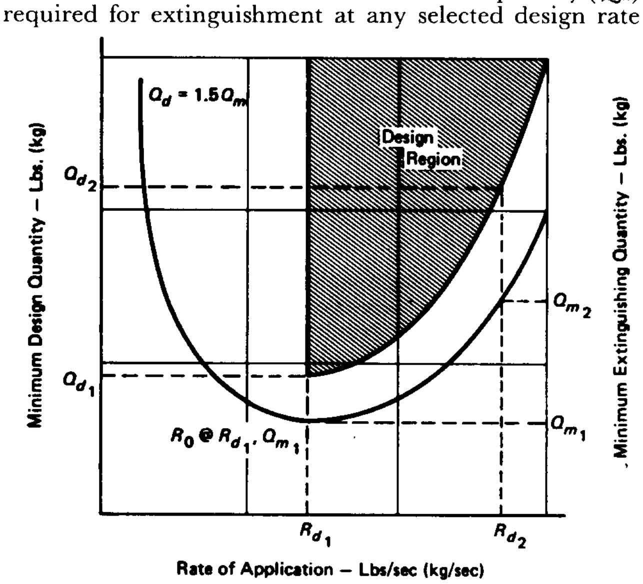


Figure 3-3.2.3 Typical data presentation for local application nozzles.

(R_d). The minimum design discharge time (T_d) shall be determined by dividing the design quantity (Q_d) by the design rate (R_d).

3-3.2.4 The basis for nozzle selection for local application systems shall be a curve similar to Figure 3-3.2.3 together with other performance data that clearly depict the interrelationship between agent quantity, discharge time, area coverage, and the distance of the nozzle from the protected surface.

3-3.2.5 The information in 3-3.2.4 shall be contained in the listings of a testing laboratory.

3-3.2.6 Where there is the likelihood that metal, fuel, or other material may become heated over the ignition temperature of the fuel, additional means shall be provided to prevent reignition.

3-3.2.7 The total rate of discharge for the system shall be the sum of the individual rates of all the nozzles or discharge devices used on the system.

3-3.3 Area per Nozzle.

3-3.3.1 The maximum area protected by each nozzle shall be determined on the basis of nozzle discharge pattern, distance from the protected surface, and the design discharge rate in accordance with listings of a testing laboratory.

3-3.3.2 Irregular-shaped or three-dimensional hazards shall be protected by a nozzle or combination of nozzles to ensure complete agent coverage of all exposed surfaces. The protected surface area shall be used to determine the nozzle coverage, but all surfaces protected by a nozzle shall lie within the nozzle's listed range limitations.

3-3.3.3 When deep layer flammable liquids are to be protected, a minimum freeboard shall be provided in accordance with the listings of a testing laboratory.

3-3.4 Location and Number of Nozzles.

3-3.4.1 A sufficient number of nozzles shall be used to cover the entire hazard area on the basis of the unit areas protected by each nozzle.

3-3.4.2 Tankside or linear-type nozzles shall be located in accordance with spacing and discharge rate limitations stated in nozzle listings.

3-3.4.3 Overhead nozzles shall be installed perpendicular to the hazard and centered over the area protected by the nozzle unless listed for installation at other angles to the surface.

3-3.4.4 Nozzles shall be located to be free of possible obstructions that could interfere with the proper projection of the discharged agent.

3-3.4.5 Nozzles shall be located to protect coated stock or other hazard extending above a protected surface.

3-3.4.6 The possible effects of air current, winds, and forced drafts shall be compensated for by locating nozzles or by providing additional nozzles to protect the outside areas of the hazard.

Chapter 4 Referenced Publications

4-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 70-1990, *National Electrical Code*

NFPA 72A-1987, *Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems*

NFPA 72E-1987, *Standard on Automatic Fire Detectors.*

4-1.2 Other Publications.

4-1.2.1 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

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

ANSI B31.1-1986, *Power Piping Code*

ANSI B36.10-1985, *Welded and Seamless Wrought Steel Pipe*

ANSI/UL 536-1984, *Flexible Metal Hose.*

4-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A53-88, *Specifications for Welded and Seamless Steel Pipe*

ASTM A106-88, *Specifications for Seamless Carbon Steel Pipe for High Temperature Service*

ASTM A197-87, *Specifications for Cupola Malleable Iron*

ASTM A234-88, *Specifications for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

ASTM A395-80, *Specification for Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures*

ASTM B88-88, *Specifications for Seamless Copper Water Tube*

ASTM E380-86, *Standard for Metric Practice.*

4-1.2.3 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*-1986.

4-1.2.4 CSA Publications. Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.

CAN3-Z234.1-89, *Canadian Metric Practice Guide*

C22.1-1986, *Canadian Electrical Code, Part I.*

4-1.2.5 ULC Publications. Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario, Canada M1R 3A9.

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

CAN/ULC S529-M87, *Smoke Detectors in Fire Alarm Systems*

CAN/ULC S536-M86, *Standard for the Inspection and Testing of Fire Alarm Systems.*

4-1.2.6 US Government Publication. Superintendent of Documents, US Government Printing Office, Washington, DC 20401.

Code of Federal Regulations, Title 49, Transportation, Parts 170-190.

4-1.2.7 CTC Publication. Queen's Printer, Ottawa, Ontario, Canada K1A 0N9.

Canadian Transport Commission's Regulations for Transportation of Dangerous Commodities by Rail.

4-1.2.8 CGA Publication. Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

CGA Pamphlet 6-1984, *Standards for Visual Inspection of Steel Compressed Gas Cylinders*, Section 3.

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-5 Halogenated Extinguishing Agents. A halogenated compound is one that contains one or more atoms of an element from the halogen series: 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 is not only nonflammable, but 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:

Halon 1011, bromochloromethane, CH_2BrCl

Halon 1211, bromochlorodifluoromethane, $CBrClF_2$

Halon 1202, dibromodifluoromethane, CBr_2F_2

Halon 1301, bromotrifluoromethane, $CBrF_3$

Halon 2402, dibromotetrafluoroethane, $CBrF_2CBrF_2$

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 = 1st digit times 2, plus 2, minus the sum of the remaining digits).

A-1-5.2 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.

Physical Properties. A list of important physical properties of Halon 1301 is given in A-1-5.2. Under normal conditions, Halon 1301 is a colorless, odorless gas with a density approximately 5 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 A-1-5.2. 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.

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, etc.

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 physiochemical 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 that 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.

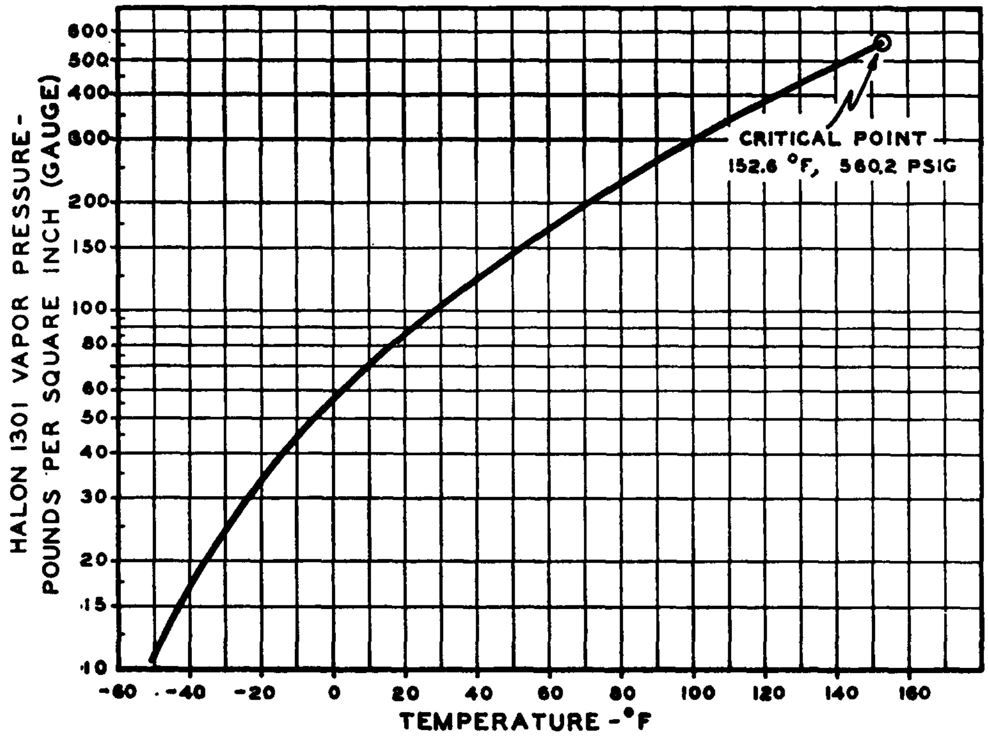


Figure A-1-5.2 Vapor pressure of Halon 1301 vs. temperature.

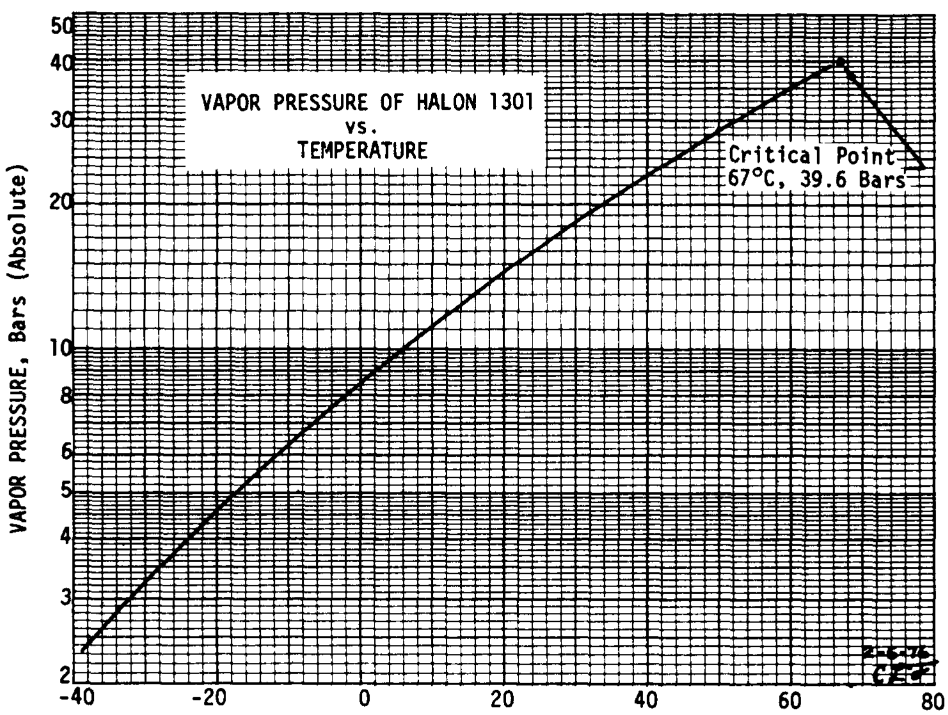


Figure A-1-5.2 (Metric)

Table A-1-5.2
Physical Properties of Halon 1301

	British	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
Critical volume	0.0215 ft^3/lb	0.000 276 m^3/kg
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} Poiseuille
Viscosity, vapor, at 77°F (25°C)	1.08×10^{-5} lb/ft-sec	1.63×10^{-5} Poiseuille
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	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 wt	0.03% by wt
Solubility of water in Halon 1301 at 70°F (21°C)	0.0095% by wt	0.0095% by wt

A-1-6.1 Hazards to Personnel. The discharge of Halon 1301 to extinguish a fire may 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:

(a) *Noise.* Discharge of a system can cause noise loud enough to be startling but ordinarily insufficient to cause traumatic injury.

(b) *Turbulence.* High velocity discharge from nozzles may be sufficient to dislodge substantial objects directly in the path. System discharge may cause enough general turbulence in the enclosures to move unsecured paper and light objects.

(c) *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 may occur for a brief period due to the condensation of water vapor.

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.

Animals. Halon 1301 has a 15-minute approximate lethal concentration (ALC) of 83 percent† (O_2 added)[1]*, suggesting a very low degree of acute inhalation toxicity. In monkeys and dogs, mild CNS effects occur after a few minutes' exposure above 10 percent, progressing to lethargy in monkeys and tremors and convulsion in dogs at levels above 20 percent.[2]

Spontaneous effects on blood pressure and cardiac rhythm occur at much higher levels, approximately 20 percent and 40 percent, respectively.[2]

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.[3]

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 5-10 minutes, and fall rapidly upon cessation of exposure. There is no accumulation of Halon 1301 as indicated by similar blood concentration at 5-10 minutes

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

*See C-1.6 for references.

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 10.0 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.[4]

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.[5] 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.

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.[3] 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' exposure, but the subject reverted to a normal rhythm upon removal to fresh air.[6] In recent studies at the Medical College of Wisconsin[7], 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:

7 percent and below	— 15 minutes
7-10 percent	— 1 minute
10-15 percent	— 30 seconds
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 may produce cardiac arrhythmias, including ventricular fibrillation.

Halon 1301 is colorless and odorless. Discharge of the agent may 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 (5 times that of air) requires the use of discharge nozzles that will achieve a well-mixed atmosphere to avoid local pockets of higher concentration. It is also possible to develop local pockets of higher concentration in pits or low-lying areas adjacent to local application systems. Once mixed into the air, the agent will not settle out.

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 A-1-5.2*). 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-sq ft (2.3-m^2) heptane fire in a 10,000-cu ft (283-m^3) enclosure within 0.5 seconds 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.

A-1-6.1.2 Safety Requirements. The steps and safeguards necessary to prevent injury or death to personnel in areas whose atmospheres will be made hazardous by the discharge or thermal decomposition of Halon 1301 may include the following:

(a) Provision of adequate aisleways and routes of exit and keeping them clear at all times.

(b) Provision of emergency lighting and directional signs as necessary to ensure quick, safe evacuation.

(c) Provision of alarms within such areas that will operate immediately upon detection of the fire.

(d) Provision of only outward-swinging, self-closing doors at exits from hazardous areas, and, where such doors are latched, provision of panic hardware.

(e) Provision of continuous alarms at entrances to such areas until the atmosphere has been restored to normal.

(f) 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 may contain additional instructions pertinent to the conditions of the hazard.

(g) Provision for prompt discovery and rescue of persons rendered unconscious in such areas. This may 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.

(h) Provision of instruction and drills for all personnel within or in the vicinity of such areas, including maintenance or construction people who may be brought into the area, to ensure their correct action when Halon 1301 protective equipment operates.

(i) 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.

(j) Prohibition against smoking by persons until the atmosphere has been purged of Halon 1301.

(k) Provision of such other steps and safeguards that a careful study of each particular situation indicates is necessary to prevent injury or death.

A-1-7.4 When a full discharge test is conducted, the following procedures are recommended.

A. Planning for the Acceptance Test.

1. A date and time should be set well in advance of the test to assure that proper preparations are made.

2. To assure 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.

B. Conducting the Discharge Test

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

2. 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.)

3. The following equipment will be required for the test:

(a) An accurate concentration meter capable of providing both direct readout and printout. Multiple recorders may be required for large installations.

(b) A stopwatch.

(c) Portable exhaust fans, if needed for post-test ventilation.

C. The following procedure should be used for the test:

1. Halon 1301 should not be used as a test agent. Availability of Halon 1301 is limited by the Montreal Protocol on Substances that Deplete the Ozone Layer. Use of Halon 1301 as a test agent further reduces availability for fire extinguishing purposes. As such this standard recommends that Halon 1301 should not be used as a test agent.

HCFC 22 and sulfur hexafluoride have been identified as candidate alternate test materials. At the time of preparation of this standard, active programs to evaluate these materials were being undertaken.

2. Where permitted by the authority having jurisdiction, Halon 122 or other agents are sometimes used in acceptance testing of new Halon 1301 systems. Where Halon 122 or other agents are used, the authority having jurisdiction should assure that they provide a meaningful test of the system.

Known differences between Halon 1301 and Halon 122 include:

(a) Halon 122 causes less turbulence than Halon 1301.

(b) Distribution from unbalanced systems may be substantially different.

(c) Halon 122 mixes with the atmosphere less readily than Halon 1301.

(d) The toxicity of Halon 122 is greater than Halon 1301.

(e) The vapor density of Halon 122 is less than Halon 1301.

(f) Halon 122 is not a recognized fire extinguishing agent.

(g) The test cylinder for Halon 122 is loaded to 82 percent by weight of the Halon 1301 charge.

(1) If Halon 122 is used as a test gas, personnel should be provided with self-contained breathing apparatus or excluded from all potentially affected areas until Halon 122 vapors have been removed and the building can be safely occupied.

(2) Provision should be made for safe ventilation of Halon 122 after the test. Containers charged with Halon 122 should be distinctly identified.

(3) Reference to Halon 122 manufacturers' bulletins is important.

3. Replacement 1301 should be on hand and the replacement containers should be weighed at the site.

D. Predischarge Checklists and Functional Test. The following guidelines are for information purposes only and are not intended to replace or restrict the manufacturers' recommendations.

1. 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 may be moved by the discharge of Halon should be removed.

(e) All areas where Halon discharge may 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.

E. Total Flooding Test. 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 shall 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 may 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 one 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 2-4*). Where an inerting concentration is required, a more stringent test may be necessary. Refer to 2-1.1.3 to determine that concentrations do not exceed the safety limits specified therein. 110-volt, 60-cycle power should be available for operating a recordable-type analyzer. The power to the analyzer should remain on when the fire extinguisher system is activated.

1. Halon analyzers should be field calibrated and adjusted prior to each test.

2. 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.

3. Actuate the system for discharge.

4. 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.

5. The following items should be complied with to designate the system as acceptable.

(a) Liquid discharge should be in accordance with 2-6.2.2.

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

(c) The specified concentration should be maintained for the specified holding period.

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

6. Once the requirement for hold time has been completed, ventilation to exhaust the Halon from the area should be started and maintained as necessary.

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

F. Failure Classification. Discharge test failure may be classified as one of the following:

1. *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.).

2. *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.).

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

G. 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:

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

2. Copies of clearly identified analyzer chart records showing Halon concentration. This must also include analyzer calibration results, and the tapes should be signed by authority having jurisdiction.

3. A signoff by each member of the test team.

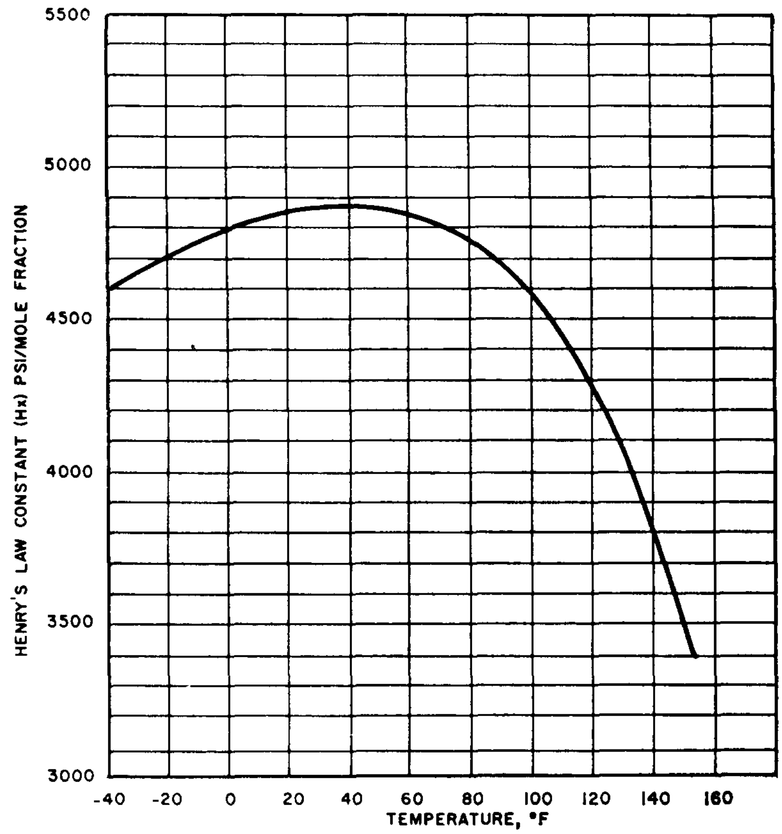


Figure A-1-9.4(a) Henry's Law Constant for Nitrogen Solubility in Liquid Halon 1301.

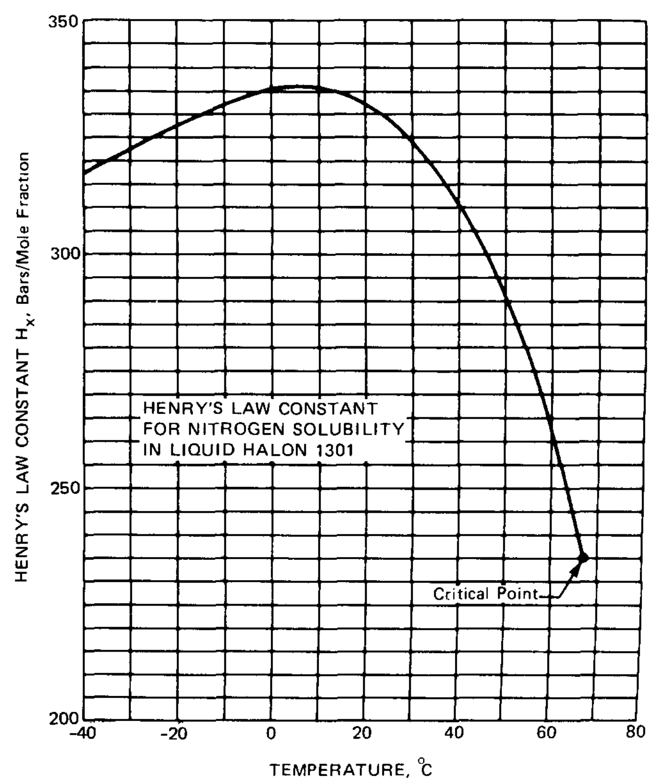


Figure A-1-9.4(a) (Metric)

H. Place the system back in service. (Refer to the manufacturer's recommendations.)

1. Verify that all detectors and manual pull stations have been reset.

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

3. 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.

4. Secure the system control unit and lock where applicable.

5. Verify that the end-user has been properly instructed in the use and operation of this system.

6. Clean the area of any debris that may have resulted during the system installation.

7. Verify that an emergency telephone number has been left with the end-user.

A-1-8.5.3 The abort switch should be located near the means of egress for the area.

A-1-9.4 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 the U.S. Department of Transportation requirements will be used to contain quantities up to approximately 100 lb (45 kg) Halon 1301. Manifolded cylinders are used for larger 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.

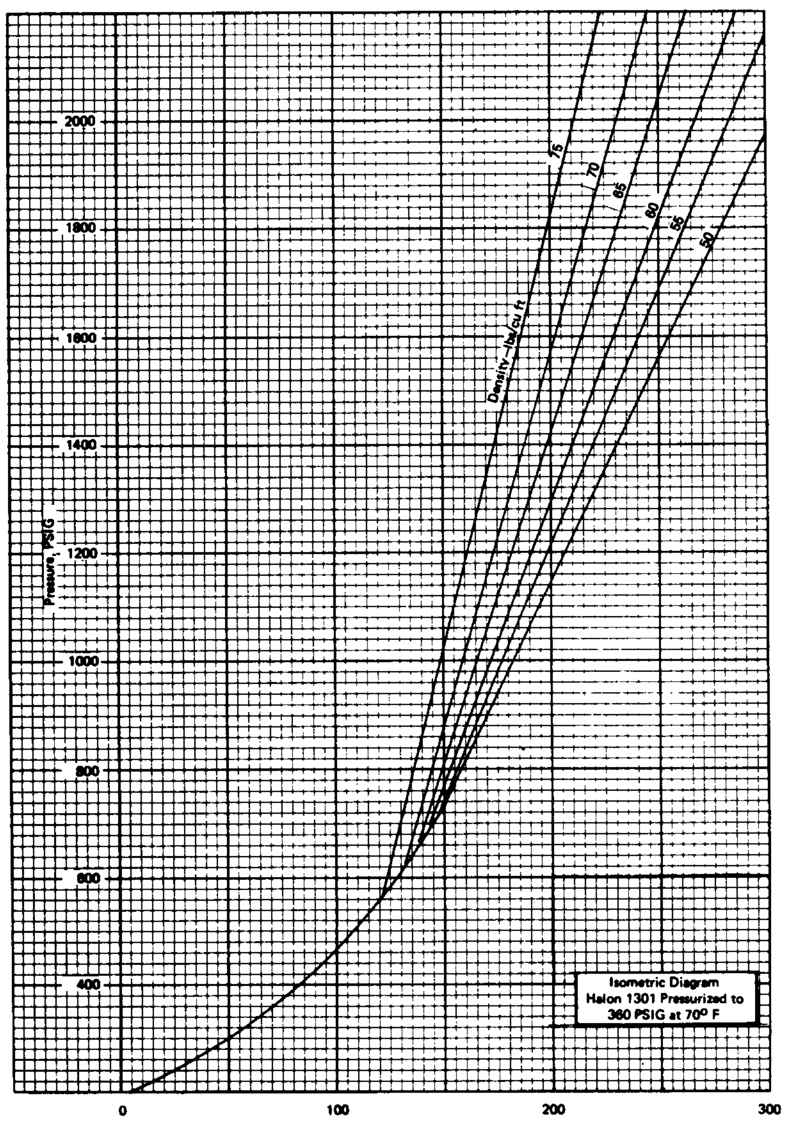


Figure A-1-9.4(b) Isometric diagram. Halon 1301 pressurized to 360 psig at 70 °F.

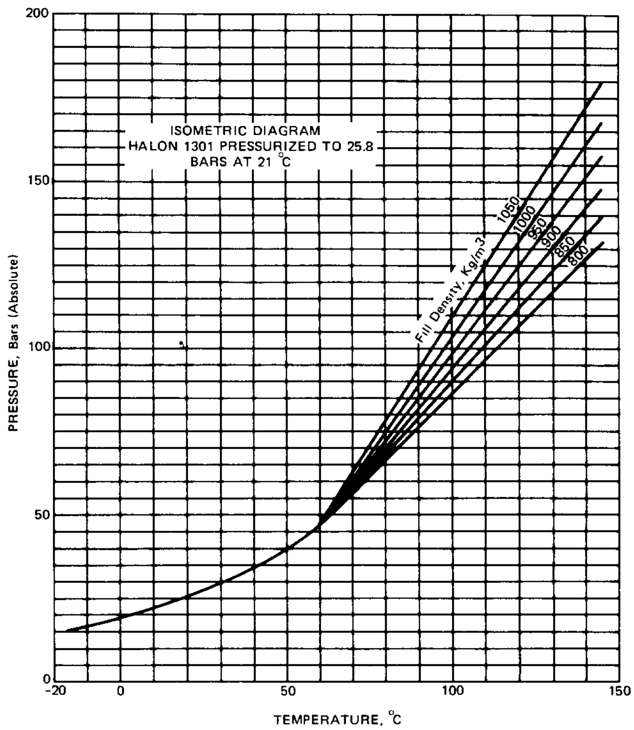


Figure A-1-9.4(b) (Metric)

Nitrogen Superpressurization. Although the 199 psig (14.73 bars) 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 (4.92 bars), and at − 40 °F (− 40 °C) it is only 17.2 psig (2.20 bars). 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 (bars) per mole fraction.

P_n = Partial pressure of nitrogen above solution, psi (bars).

X_n = Nitrogen concentration in liquid Halon 1301, mole fraction.

Nitrogen partial pressure may be calculated from the total pressure of the system and the vapor pressure of Halon 1301 (Figure A-1-5.2) as follows:

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

Where:

P = Total pressure of system, psi absolute (psi gage + 14.696) (bars).

P_v = Vapor pressure of Halon 1301, psi absolute (psi gage + 14.696) (bars).

Figure A-1-9.4(a) shows that variation of Henry's Law constant, H_x, with temperature.

Filling Density. The filling density of a container is defined as the number of pounds of Halon 1301 per cu ft of container volume. Isometric diagrams for Halon 1301 superpressurized with nitrogen, Figures A-1-9.4(b) (360 psig) and A-1-9.4(c) (600 psig), 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/cu ft (1566 kg/m^3) and subsequently superpressurized to 600 psig (42.38 bars) would develop a pressure of 3000 psig (207.86 bars) when heated to 130 °F (54 °C); if filled to 70 lb/cu ft (1121 kg/m^3) or less as permitted in this standard, a pressure of 1040 psig (72.72 bars) 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.

A-1-10.1 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-1-10.1.1 The following presents calculations to provide minimum pipe schedules (wall thickness) for use with both 360 psi and 600 psi Halon 1301 fire extinguishing systems in accordance with this standard. Paragraph 1-10.1 requires that "the pipe wall shall be calculated in accordance with ANSI B31.1, *Power Piping Code.*"

Minimum Piping Requirements for Halon 1301 Systems

360 psi and 600 psi Charging Pressure

1. Limitations on piping to be used for Halon systems (or any pressurized fluid) are set by:

(a) Maximum pressure expected within the pipe;

(b) Material of construction of the pipe, tensile strength of the material, yield strength of the material, and temperature limitations of the material;

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

(d) Pipe construction method, i.e., seamless, ERW (electric resistance welded), furnace welded, etc.;

(e) Pipe diameter; and

(f) Wall thickness of the pipe.

2. The calculations are based on the following:

(a) The minimum calculated pressure is **1000 psi for** systems using an initial charging pressure **of 600 psi, and**

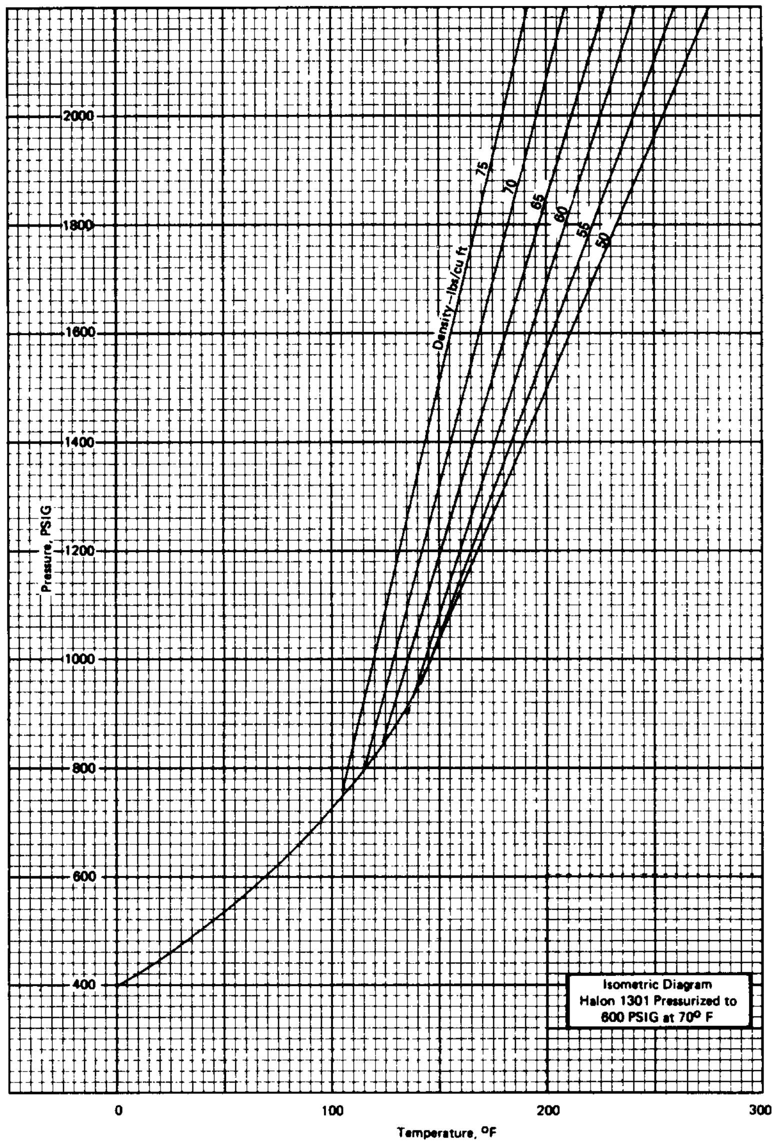


Figure A-1-9.4(c) Isometric diagram. Halon 1301 pressurized to 600 psig at 70 °F.

620 psi for systems using an initial charging pressure of 360 psi;

(b) The calculations apply only to steel pipe conforming to ASTM A-53 or ASTM A-106, and copper tubing conforming to ASTM B-88; and

(c) The calculations cover threaded, welded, and grooved joints for steel pipe; and compression fittings for copper tubing.

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

$$t = [PD/2SE] + A$$

Where:

t = required wall thickness (inches)

D = outside pipe diameter (inches)

P = maximum allowable pressure (psi)

SE = maximum allowable stress [including joint efficiency] (psi)

A = allowance for threading, grooving, etc. (inches)

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 ⅔ of the yield strength (whichever is lower) multiplied by a joint efficiency factor.

Joint efficiency factors are:

1.0 for seamless

0.85 for ERW (Electric resistance welded)

0.60 for furnace butt weld (continuous weld) (Class F)

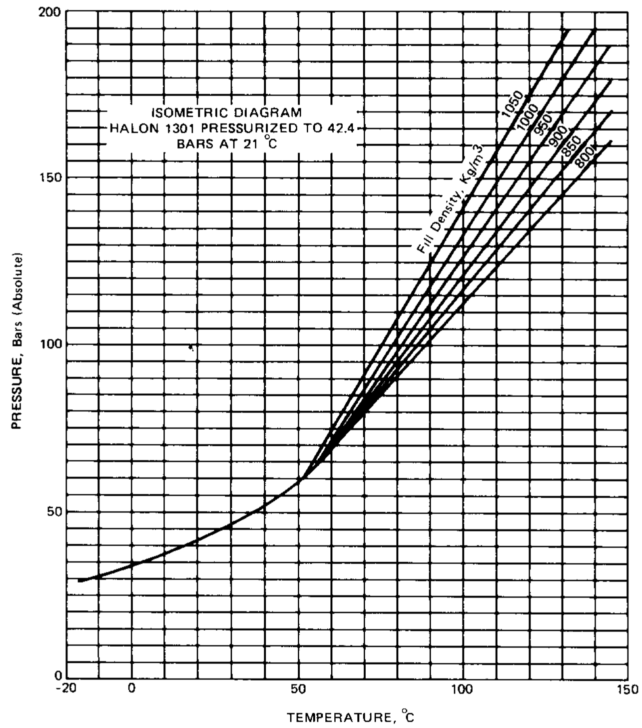


Figure A-1-9.4(c) (Metric)

4. The following listing gives values for SE as taken from Appendix A of the ASME/ANSI *Code for Pressure Piping* (ASME/ANSI B31). Identical values are given in ASME/ANSI B31.1 (*Power Piping*) and ASME/ANSI 31.9 (*Building Services Piping*).

		SE Value
Grade C Seamless Pipe	ASTM A-106	17500 psi
Grade B Seamless Pipe	ASTM A-53	15000 psi
Grade B Seamless Pipe	ASTM A-106	15000 psi
Grade A Seamless Pipe	ASTM A-53	12000 psi
Grade A Seamless Pipe	ASTM A-106	12000 psi
Grade B ERW Pipe	ASTM A-53	12800 psi
Grade A ERW Pipe	ASTM A-53	10200 psi
Class F Furnace Welded Pipe	ASTM A-53	6800 psi
Seamless Copper Tubing (Annealed)	ASTM B-88	5100 psi
Seamless Copper Tubing (Drawn)	ASTM B-88	9000 psi

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

$$P = 2SE\,(t - A)/D$$

As required by 10-1.1 of this standard, for systems having a charging pressure of 360 psi, the calculated pressure (P) must be equal to or greater than 620 psi.

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

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

6. 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.

7. Paragraph 102.2.4(B) of the *Power Piping Code* (ASME/ANSI 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 criteria. Therefore, the piping calculations set out in this paragraph are based on values of SE which are 20 percent greater than that outlined above in paragraph four (*per appendix A of the Power Piping Code*). The specific values for maximum allowable stress used in these calculations are as follows:

		SE Value
Grade C Seamless Pipe	ASTM A-106	21000 psi
Grade B Seamless Pipe	ASTM A-53	18000 psi
Grade B Seamless Pipe	ASTM A-106	18000 psi
Grade A Seamless Pipe	ASTM A-53	14400 psi
Grade A Seamless Pipe	ASTM A-106	14400 psi
Grade B Seamless Pipe	ASTM A-53	15360 psi
Grade A ERW Pipe	ASTM A-53	12240 psi
Class F Furnace Welded Pipe	ASTM A-53	8160 psi
Seamless Copper Tubing (Annealed)	ASTM B-88	6120 psi
Seamless Copper Tubing (Drawn)	ASTM B-88	10800 psi

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, 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: The above calculations do not apply to extended discharge exceeding 14.4 minutes.

NOTE 5: Compression fittings should be listed approved for use with the type of tubing and pressures per 1-10.2.2 of this standard (600 psi systems 1000 psi working pressure; 360 psi systems 620 psi working pressure).

Minimum Piping Requirements
Halon 1301 Systems—360 psi Charging Pressure

Steel Pipe—Threaded Connections

ASTM A-106 Seamless, Grade C	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—⅛ in. thru 1½ in. NPS
	Schedule 80—2 in. thru 8 in. NPS

Steel Pipe—Welded or Rolled Groove Connections

ASTM A-106 Seamless, Grade C	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—⅛ in. thru 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—⅛ in. thru 8 in. NPS

ASTM A-53 ERW Grade A	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. thru 6 in. NPS
	Schedule 80—8 in. NPS

Steel Pipe—Cut Groove Connections

ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. thru 5 in. NPS
	Schedule 80—6 in. thru 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. thru 3 in. NPS
	Schedule 80—4 in. thru 8 in. NPS

Copper Tubing—Compression Fittings

ASTM B-88 Seamless, Drawn	Type K 1/4 in. thru 8 in.
ASTM B-88 Seamless, Drawn	Type L 1/4 in. thru 3 in.
ASTM B-88 Seamless, Drawn	Type M 1/4 in. thru 1 1/2 in.
ASTM B-88 Seamless, Annealed	Type K 1/4 in thru 1 in.
ASTM B-88 Seamless, Annealed	Type L 1/4 in. thru 3/4 in.
ASTM B-88 Seamless, Annealed	Type M 1/4 in. ONLY

Minimum Piping Requirements
Halon 1301 Systems—600 psi Charging Pressure

Steel Pipe—Threaded Connections

ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. thru 5 in. NPS
	Schedule 80—6 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. thru 2 1/2 in. NPS
	Schedule 80— 3 in. thru 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. thru 3 in. NPS
	Schedule 80— 4 in. thru 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. thru 1 1/4 in. NPS
	Schedule 80—1 1/2 in. thru 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. thru 1/2 in. NPS
	Schedule 80—3/4 in. thru 2 1/2 in. NPS
	Schedule 120—3 in. thru 8 in. NPS

Steel Pipe—Welded Connections

ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. thru 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. thru 6 in. NPS
	Schedule 80—8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. thru 3 in. NPS
	Schedule 80—4 in. thru 6 in. NPS
	Schedule 120—8 in. NPS

Copper Tubing—Compression Fittings

ASTM B-88 Seamless, Drawn	Type K 1/4 in. thru 1 1/4 in.
ASTM B-88 Seamless, Drawn	Type L 1/4 in. thru 3/4 in.
ASTM B-88 Seamless, Drawn	Type M 1/4 in. thru 3/8 in.
ASTM B-88 Seamless, Annealed	Type K 1/4 in thru 3/8 in.
ASTM B-88 Seamless, Annealed	Type L DO NOT USE
ASTM B-88 Seamless, Annealed	Type M DO NOT USE

A-1-10.2.2

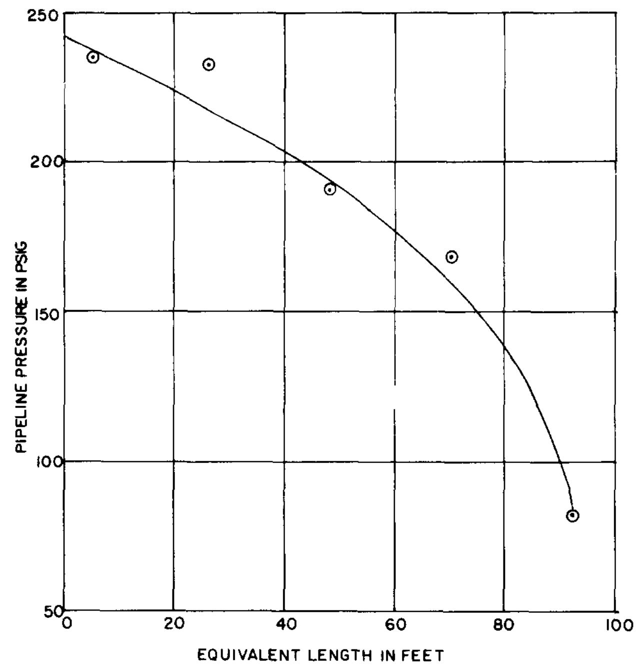
(a) 300 lb class malleable iron fittings, sizes through 3 in., are acceptable. Forged steel fittings should be used for all larger sizes. Flanged joints should be class 600 lb.

(b) 300 lb class malleable iron fittings are acceptable through 3 in. IPS and 1,000 ductile iron or forged steel fittings should be used in larger sizes. Flanged joints should be 300 lb class.

The above listed materials do not preclude the use of other materials which would satisfy the requirements of 1-10.2.2.

A-1-10.6 System Flow Calculations. 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 which is used to determine pipeline pressures, densities and other design factors. Unfortunately, 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.



For SI Units: 1 ft = 0.3048 m; 1 psi = 0.068 95 bar.

Figure A-1-10.6 Comparison of test data with calculated pressure drop using two-phase flow equation (*see 1-10.6.5*).

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 Tables A-1-10.6(a) and A-1-10.6(b).

Changes in elevation are accounted for by the following equation:

$$\Delta P = \frac{p \times \Delta EL}{144}$$

Where:

ΔP = Pressure drop, psi.

p = Pipeline density of agent at point of elevation change, lb/cu ft.

ΔEL = Net change in elevation within the piping section, increase (+) and decrease (−).

Table A-1-10.6(a)
Equivalent Length in Feet of Threaded Pipe Fittings
Schedule 40 Steel Pipe

Pipe Size, in.	Elbow Std. 45°	Elbow Std. 90°	Elbow 90° Long Rad. & Tee Thru Flow	Tee Side	Union Coupling or Gate Valve
3/8	0.6	1.3	0.8	2.7	0.3
1/2	0.8	1.7	1.0	3.4	0.4
3/4	1.0	2.2	1.4	4.5	0.5
1	1.3	2.8	1.8	5.7	0.6
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 A-1-10.6(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	Gate Valve
3/8	0.2	0.7	0.5	1.6	0.3
1/2	0.3	0.8	0.7	2.1	0.4
3/4	0.4	1.1	0.9	2.8	0.5
1	0.5	1.4	1.1	3.5	0.6
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

A-1-10.6.3 Flow should 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 A-1-10.6.3(d).

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 may 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.

$$\text{Percent in Piping} = 100\ \Sigma \frac{(Vp)\ (\bar{p})}{W}$$

Where:

Σ = Summation of (Vp) ($\bar{p}$) values for all pipeline sections.

Vp = Internal volume of each section of piping (cu ft)

\- = Average pipeline density of agent for each section of piping (lbs/cu ft)

W = Initial charge weight of Halon 1301 (lbs).

NOTE: Internal volume figures for steel pipe and tubing are given in Tables A-1-10.6.4(a) and A-1-10.6.4(b).

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 storage is plotted on Figures A-1-10.6.3(a) and A-1-10.6.3(b), respectively.

The rate of pressure recession in the storage container depends on the initial filling density as illustrated in Figures A-1-10.6.3(a) and A-1-10.6.3(b). 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

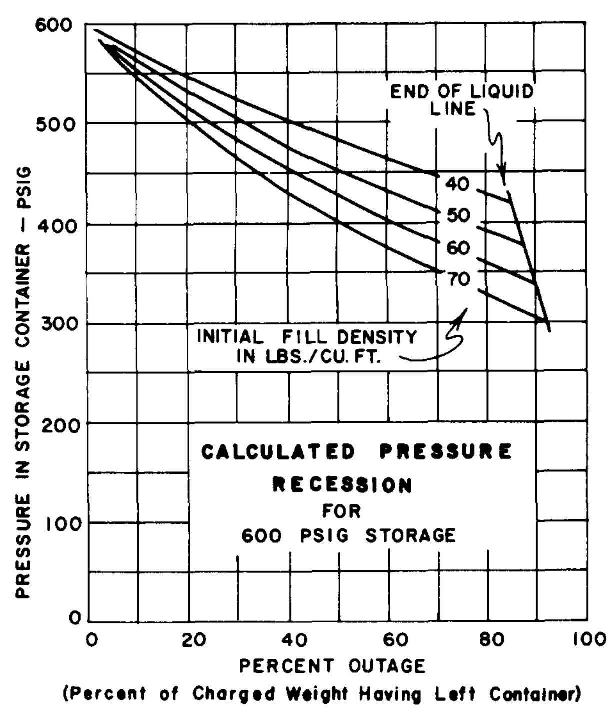


Figure A-1-10.6.3(a) Calculated pressure recession for 600 psig storage.

during discharge, reducing the average container pressure during actual discharge from the nozzle.

Figure A-1-10.6.3(c) 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 system with initial filling density of 70 lb/cu ft is reduced from a maximum of 403 psig to 355 psig. 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 A-1-10.6.3(d). 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.

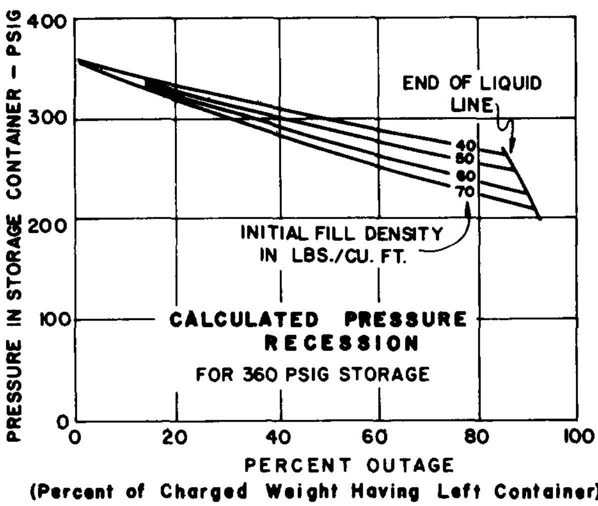


Figure A-1-10-6.3(b) Calculated pressure recession for 360 psig storage.

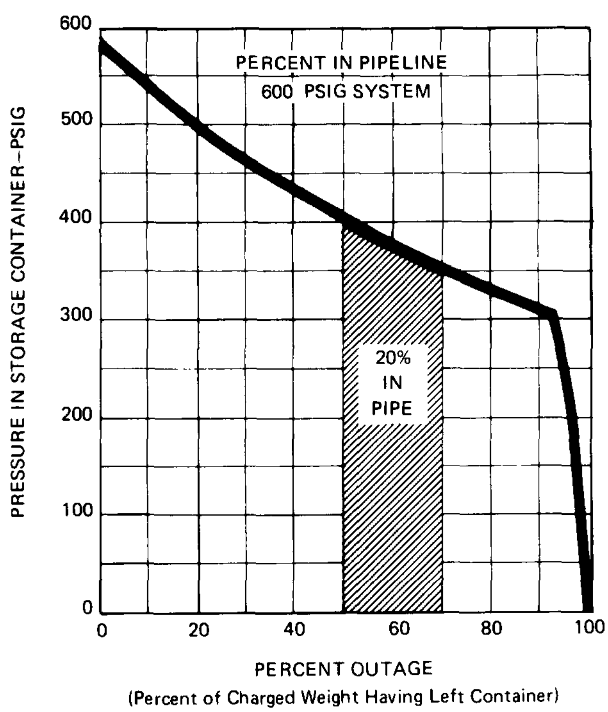


Figure A-1-10.6.3(c) Percent outage.

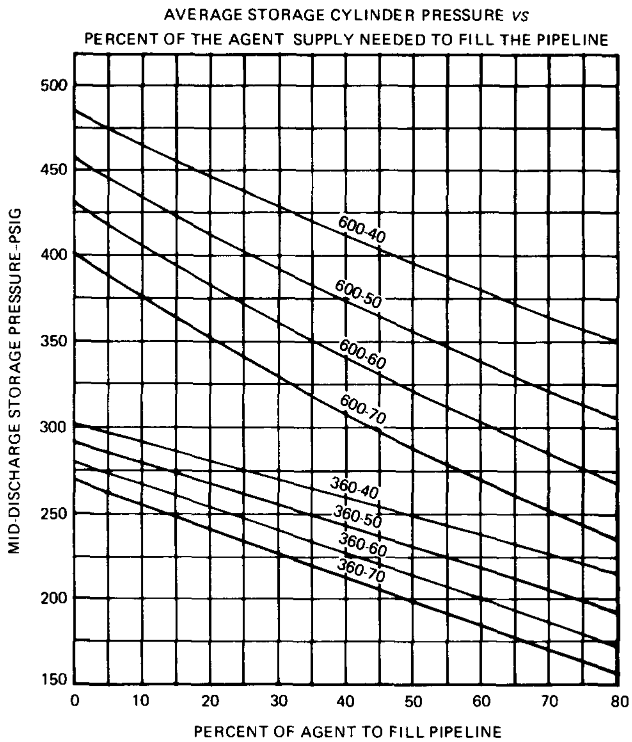


Figure A-1-10.6.3(d) Percent of agent to fill pipeline.

A-1-10.6.4 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 may 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.

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

Where:

W = Initial charge weight of Halon 1301, lb

V_p = Internal pipe volume, cu ft

K_1 and K_2 = Constants from Table A-1-10.6.4

An alternative solution of the percent in piping after terminal pressures have been calculated is to use the equation given in 1-10.6.4. Average density values can be obtained from Figure A-1-10.6.4(a) for the 600 psig systems and from Figure A-1-10.6.4(b) for the 360 psig systems.

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

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

Where:

Q = Flow rate, lbs/second

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 A-1-10.6.4
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
360	60	6770	46
360	50	6810	40
360	40	6850	34

Table A-1-10.6.4(a)
Internal Volume of Steel Pipe
Cubic Feet per Foot of Length

Nominal Pipe Diameter in.	Schedule 40 Inside Diameter in.	ft³/ft	Schedule 80 Inside Diameter in.	ft³/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 A-1-10.6.4(b)
Internal Volume of Copper Tubing

Size	Type	Actual Inside Diameter-inches	Internal Volume ft³/ft
¼	M	—	—
	L	0.315	0.0005
	K	0.305	0.0005
⅜	M	0.450	0.0011
	L	0.430	0.0010
	K	0.402	0.0009
½	M	0.569	0.0018
	L	0.545	0.0016
	K	0.527	0.0015
¾	M	0.811	0.0037
	L	0.785	0.0034
	K	0.745	0.0030
1	M	1.055	0.0061
	L	1.025	0.0057
	K	0.995	0.0054
1¼	M	1.291	0.0091
	L	1.265	0.0087
	K	1.245	0.0085
1½	M	1.527	0.0127
	L	1.505	0.0124
	K	1.481	0.0120
2	M	2.009	0.0220
	L	1.985	0.0215
	K	1.959	0.0209
2½	M	2.495	0.0340
	L	2.465	0.0331
	K	2.435	0.0323
3	M	2.981	0.0485
	L	2.945	0.0473
	K	2.907	0.0461
3½	M	3.459	0.0653
	L	3.425	0.0640
	K	3.385	0.0625
4	M	3.935	0.0845
	L	3.905	0.0832
	K	3.857	0.0811

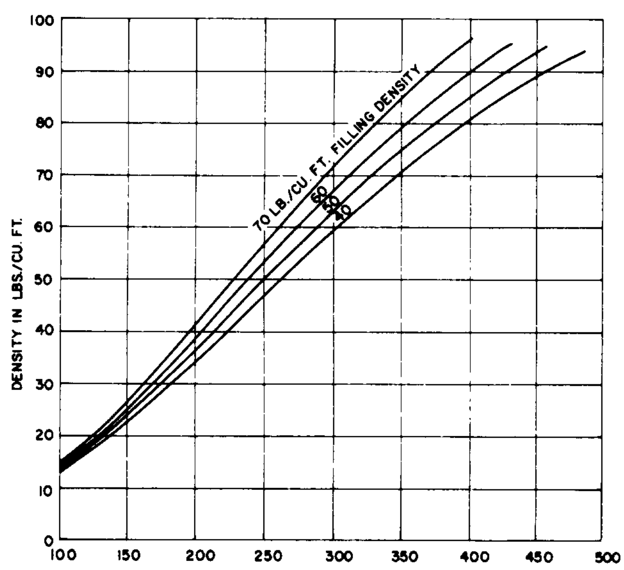


Figure A-1-10.6.4(a) Pipeline density for 600 psig systems based on constant enthalpy expansion.

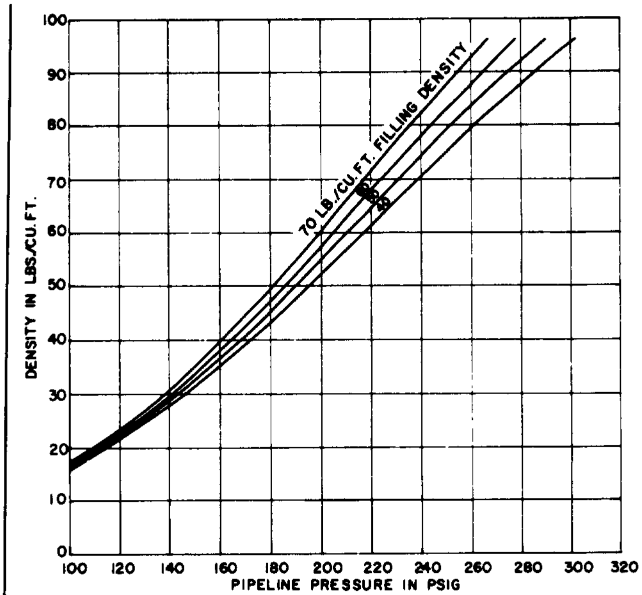


Figure A-1-10.6.4(b) Pipeline density for 360 psig systems based on constant enthalpy expansion.

A-1-10.6.5 Sample Calculation. An 80-lb supply of agent is to be discharged in 10 seconds through the piping system shown in Figure A-1-10.6.5. The agent storage container is pressurized to 360 psig and has a filling density of 70 lb/cu ft.

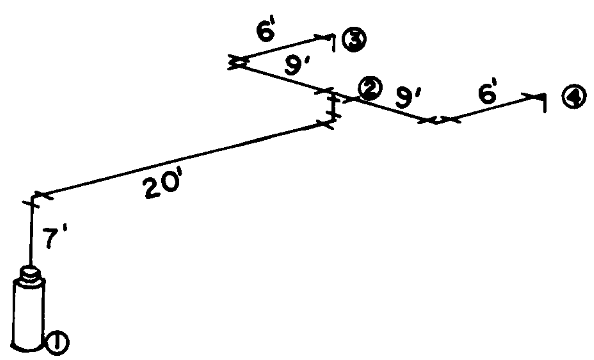


Figure A-1-10.6.5 Calculated Solution.

The two-phase flow equation as given in A-1-10.6.4 becomes specific for Halon 1301 when the Y and Z factors are based on the proper pressure and density values using the following equations:

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

$$Z = \ln \frac{p'}{p}$$

Where:

P_1 = Storage pressure, psia
P = Pipeline pressure, psia
p_1 = Density at pressure P_1, lbs/cu ft
p = Density at pressure P, lbs/cu ft
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.

$$Y_2 = Y_1 + (LQ^2/A) + B(Z_2 - Z_1)\,Q^2$$

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, lbs/sec
D = I.D. of pipe, in.

NOTE: A and B factors are for steel pipe.

The Y and Z factors depend on both storage pressure and filling density; therefore, separate tables are required for each storage condition. Tables A-1-10.6.5(a), (b), (c), and (d) are for the 600 psig systems with filling densities of 70, 60, 50, and 40 lb/cu ft. Tables A-1-10.6.5(e), (f), (g), and (h) are for the 360 psig systems with the same filling densities.

Two-Phase Solution

Section	Pipe	L	EQL	Elevation	Rate	Start Psig	End Psig
1-2	1" Sch. 40	27'	58'	7'	8	243	197
2-3	¾" Sch. 40	15'	19'	0'	4	197	181
2-4	¾" Sch. 40	15'	19'	0'	4	197	181

(1) Calculate A and B.

For 1-inch pipe, A = 1.302 and B = 6.59.

For ¾-inch pipe, A = 0.3666 and B = 17.3.

(2) Determine Piping Volume. Using Table A-1-10.6.4(a).

(3) Estimate Percent in Piping. Use the equation given in A-1-10.6.4.

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

(4) Determine Average Container Pressure During Discharge. Using Figure A-1-10.6.3(d), based on the estimated 19.5 percent in piping the average storage container pressure in 243 psig.

(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 A-1-10.6 is used:

$$\Delta P = \frac{p \times \Delta EL}{144}$$

The elevation change (EL) is 7 ft. The density (P) of the Halon 1301 at the 243 psig starting pressure of the section is found to be 83 lb/cu ft in Figure A-1-10.6.4(b) on the 70 lb/cu ft fill density curve. The pressure loss due to the 7 ft increase in elevation is:

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

New start psig = 243 − 4 = 239

(6) Determine Y_1 and Z_1 from Table A-1-10-6.5(e).

For a starting pressure of 239 psig:

Y_1 = 2819

Z_1 = 0.173"

(7) Determine Y_2 from Equation.

$Y_2 = 2819 + 58(8)^2/1.302 + 6.59(Z_2 - 0.173)(8)^2$

The Z term is small and may be neglected for initial solution.

$Y_2 = 5670''$

(8) Determine Terminal Pressure.

The terminal pressure of Section 1-2 is 200 psig from Table A-1-10.6.5(e). 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 2-3.

For the next section:

$Y_2 = 5797 + 19(4)^2/0.366 + 17.3(Z_2 - 0.475)(4)^2$

$Y_2 = 6628$

Terminal pressure = 182 psig

$Z_2 = 0.652$

$Y_2 = 6628 + 17.3(.652 - .452)(4)^2$

$Y_2 = 6628 + 46 = 6674$

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

Table A-1-10.6.5 Precalculated A and B Factors for Steel Pipe

Pipe Size Nominal	Schedule 40 A	Schedule 40 B	Schedule 80 A	Schedule 80 B
⅜	0.02472	135	0.01106	249
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	0.0304	1162	0.0372
5	4972	0.0123	3875	0.0149
6	13050	0.00589	9959	0.00724

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.

Table A-1-10.6.5(a) Halon 1301 at 600 psig and 70 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
400	.006	290	194	97	0	0	0	0	0	0	0
390	.028	1243	1149	1054	960	865	769	674	578	482	386
380	.051	2176	2084	1991	1898	1806	1712	1619	1525	1432	1338
370	.076	3086	2996	2906	2816	2725	2634	2543	2451	2360	2268
360	.102	3974	3886	3798	3710	3622	3533	3444	3355	3266	3176
350	.129	4838	4753	4667	4581	4495	4409	4323	4236	4149	4062
340	.159	5678	5595	5512	5428	5345	5261	5177	5093	5008	4923
330	.191	6492	6412	6331	6251	6169	6088	6007	5925	5843	5760
320	.224	7281	7203	7125	7047	6968	6890	6811	6731	6652	6572
310	.260	8042	7967	7892	7816	7741	7665	7588	7512	7435	7358
300	.298	8776	8704	8631	8559	8486	8413	8339	8265	8191	8117
290	.339	9482	9412	9343	9273	9203	9132	9062	8991	8919	8848
280	.382	10158	10092	10025	9958	9891	9823	9756	9688	9619	9551
270	.429	10805	10741	10678	10614	10550	10485	10420	10355	10290	10224
260	.478	11421	11361	11300	11239	11178	11117	11055	10993	10930	10868
250	.531	12007	11950	11892	11834	11776	11718	11659	11600	11541	11481
240	.588	12561	12507	12453	12398	12343	12288	12232	12176	12120	12064
230	.649	13084	13033	12982	12930	12878	12826	12774	12721	12668	12615
220	.713	13575	13527	13479	13431	13382	13333	13284	13234	13184	13134
210	.782	14034	13990	13945	13900	13854	13808	13762	13716	13669	13622
200	.855	14462	14421	14379	14337	14295	14252	14209	14166	14122	14078
190	.934	14859	14820	14782	14743	14704	14664	14624	14584	14544	14503
180	1.017	15225	15190	15154	15118	15082	15046	15009	14972	14934	14897
170	1.105	15561	15528	15496	15463	15430	15396	15363	15329	15294	15260
160	1.198	15868	15838	15809	15779	15748	15718	15687	15656	15624	15593
150	1.297	16146	16120	16093	16066	16038	16010	15982	15954	15926	15897
140	1.402	16398	16374	16350	16325	16301	16276	16250	16225	16199	16173
130	1.513	16624	16603	16581	16559	16537	16514	16491	16469	16445	16422
120	1.631	16826	16807	16787	16768	16748	16728	16708	16687	16666	16645
110	1.755	17004	16987	16970	16953	16935	16918	16900	16882	16863	16845
100	1.888	17161	17147	17132	17116	17101	17085	17070	17054	17037	17021
90	2.029	17298	17286	17273	17259	17246	17232	17219	17205	17190	17176
80	2.181	17417	17406	17395	17383	17372	17360	17348	17336	17324	17311
70	2.347	17518	17509	17499	17489	17479	17469	17459	17449	17438	17428
60	2.530	17603	17595	17587	17579	17571	17562	17554	17545	17536	17527

Table A-1-10.6.5(b) Halon 1301 at 600 psig and 60 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
420	.019	956	861	766	671	575	480	384	289	193	96
410	.039	1893	1800	1707	1614	1520	1426	1333	1239	1144	1050
400	.060	2811	2720	2629	2537	2446	2354	2262	2170	2078	1985
390	.083	3709	3620	3531	3442	3352	3262	3172	3082	2992	2901
380	.106	4587	4500	4413	4325	4238	4150	4062	3974	3886	3798
370	.132	5443	5358	5273	5188	5103	5017	4932	4846	4760	4673
360	.158	6277	6195	6112	6029	5946	5863	5779	5696	5612	5527
350	.187	7089	7009	6929	6848	6767	6686	6605	6523	6442	6360
340	.217	7877	7800	7722	7643	7565	7486	7407	7328	7249	7169
330	.249	8642	8566	8491	8415	8339	8263	8186	8109	8032	7955
320	.283	9381	9308	9235	9162	9088	9014	8940	8866	8791	8717
310	.319	10095	10025	9954	9883	9812	9741	9670	9598	9526	9454
300	.358	10783	10715	10647	10579	10511	10442	10373	10304	10235	10165
290	.399	11444	11379	11314	11248	11183	11117	11050	10984	10917	10850
280	.442	12077	12015	11953	11890	11827	11764	11701	11637	11573	11508
270	.489	12683	12624	12564	12504	12444	12384	12323	12262	12201	12139
260	.538	13261	13204	13148	13090	13033	12976	12918	12859	12801	12742
250	.591	13809	13756	13702	13648	13593	13539	13484	13428	13373	13317
240	.647	14329	14278	14227	14176	14125	14073	14021	13968	13916	13863
230	.707	14820	14772	14724	14675	14627	14578	14529	14479	14430	14379
220	.770	15281	15236	15191	15145	15100	15054	15008	14961	14914	14867
210	.838	15713	15671	15629	15586	15543	15500	15457	15413	15369	15325
200	.909	16116	16077	16037	15998	15958	15918	15877	15837	15796	15754
190	.985	16490	16454	16417	16381	16344	16306	16269	16231	16193	16154
180	1.066	16836	16802	16769	16735	16701	16666	16632	16597	16561	16526
170	1.152	17154	17123	17093	17061	17030	16998	16966	16934	16902	16869
160	1.243	17445	17418	17389	17361	17332	17303	17274	17244	17214	17184
150	1.339	17711	17685	17660	17634	17608	17581	17555	17528	17501	17473
140	1.441	17951	17928	17905	17882	17858	17834	17810	17786	17761	17736
130	1.549	18168	18147	18126	18105	18084	18062	18041	18019	17996	17974
120	1.664	18361	18343	18324	18306	18287	18267	18248	18228	18208	18188
110	1.785	18534	18517	18501	18484	18467	18450	18433	18415	18398	18380
100	1.914	18686	18671	18657	18642	18627	18612	18597	18581	18566	18550
90	2.052	18818	18806	18793	18781	18767	18754	18741	18727	18714	18700
80	2.201	18934	18923	18912	18901	18890	18878	18867	18855	18843	18831
70	2.363	19032	19023	19014	19004	18995	18985	18975	18965	18955	18944
60	2.543	19116	19108	19100	19092	19084	19076	19068	19059	19050	19041

Table A-1-10.6.5(c) Halon 1301 at 600 psig and 50 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
450	.012	667	573	478	382	287	192	96	0	0	0
440	.030	1607	1513	1420	1327	1233	1139	1045	951	857	762
430	.049	2529	2437	2346	2254	2162	2070	1978	1885	1792	1700
420	.068	3434	3344	3254	3164	3074	2984	2893	2802	2711	2620
410	.089	4321	4233	4145	4056	3968	3879	3791	3702	3613	3523
400	.111	5189	5103	5017	4930	4844	4757	4670	4583	4496	4408
390	.134	6038	5954	5870	5785	5701	5616	5531	5446	5360	5275
380	.158	6867	6785	6702	6620	6538	6455	6372	6289	6205	6122
370	.184	7675	7595	7515	7435	7354	7273	7192	7111	7030	6948
360	.212	8462	8384	8306	8228	8150	8071	7992	7913	7834	7755
350	.241	9227	9151	9076	9000	8924	8847	8771	8694	8617	8539
340	.272	9970	9896	9823	9749	9675	9601	9527	9452	9377	9302
330	.304	10689	10618	10547	10476	10404	10332	10260	10188	10115	10043
320	.339	11385	11316	11247	11178	11109	11040	10970	10900	10830	10760
310	.375	12056	11990	11924	11857	11790	11723	11656	11589	11521	11453
300	.414	12702	12639	12575	12511	12447	12382	12318	12252	12187	12122
290	.455	13324	13263	13201	13140	13078	13016	12954	12891	12829	12766
280	.499	13919	13861	13802	13743	13684	13625	13565	13505	13445	13384
270	.546	14488	14432	14376	14320	14264	14207	14150	14092	14035	13977
260	.595	15031	14978	14924	14871	14817	14763	14708	14654	14599	14544
250	.647	15546	15496	15445	15394	15343	15292	15240	15188	15136	15083
240	.703	16035	15987	15939	15891	15842	15794	15745	15696	15646	15596
230	.762	16496	16451	16406	16360	16315	16269	16222	16176	16129	16082
220	.825	16930	16888	16845	16802	16759	16716	16673	16629	16585	16540
210	.892	17337	17297	17257	17217	17177	17137	17096	17055	17013	16972
200	.962	17716	17680	17642	17605	17568	17530	17492	17453	17415	17376
190	1.037	18069	18035	18001	17966	17931	17896	17861	17825	17789	17753
180	1.117	18396	18365	18333	18301	18269	18236	18203	18170	18137	18103
170	1.201	18698	18669	18639	18610	18580	18550	18520	18489	18459	18428
160	1.290	18974	18947	18921	18894	18866	18839	18811	18783	18755	18726
150	1.384	19226	19202	19178	19153	19128	19103	19078	19052	19026	19000
140	1.484	19455	19433	19411	19389	19366	19343	19320	19297	19274	19250
130	1.589	19662	19642	19622	19602	19582	19561	19540	19519	19498	19477
120	1.701	19847	19829	19811	19793	19775	19757	19738	19719	19700	19681
110	1.820	20012	19996	19981	19965	19948	19932	19915	19898	19881	19864
100	1.947	20158	20144	20130	20116	20102	20087	20073	20058	20043	20027
90	2.083	20286	20274	20262	20249	20237	20224	20211	20198	20185	20172
80	2.229	20397	20387	20376	20366	20355	20344	20333	20321	20310	20298
70	2.385	20493	20484	20475	20466	20457	20447	20437	20428	20418	20408
60	2.555	20574	20567	20559	20551	20543	20535	20527	20519	20510	20502

Table A-1-10.6.5(d) Halon 1301 at 600 psig and 40 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
480	.008	475	380	285	190	95	0	0	0	0	0
470	.024	1414	1321	1227	1134	1040	946	852	758	664	570
460	.041	2337	2246	2154	2062	1970	1878	1785	1692	1600	1507
450	.058	3245	3155	3065	2975	2884	2793	2702	2611	2520	2429
440	.076	4137	4049	3960	3871	3782	3693	3604	3515	3425	3335
430	.096	5012	4926	4839	4752	4664	4577	4489	4402	4314	4225
420	.116	5871	5785	5700	5615	5529	5444	5358	5272	5185	5099
410	.137	6711	6628	6544	6461	6377	6293	6209	6125	6040	5955
400	.160	7533	7452	7370	7288	7206	7124	7042	6959	6877	6794
390	.184	8336	8257	8177	8097	8017	7937	7856	7776	7695	7614
380	.209	9120	9042	8965	8887	8809	8730	8652	8573	8494	8415
370	.236	9883	9808	9732	9656	9580	9504	9428	9351	9274	9197
360	.264	10627	10553	10480	10406	10332	10258	10183	10109	10034	9959
350	.293	11348	11277	11206	11134	11062	10990	10918	10845	10773	10700
340	.325	12049	11980	11910	11841	11771	11701	11631	11561	11490	11419
330	.358	12727	12660	12593	12526	12458	12391	12323	12254	12186	12118
320	.393	13382	13318	13253	13188	13123	13057	12992	12926	12860	12793
310	.430	14014	13952	13890	13827	13764	13701	13638	13574	13510	13446
300	.469	14623	14563	14503	14443	14382	14321	14260	14199	14138	14076
290	.511	15207	15150	15092	15034	14976	14918	14859	14800	14741	14682
280	.555	15767	15712	15657	15601	15546	15490	15434	15378	15321	15264
270	.602	16302	16250	16197	16144	16091	16038	15984	15930	15876	15821
260	.651	16812	16762	16712	16662	16611	16560	16509	16458	16406	16354
250	.704	17296	17249	17202	17154	17106	17057	17009	16960	16911	16861
240	.759	17756	17711	17666	17621	17575	17529	17483	17437	17390	17344
230	.818	18189	18147	18105	18062	18019	17976	17932	17888	17844	17800
220	.880	18597	18558	18518	18478	18437	18397	18356	18314	18273	18231
210	.946	18980	18943	18906	18868	18830	18792	18754	18715	18676	18637
200	1.016	19338	19303	19268	19233	19198	19162	19126	19090	19054	19017
190	1.090	19671	19639	19606	19574	19541	19508	19474	19440	19407	19372
180	1.168	19979	19950	19920	19889	19859	19828	19797	19766	19735	19703
170	1.251	20264	20237	20209	20181	20153	20125	20096	20067	20038	20009
160	1.339	20526	20500	20475	20449	20424	20398	20371	20345	20318	20291
150	1.431	20764	20742	20718	20695	20672	20648	20624	20600	20575	20550
140	1.529	20982	20961	20940	20919	20897	20876	20854	20832	20810	20787
130	1.633	21178	21159	21140	21121	21102	21082	21063	21043	21023	21002
120	1.744	21354	21338	21321	21304	21286	21269	21251	21233	21215	21197
110	1.861	21512	21497	21482	21467	21451	21435	21420	21404	21387	21371
100	1.986	21651	21638	21625	21611	21598	21584	21570	21556	21541	21527
90	2.120	21774	21763	21751	21739	21727	21715	21702	21690	21677	21664
80	2.264	21881	21871	21861	21850	21840	21829	21819	21808	21797	21785
70	2.420	21973	21964	21955	21947	21938	21929	21919	21910	21900	21891
60	2.591	22051	22044	22036	22029	22021	22013	22006	21998	21989	21981

Table A-1-10.6.5(e) Halon 1301 at 360 psig and 70 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
260	.050	962	868	773	678	583	487	391	294	196	98
250	.105	1874	1785	1696	1606	1515	1424	1333	1241	1148	1055
240	.166	2735	2652	2567	2483	2397	2311	2225	2138	2051	1963
230	.233	3543	3465	3386	3307	3227	3146	3065	2984	2901	2819
220	.307	4297	4224	4150	4076	4002	3927	3851	3775	3698	3621
210	.387	4994	4927	4859	4791	4722	4652	4582	4512	4441	4369
200	.475	5635	5573	5511	5449	5385	5322	5257	5192	5127	5061
190	.570	6220	6164	6107	6050	5993	5935	5876	5816	5757	5696
180	.673	6750	6699	6648	6597	6544	6492	6439	6385	6330	6275
170	.783	7227	7181	7135	7089	7042	6995	6947	6898	6849	6800
160	.899	7652	7612	7571	7530	7488	7446	7403	7359	7316	7271
150	1.021	8030	7994	7958	7922	7885	7847	7809	7771	7732	7692
140	1.149	8364	8332	8300	8268	8235	8202	8169	8135	8100	8066
130	1.282	8656	8629	8601	8573	8544	8515	8486	8456	8425	8395
120	1.422	8912	8888	8864	8839	8814	8789	8763	8737	8710	8684
110	1.567	9133	9113	9092	9070	9049	9027	9004	8982	8959	8935
100	1.719	9324	9306	9288	9270	9251	9232	9213	9194	9174	9154
90	1.879	9488	9472	9457	9441	9425	9409	9393	9376	9359	9342
80	2.047	9626	9614	9600	9587	9574	9560	9546	9532	9517	9503
70	2.225	9743	9732	9721	9710	9699	9687	9676	9664	9651	9639
60	2.417	9840	9831	9822	9813	9804	9794	9784	9774	9764	9754

Table A-1-10.6.5(f) Halon 1301 at 360 psig and 60 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
280	.004	98	0	0	0	0	0	0	0	0	0
270	.051	1056	962	868	774	678	583	487	390	293	196
260	.102	1969	1880	1790	1700	1609	1518	1427	1335	1242	1150
250	.158	2834	2750	2665	2579	2494	2407	2321	2233	2146	2057
240	.219	3650	3571	3491	3410	3330	3248	3166	3084	3001	2918
230	.286	4415	4341	4266	4191	4115	4039	3962	3885	3807	3729
220	.360	5129	5060	4990	4920	4850	4779	4707	4635	4562	4489
210	.440	5789	5726	5662	5597	5532	5466	5399	5333	5265	5197
200	.527	6397	6339	6280	6220	6160	6100	6039	5977	5915	5853
190	.621	6952	6899	6845	6791	6736	6681	6625	6569	6512	6455
180	.722	7456	7408	7359	7310	7260	7210	7160	7108	7057	7005
170	.829	7910	7866	7823	7778	7734	7689	7643	7597	7550	7503
160	.942	8316	8278	8239	8199	8159	8119	8078	8036	7995	7952
150	1.062	8678	8644	8609	8574	8538	8503	8466	8429	8392	8354
140	1.187	8998	8968	8937	8906	8875	8843	8811	8778	8745	8712
130	1.318	9280	9254	9227	9199	9172	9144	9115	9087	9058	9028
120	1.455	9527	9503	9480	9456	9432	9408	9383	9358	9332	9306
110	1.598	9741	9721	9700	9680	9659	9638	9616	9594	9572	9549
100	1.748	9926	9909	9891	9873	9855	9837	9818	9799	9780	9761
90	1.905	10085	10070	10055	10040	10024	10009	9993	9976	9960	9943
80	2.071	10220	10207	10195	10182	10169	10155	10142	10128	10114	10099
70	2.248	10334	10323	10313	10302	10291	10279	10268	10256	10244	10232
60	2.437	10429	10420	10411	10402	10393	10384	10374	10364	10354	10344

Table A-1-10.6.5(g) Halon 1301 at 360 psig and 50 lbs/cu ft Y and Z Factors

PSIG	Z.	0	1	2	3	4	5	6	7	8	9
290	.008	195	98	0	0	0	0	0	0	0	0
280	.051	1148	1055	961	867	772	677	581	485	389	292
270	.098	2059	1970	1880	1790	1700	1609	1518	1426	1334	1241
260	.150	2926	2841	2756	2670	2584	2498	2411	2324	2236	2148
250	.206	3747	3667	3586	3505	3424	3342	3260	3177	3094	3010
240	.268	4521	4446	4370	4294	4217	4140	4062	3984	3906	3827
230	.335	5247	5177	5106	5035	4963	4890	4818	4744	4670	4596
220	.408	5925	5859	5793	5727	5660	5592	5524	5456	5387	5317
210	.487	6552	6491	6430	6369	6307	6244	6181	6118	6054	5989
200	.573	7129	7074	7018	6961	6904	6847	6789	6730	6671	6612
190	.666	7658	7607	7556	7504	7452	7400	7347	7293	7239	7184
180	.764	8138	8092	8046	7999	7952	7904	7856	7807	7758	7708
170	.870	8572	8530	8489	8446	8404	8361	8317	8273	8228	8183
160	.981	8961	8924	8887	8849	8810	8772	8733	8693	8653	8613
150	1.097	9308	9275	9242	9208	9174	9140	9105	9069	9034	8998
140	1.220	9617	9587	9558	9528	9498	9467	9436	9405	9373	9341
130	1.348	9889	9863	9837	9811	9784	9757	9730	9702	9674	9645
120	1.482	10127	10105	10082	10059	10036	10012	9988	9963	9939	9914
110	1.623	10335	10316	10296	10276	10255	10235	10214	10193	10171	10149
100	1.770	10515	10498	10481	10464	10446	10428	10410	10392	10373	10354
90	1.926	10670	10656	10641	10626	10611	10596	10580	10564	10548	10532
80	2.090	10802	10790	10777	10765	10752	10739	10725	10712	10698	10684
70	2.264	10913	10903	10893	10882	10871	10860	10849	10837	10826	10814
60	2.454	11006	10998	10989	10980	10971	10962	10953	10943	10933	10923

Table A-1-10.6.5(h) Halon 1301 at 360 psig and 40 lbs/cu ft Y and Z Factors

PSIG	Z	0	1	2	3	4	5	6	7	8	9
300	.011	292	195	98	0	0	0	0	0	0	0
290	.051	1239	1146	1053	959	865	770	675	580	484	388
280	.094	2149	2060	1970	1880	1790	1699	1608	1516	1425	1332
270	.142	3017	2932	2847	2761	2675	2588	2501	2414	2326	2237
260	.194	3843	3763	3682	3600	3518	3436	3353	3270	3186	3102
250	.251	4626	4550	4473	4396	4318	4240	4162	4083	4003	3924
240	.313	5363	5292	5219	5147	5074	5000	4926	4852	4777	4702
230	.380	6055	5988	5920	5852	5784	5715	5646	5576	5505	5435
220	.453	6700	6637	6574	6511	6447	6383	6318	6253	6188	6121
210	.532	7297	7240	7182	7123	7064	7004	6944	6884	6823	6762
200	.616	7848	7795	7742	7688	7634	7579	7523	7468	7411	7355
190	.707	8353	8304	8256	8206	8156	8106	8056	8004	7953	7901
180	.805	8812	8768	8724	8679	8634	8588	8542	8495	8448	8401
170	.908	9228	9188	9148	9107	9066	9025	8983	8941	8899	8856
160	1.016	9601	9566	9530	9493	9457	9420	9382	9344	9306	9267
150	1.131	9936	9904	9872	9839	9807	9773	9740	9706	9671	9637
140	1.251	10233	10205	10176	10148	10118	10089	10059	10029	9998	9967
130	1.377	10496	10471	10446	10421	10395	10369	10342	10315	10288	10261
120	1.508	10727	10705	10683	10661	10638	10615	10592	10569	10545	10521
110	1.646	10929	10910	10891	10872	10852	10832	10811	10791	10770	10749
100	1.792	11105	11088	11072	11055	11038	11020	11003	10985	10966	10948
90	1.945	11256	11242	11227	11213	11198	11183	11168	11153	11137	11121
80	2.107	11385	11373	11361	11348	11336	11323	11310	11297	11283	11270
70	2.280	11494	11484	11474	11463	11453	11442	11431	11420	11408	11397
60	2.465	11586	11577	11569	11560	11551	11542	11533	11523	11514	11504

A-1-10.6.7 The discharge nozzle is the device that ultimately delivers the agent to the hazard area. Its function is two-fold: (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 given in 1-10.6.6. Figure A-1-10.6.7 shows the calculated maximum open-end pipe specific flow rate versus total terminal pressure. The general shape of the curve is also characteristic of nozzle flow curves.

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

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

$$\text{velocity head} = \frac{3.63 \times Q^2}{p D^4}$$

Where: Q is the nozzle flow rate in lbs/sec

p is the density in lbs/cu ft at the Terminal static pressure

D is the feed pipe diameter in in.

A-1-10.6.8 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 A-1-10.6.8.

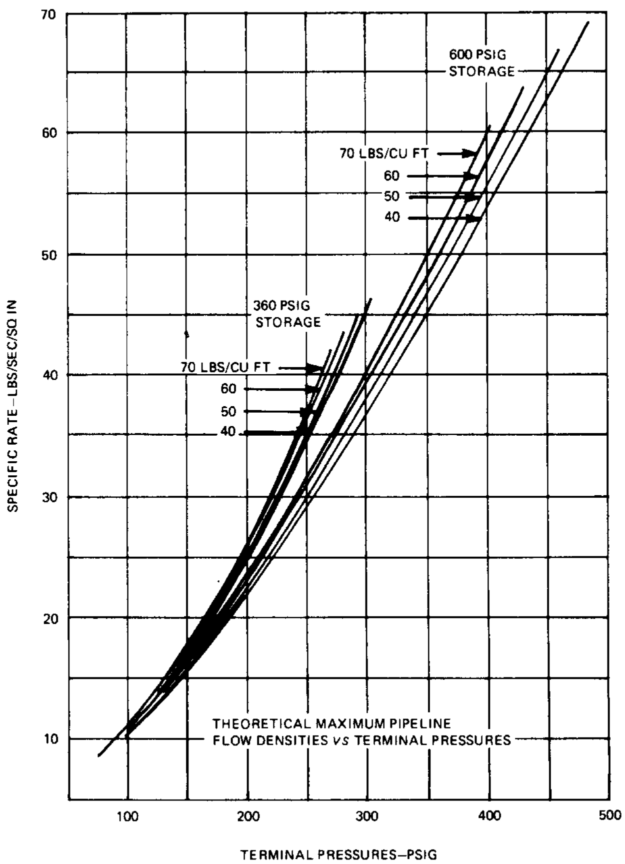


Figure A-1-10.6.7

Table A-1-10.6.8
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

For SI Units: 1 lb/sec = 0.454 kg/s

A-1-11.1 Inspection.

The entire fire extinguishing system should be completeley inspected at least annually. More frequent general inspections are recommended. Regular service contracts with the manufacturer or installing company are recommended.

In the annual inspection, particular attention should be given to the:

1. Detection and Actuation System.
2. Agent Supply.
3. Piping and Nozzles.
4. Auxiliary Equipment.

1. Detection and Actuation System.

(a) The detectors should be checked (and cleaned if necessary) to assure that they are free of foreign substances.

(b) If the detection system is supervised, the supervisory features should be checked to determine that the detection system is in satisfactory condition. The methods and procedures for this inspection should be in accordance with the manufacturer's recommendations.

(c) Automatic actuating controls should be removed from the containers equipped with such controls ("pilot cylinders") and a test made of the detection system by introducing a simulated fire condition at one or more detectors (heat, smoke, etc., as applicable). The actuating controls must move to the "discharged" position.

(d) All manual operating devices (pull boxes, manual electric switches, etc.) should be operated with the actuating control removed from the supply containers equipped with such controls ("pilot cylinders"). The actuating control must move to the "discharged" position.

(e) All actuating controls should be reset and reinstalled after testing.

2. Containers.

(a) Containers should be examined for evidence of corrosion or mechanical damage.

(b) Container bracketing, supports, etc., should be checked to determine that their condition is satisfactory.

3. Piping and Nozzles.

(a) Piping should be examined for any evidence of corrosion.

(b) Pipe hangers and straps should be examined to see that the piping is securely supported.

(c) Nozzles should be checked to determine that the orifices are clear and unobstructed.

(d) Where nozzle seals are provided, they should be checked for signs of deterioration and replaced if necessary.

(e) Nozzles should be checked for proper position and alignment.

4. Auxiliary Equipment.

(a) All auxiliary and supplementary components such as switches, door and window releases, interconnected valves, damper releases, supplementary alarms, etc., should be manually operated (where possible) to ensure that they are in proper operating condition.

(b) All devices should be returned to normal "standby" condition after testing.

A-2-1 General Information on Total Flooding Systems. 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 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. 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.

A-2-1.1.2 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 the engine will continue to operate resulting in a decrease in agent concentration and extensive decomposition of the Halon.

A-2-1.1.3 For the purposes of this standard, a normally occupied area is defined as an area intended for occupancy. Spaces occasionally visited by personnel, such as transformer bays, switch-houses, pump rooms, vaults, engine test stands, records centers, magnetic tape storage areas, cable trays and tunnels, microwave relay stations, flammable liquid storage areas, enclosed energy systems, etc., are examples of areas considered not normally occupied.

A-2-2.2.3 The design of total flooding Halon 1301 systems only beneath the raised floor of 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-2-3 Halon 1301 Requirements for Surface Fires. 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 References (1), (5), and (6) (*see C-1.7*). Liquid fuels are examined at two temperatures:

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

(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 is somewhat more conservative than that of tests using conventional total flooding techniques. (*See C-1.7.*)

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 may be plotted as shown in Figure A-2-3(a).

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 2-3.2.1 were measured using a spherical vessel described in Reference (3) (*see C-1.7*).

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.

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 may become heated or involved in the fire must be taken into account. If the volatility of the fuel can be shown to be sufficently 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 may 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:

$$\text{Fuel quantity, lbs. per 100 cu ft enclosed volume} = \frac{(LFL)(MW)(1.37)}{T + 460}$$

LFL = lower flammable limit of fuel in air, % (vol)
MW = molecular weight of fuel
T = temperature, °F

For SI Units

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

$$K = \text{kelvin} = {}^\circ C + 273.15$$

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 A-2-3.2.1 lists quantities for several fuels, to which an arbitrary safety factor of 2 has been applied. Greater safety factors may be required by individual situations.

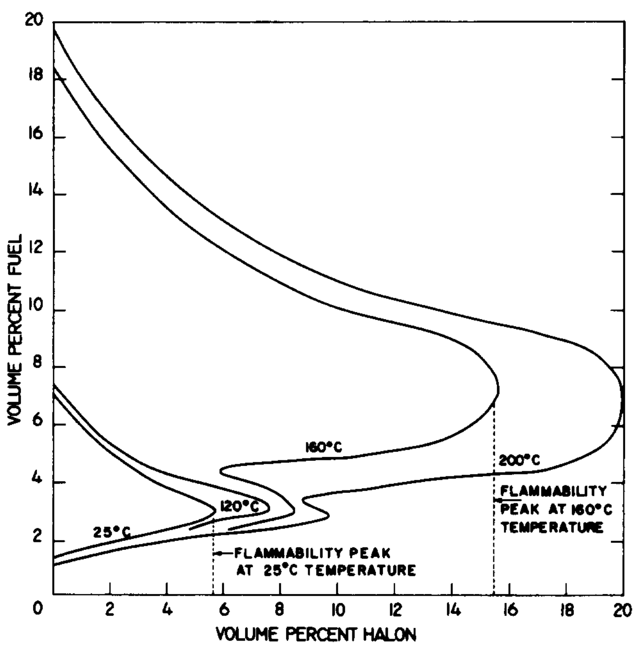


Figure A-2-3(a) Typical flammability-peak presentation.

A-2-4 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 may precede the other. For example, a wood fire may start as flaming combustion, and become smoldering as burning progresses. Conversely, spontaneous ignition in a pile of oily rags may 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.

Table A-2-3.2.1
Quantity of Fuel Required to Achieve ½ of Lower Explosive Limit in Air at 1.0 atm. and 70°F (21°C)

Material	Fuel Quantity, lbs per cu ft enclosed volume	kg/m³
n-Butane	.0014	0.0224
Isobutane	.0016	0.0256
Carbon disulfide	.00099	0.0159
Carbon monoxide	.0045	0.0721
Ethane	.0012	0.0192
Ethyl alcohol	.0018	0.0288
Ethylene	.0020	0.0320
n-Heptane	.0016	0.0256
Hydrogen	.00011	0.0018
Methane	.0011	0.0176
Propane	.0013	0.0256

Table A-2-3.2.2
Development of Halon 1301 Design Concentrations for Flame Extinguishment

	Concentration in Air in Volume Percent				
Fuel	**Average***	**Safety Factor**	**Total**	**Design*** **	**Ref****
Acetone	3.3	+0.7	=4.0	5.0	(5)(6)(7)
Benzene	3.3	+0.7	=4.0	5.0	(5)(6)(7)
Ethanol	3.8	+0.8	=4.6	5.0	(5)(6)(7)
Ethylene	6.8	+1.4	=8.2	8.2	(5)(6)(7)
Methane	3.1	+0.7	=3.8	5.0	(5)(6)(7)
n-Heptane	4.1	+0.8	=4.9	5.0	(5)(6)(7)
Propane	4.3	+0.9	=5.2	5.2	(5)(6)(7)

*Average of values reported in references measured at elevated temperature conditions.

**For references, see Appendix C-1.7.

***Measured extinguishing concentration plus safety factor are increased to a minimum 5% for design concentrations.

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 .o 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. 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 may assist the authority having jurisdiction in deciding whether such experimentation is necessary.

A-2-5.2 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.

A-2-5.3 Leakage of Halon 1301 Through Enclosure Openings. 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.

Effects of Altitude. 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 one minute. (*See 2-1.1.3 and 2-1.1.4.*)

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-2-5.3.

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-2-5.3 should be used:

Table A-2-5.3
Correction Factors for Altitude

Altitude Feet	Meters	Correction Factor (See Notes)
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
10000	3048	0.69
11000	3353	0.66
12000	3658	0.64
13000	3962	0.61
14000	4267	0.59
15000	4572	0.56

Note 1: Multiply correction factor by sea level design quantity of Halon 1301 to obtain correct quantity at a given altitude.

Note 2: Divide specific volume, S, determined at sea level by correction factor to obtain correct specific volume, S, at a given altitude.

A-2-6.2 Rate of Application. The minimum rates established are considered adequate for the usual surface or deep-seated fire. However, where the spread of fire may 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 may, 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 shall be used, or such special engineering as is required shall be carried out, to obtain the proper combination of container releases, supply piping, and orifice sizes that will produce this desired rate.

A-2-6.5.2 Of particular concern in maintaining the integrity of the enclosure is preventing the lifting of ceiling tiles.

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-3-1 General Information on Local Application Systems. A local application Halon 1301 system is designed to apply the agent directly to a fire that may occur in an area or space that has no immediate enclosure surrounding it. Such systems must be designed to deliver Halon 1301 to the hazard being protected in such a manner that the agent will cover all burning surfaces during the discharge of the system.

The flow rate and discharge times will depend on the type of fuel involved, the nature of the hazard, and the location and spacing of the Halon 1301 nozzles.

The important factors to be considered in the design of a local application system are the rate of agent flow, the distance and area limitations of the nozzles, the quantity of Halon 1301 required, and the agent distribution system. The steps necessary to design the system are as follows:

(a) Determine the area of the hazard to be protected utilizing a scaled layout drawing depicting all dimensions and noting all limitations relative to the placement of nozzles. The limits of the hazard should be defined to include all combustibles within the immediate area. Careful consideration should be given to obstructions that may be in or near the hazard area.

(b) Based on the configuration of the hazard, lay out the nozzles to cover the hazard within the limitations shown in the nozzle listings. Based on the spacing or area coverage, determine the Halon 1301 flow rate range within which each nozzle must discharge to achieve extinguishment. These parameters will be presented in listing information in a tabular form or by curves similar to those shown in Figures 3-2.3.3, A-3-1(a), and A-3-1(b).

(c) Select a nozzle design rate and discharge time for the system within the parameters of 3-3.2.3.

(d) Locate the agent storage container(s), lay out the piping, and select the appropriate pipe and nozzle sizes to produce the required rates of Halon 1301 flow.

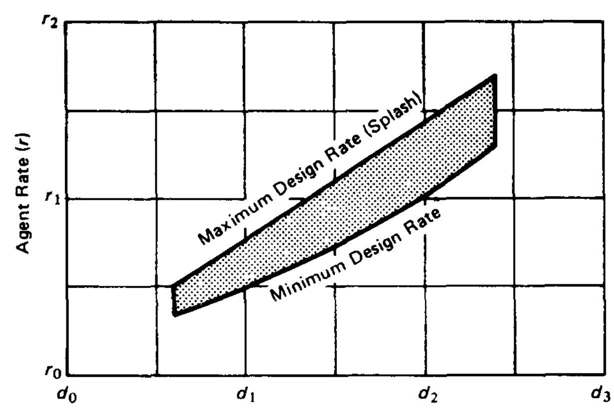


Figure A-3-1(a) Typical distance rate/relationship for overhead local application nozzles (splash curve applies to flammable liquids in depth only).

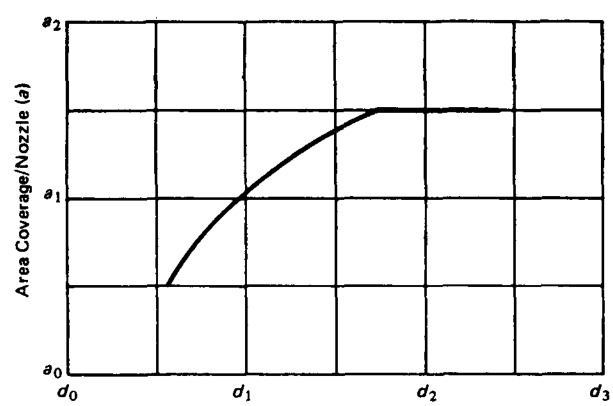


Figure A-3-1(b) Typical distance/area coverage relationship for overhead local application nozzles.

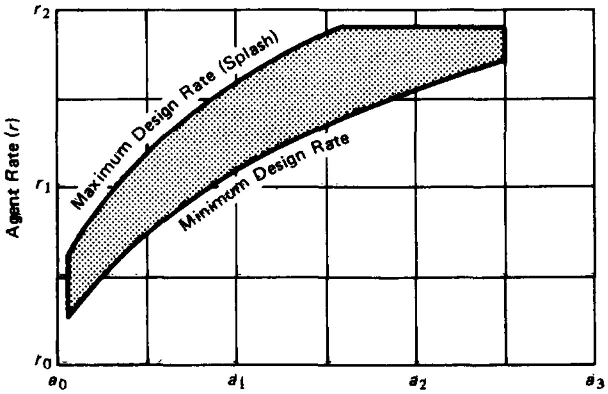


Figure A-3-1(c) Typical rate/area coverage relationship for tankside nozzles (splash curve applies to flammable liquids in depth only).

A-3-3 Halon 1301 Requirements. The agent requirements for a Halon 1301 local application system do not lend themselves to quantifiable generalization. The effectiveness of a local application system is heavily influenced by the design of the delivery hardware, especially the nozzles. Since each nozzle design has it own performance peculiarities with respect to flow rate and area coverage at various distances from the protected surface, it is essential that nozzles used for this application be limited to those that have been tested and have had their performance parameters listed by a testing laboratory. It is felt that some nozzle characteristics, such as discharge velocity, discharge turbulence, droplet size formation, and the companion rate of vaporization influence the effectiveness of a given nozzle as much as mass flow rate and area coverage. Until these characteristics are completely understood and found to be reproducible and predictable, only those nozzles that have been tested within the performance requirements of the anticipated application should be used.

However, in recent experimentation with Halon 1211 local application systems, a relationship was found between the agent rate density [(Q_m/A where A is the surface area of the hazard (*see 3-3.2.3*)]and the extinguishment time. The testing was performed with nozzles located in such a manner to provide proper area coverage and no fuel splashing in testing conducted in accordance with the provisions of UL Standard 711, "*Classification, Rating and Fire Testing of Class A, B and C Fire Extinguishers and for Class D Extinguishers or Agents for Use on Combustible Metals.*" This minimum extinguishing density, determined on square pans up to 15 sq ft in area, has been found to range from 0.06 lb per second per sq ft [(0.29 kg/sec)/m^2] for 7-second extinguishment time to 0.22 lb per second per sq ft [(1.08 kg/sec)/m^2] for 1.5-second extinguishment time.

A-3-3.1.3 When the liquid Halon 1301 flows through the pipeline, a certain amount of the agent will be vaporized if the piping is at a higher temperature than the agent. Since the agent discharge is usually under 10 seconds and the heat transfer is essentially due to conduction, the amount of agent vaporized in the piping is usually quite small. To calculate this amount, and accordingly the amount of the agent increase necessary to compensate for this effect, the following relationship is used:

$$W = \frac{2\pi kL\,(t_p - t_a)\,(T)}{3600h\,(\ln r_o/r_i)}$$

where:

W = Amount of agent increase necessary to compensate for vaporization in the piping, pounds (kg).
k = Thermal conductivity of the piping, Btu-ft/hr-ft^2-°F (W/m K).
L = Linear length of the piping, feet (m).
t_p = Temperature of the pipe, °F (°C).
t_a = Temperature of the agent, °F (°C).
T = System discharge time, seconds.
h = Heat of vaporization of the agent at t_a; Btu/lb. (kJ/kg).
ln = Natural logarithm
r_o = Outside radius of the pipe, inches (mm).
r_i = Inside radius of the pipe, inches (mm).
3600 = Seconds/hour

Due to the very short discharge times for the Halon 1301 systems, it can be assumed that the temperature of the pipe and the temperature of the agent remain constant throughout the discharge. The temperature of the agent for this calculation will be its temperature in the storage container before the discharge is initiated. The temperature of the piping will normally be the ambient temperature in the area where the piping is located. Table A-3-3.1.3 lists the latent heat of vaporization (h) for Halon 1301 at various temperatures.

Table A-3-3.1.3
Latent Heat of Vaporization for Halon 1301

Temperature °F	Latent Heat (h) BTU/lb.	Temperature °C	Latent Heat (h) kJ/kg
32	41.0	0	95.4
40	39.9	5	92.5
50	38.5	10	89.6
60	37.1	15	86.6
70	35.5	20	83.3
80	33.8	25	79.8
90	31.9	30	76.0
100	29.8	35	71.8
110	27.5	40	69.2
120	24.7	45	62.1
130	21.5	50	56.2
		55	49.2

Appendix B Enclosure Integrity Procedure

This Appendix is not a part of the requirements of this NFPA document, but is included for information 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 level of the descending interface of the halon/air mixture with respect to time.

B-1.1.2 Enclosure integrity testing is not intended to verify other aspects of Halon 1301 system reliability; i.e., 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-1.2 Limitations and Assumptions.

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

B-1.2.1.1 Halon System Design. This test procedure only concerns halon total flooding fire suppression systems using Halon 1301 and designed, installed and maintained in accordance with NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*.

B-1.2.1.2 Enclosure Construction. Halon 1301 protected enclosures, absent of any containing barriers above the false ceiling, are not within the scope of this document.

B-1.2.1.3 Halon Concentration. Special consideration should be given to Halon 1301 systems with concentrations greater than 10% where the concern exists that high concentrations may result in significant over-pressures from the discharge event in an enclosure with minimal leakage.

B-1.2.1.4 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.

B-1.2.1.5 Static Pressures. Where at all possible, static pressure differentials (HVAC system, elevator connections, etc.) across the enclosure envelope should be minimized.

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

B-1-2.2.1 Door Fan Standards. Guidance regarding fan pressurization apparatus design, maintenance and operation is provided by ASTM E779-81, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and CAN/CGSB-149.10-M86, *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method.*

B-1-2.2.2 Attached Volumes. There can be no significant attached volumes outside the known 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.

B-1-2.2.3 Return Path. All significant leaks must have an unrestricted return path to the door fan.

B-1.2.2.4 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 section B-2.6.2, the value attained for BCLA is assumed to exist entirely at the lowest point in the enclosure.

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

B-1.2.3.1 Dynamic Discharge Pressures. Losses due to the dynamic discharge pressures resulting from halon system actuation are not specifically addressed.

B-1.2.3.2 Static Pressure. Variable external static pressure differences (wind etc.) are additive and should be considered.

B-1.2.3.3 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.

B-1.2.3.4 Floor Area. The floor area is assumed to be the volume divided by the maximum height of the protected enclosure.

B-1.2.3.5 Descending Interface. Two quiescent stable mixtures exist separated by a horizontal, clearly defined descending interface. For some situations, the Descending Interface is not sharp but instead has a finite thickness. For this condition, it is important to define the Descending Interface as the point within this zone where the halon concentration is ½ the design concentration. Mechanical mixing of the halon mixture is not considered.

B-1.2.3.6 Leak Flow Characteristics. All leak flow is one-dimensional and does not take into account stream functions.

B-1.2.3.7 Leak Flow Direction. A particular leak area does not have bi-directional flow at any point in time. Flow through a leak area is either into or out of the enclosure.

B-1.2.3.8 Leak Discharge. The outflow from the leak discharges into an infinitely large space.

B-1.2.3.9 Leak Locations. Calculations are based on worst case halon leak locations.

B-1.2.3.10 Halon Delivery. The calculations assume that the design concentration of halon will be achieved.

B-1.3 Terminology. For the purpose of Appendix B, the following definitions are to apply:

Attached Volumes. A space within the enclosure envelope that is not provided with halon.

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.

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

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. 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 which 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 Area. Plan area for a known elevation.

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.

Relief Area. The volume outside the enclosure envelope for the discharge or intake of air for the door fan.

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

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, i.e., 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:

(a) provide a description of the test,

(b) advise the time required,

(c) determine the staff needed (to control traffic flow, set HVAC, etc.),

(d) determine the equipment required (e.g., ladders),

(e) obtain a description of the HVAC system,

(f) establish the existence of a false ceiling space and the size of ceiling tiles,

(g) visually determine the readiness of the room with respect to the completion of obvious sealing,

(h) determine if conflict with other building trades will occur,

(i) determine the size of doorways,

(j) determine the existence of adequate backflow relief area outside the enclosure envelope used to accept or supply the door fan air,

(k) evaluate other conflicting activities in and around space (e.g., interruption to the facility being tested).

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 or fans should have a total air flow capacity capable of producing a pressure difference at least equal to the predicted column pressure.

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 air flow units or be connected to an air flow metering system.

B-2.2.1.4 The accuracy of air flow measurement should be $\pm 5\%$ 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 A second blower or multiple blowers with flex duct and panel to flow to above ceilings spaces is optional.

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

(a) smoke gun, fully charged,

(b) bright light source,

(c) floor tile lifter,

(d) measuring tape,

(e) masking or duct tape,

(f) test forms,

(g) multi-tip screwdrivers,

(h) shop knife or utility knife,

(i) several sheets of thin plastic and cardboard,