NFPA

12A

ANSI / NFPA 12A
An American
National
Standard
November 20, 1980

HALON 1301 FIRE EXTINGUISHING SYSTEMS 1980

NFPA®

NATIONAL FIRE PROTECTION ASSOCIATION, INC.
Batterymarch Park, Quincy, MA 02269

4M-1-81-FP
Printed in U.S.A.

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Standard on
Halon 1301 Fire Extinguishing Systems

NFPA 12A–1980

1980 Edition of NFPA 12A

This 1980 edition of NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, was prepared by the Technical Committee on Halogenated Fire Extinguishing Systems and was adopted by the National Fire Protection Association, Inc. on November 20, 1980 at its Fall Meeting in San Diego, California. It was released for publication by the Standards Council on December 10, 1980. It supersedes the 1977 edition.

Changes other than editorial are denoted by a vertical line in the margin of the pages in which they appear.

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 the NFPA held at Toronto, Ontario in May 1970. Revisions were made in 1972, 1973, and 1977.

The 1977 edition of this standard was approved by the American National Standards Institute as an American National Standard. The 1980 edition will be submitted for similar approval.

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NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or of any document developed by the Committee on which the member serves.

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Halon 1301 Fire Extinguishing Systems

NFPA 12A-1980

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 Appendix B.

Chapter 1 General

1-1 Scope. This standard contains minimum requirements for halogenated agent fire extinguishing systems. It includes only the necessary essentials to make the standard workable in the hands of those skilled in this field. Portable halogenated agent 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 in order 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), in order that such equipment will function as intended throughout its life.

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, pressurization levels, and quantities of agent 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 which 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.

Appendix A—Explanatory.

Appendix B—Referenced Publications.

Chapters 1 through 3 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.

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.

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 which 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 = 3.785 L
cubic decimeter	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.068 95 bar
bar	bar	1 bar = 10^5 Pa

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

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 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, or where weight vs. extinguishing potential is a factor.

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, oxy-acetylene 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 4 hrs 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 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 Personnel may be exposed to Halon 1301 vapors in low concentrations for brief periods without serious risk. (*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 by Halon 1301, the atmosphere may also contain combustion and decomposition products in quantities which 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 so located as to maintain minimum clearances from live parts as shown in Table 1-6.2 and Figure 1-6.2.

As used in this standard, "clearance" is the air distance between halon equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential.

The clearances given are for altitudes of 3,300 ft (1,000 m) or less. At altitudes in excess of 3,300 ft (1,000 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 (1,000 m).

The clearances are based upon 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 and is dependent upon several variables so that the required clearances to ground shall be based upon the design BIL used rather than on the nominal line or ground voltage.

Possible design variations in the clearance required at higher voltages are evident in Table 1-6.2, where a range of voltages is indicated opposite the various BIL test values 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 system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

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

Nominal Line Voltage (KV)	Nominal Voltage to Ground (KV)	Design BIL (KV)	Minimum Clearance* (Inches)	mm
To 15	To 9	110	7	178
23	13	150	10	254
34.5	20	200	13	330
46	27	250	17	432
69	40	350	25	635
115	66	550	37	940
138	80	650	44	1118
161	93	750	52	1321
196-230	114-132	900	63	1600
		1050	76	1930
287-380	166-220	1175	87	2210
		1300	98	2489
		1425	109	2769
		1550	120	3048
500	290	1675	131	3327
		1800	142	3607
500-700	290-400	1925	153	3886
		2100	168	4267
		2300	184	4574

*For voltages up to 69 kv the clearances are taken from NFPA 70, *National Electrical Code*.®

NOTE 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.

NOTE 2: 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.

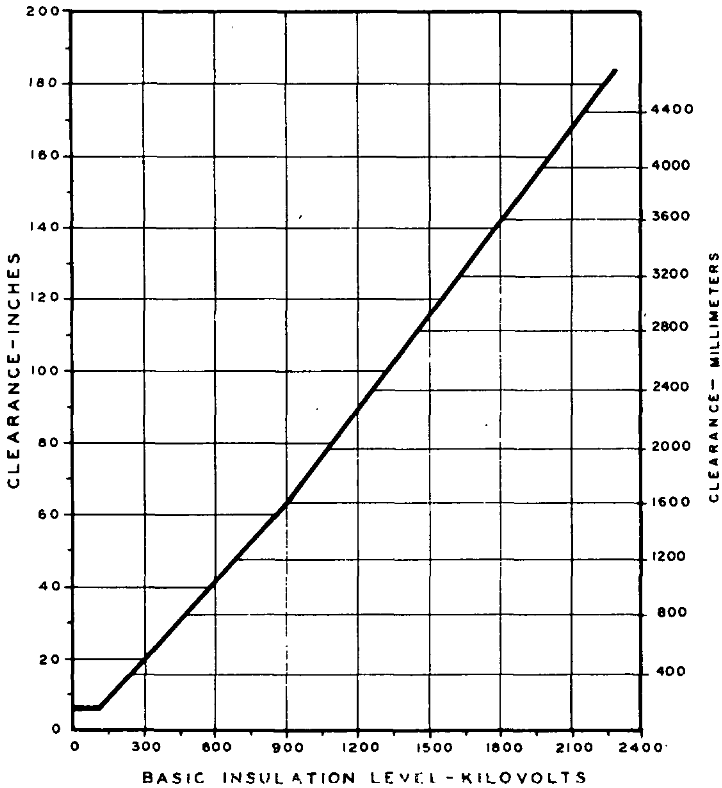


Figure 1-6.2. Clearance from halon equipment to live uninsulated electrical components.

1-7 Specifications, Plans and Approvals.

1-7.1 Specifications. Specifications for Halon 1301 fire extinguishing systems shall be prepared with care under the supervision of a competent engineer 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. Where plans are required they shall be prepared with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction.

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 or hazards 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 hazard.

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. 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.

1.7.3 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. 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:

(a) A thorough visual inspection of the installed system and hazard area. The piping, operational equipment, and discharge nozzles shall be inspected for proper size and location. The locations of alarms and manual emergency releases shall be confirmed. The configurations of the hazard shall be compared to the original hazard specification. The hazard shall be inspected closely for unclosable openings and sources of agent loss which may have been overlooked in the original specification.

(b) A check of labeling of devices for proper designations and instructions. Nameplate data on the storage containers shall be compared to specifications.

(c) A test for mechanical tightness of the piping and associated equipment to assure that leakage will not occur and that there will be no hazardous pipe movements during discharge.

(d) Nondestructive operational tests on all devices necessary for proper functioning of the system, including detection and actuation devices.

1-8* Detection, Actuation and Control Systems.

1-8.1 Detection, Actuation and Control Systems shall be installed in accordance with NFPA 71, *Standard for the Installation, Maintenance and Use of Central Station Signaling Systems*; NFPA 72A, *Standard for the Installation, Maintenance and use of Local Protective Signaling Systems for Watchman, 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*; and NFPA 72D, *Standard for the Installation, Maintenance and Use of Proprietary Protective Signaling Systems for Guard, Fire Alarm and Supervisory Service.*

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

Exception: Manual actuation may be used if acceptable to the authority having jurisdiction. Some points to be considered are hazards to personnel, undesirable side reaction, an increase in the hazard or other alternatives.

1-8.2 Automatic Detection.

1-8.2.1 Automatic detection shall be by any listed or approved method or device that is 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.

1-8.2.2 Heat detectors installed on standard spacing are about equal to an ordinary sprinkler in response time. If detectors are installed at reduced spacing from that recognized in approvals or listings response time may be reduced. An adequate and reliable source of energy shall be used in detection systems.

1-8.2.3 Detecting equipment shall be installed, tested and maintained in accordance with NFPA 72E, *Standard on Automatic Fire Detectors*.

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 (-30°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 which would render them inoperative.

1-8.3.5 The normal manual control for actuation shall be located so as to be conveniently and easily accessible at all times including the time of fire. This control shall cause the complete system to operate in its normal fashion.

1-8.3.6 All automatically operated valves controlling agent release and distribution shall be provided with approved independent means for emergency manual operation. If the means for manual actuation of the system as allowed in 1-8.1 provides approved positive operation independent of the automatic actuation, it may be used as an emergency means. The emergency means, preferably mechanical, shall be easily accessible and located close to the valves controlled. Emergency actuation that can be accomplished from one location is desirable. This does not require the emergency manual control on "reserve" containers to control any selector valves or equipment beyond the containers.

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 Supervision of automatic systems shall be provided and shall include electrical supervision of the actuating device and the wiring connecting the actuating device and the detection system.

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 A positive alarm or indicator shall be provided to show that the system has operated.

1-8.5.3 Alarms shall be provided to give positive warning of a discharge or pending discharge where a hazard to personnel may exist.

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.

1-9 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 uninterrupted protection is required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary.

1-9.1.3 Both primary and reserve supplies for fixed storage shall be permanently connected to the piping and arranged for easy changeover, except where the authority having jurisdiction permits an unconnected reserve.

1-9-2* Quality. The Halon 1301 shall comply with Military Specification MIL-M-12218B (*see A-1-9.2*).

1-9.3 Replenishment. The time needed to obtain Halon 1301 for replenishment to restore systems to operating condition shall be considered as a major factor in determining the reserve supply needed.

1-9.4 Storage Container Arrangement.

1-9.4.1 Storage containers and accessories shall be so located and arranged that inspection, testing, recharging and other maintenance is facilitated and interruption to protection is held to a minimum.

1-9.4.2 Storage containers shall be located as near as possible to the hazard or hazards they protect, but shall not be exposed to a fire in a manner that is likely to impair system performance.

1-9.4.3 Storage containers shall not be located so as to be subject to severe weather conditions or be subject to mechanical, chemical, or other damage. When excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

1-9.5* Storage Containers.

1-9.5.1 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).

1-9.5.2 Each container shall have a permanent nameplate specifying the agent, tare and gross weight in addition to the superpressurization level.

1-9.5.3 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 Board of Transport Commissioners[1], if used as a shipping container. 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 1-9.5.8*).

[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, D.C. 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.

1-9.5.4 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.

1-9.5.5 Container Test.

1-9.5.5.1 Halon 1301 cylinders shall not be recharged without a test for cylinder strength and a complete visual inspection if more than 5 years have elapsed since the date of the last test and inspection.

1-9.5.5.2 Cylinders continuously in service without discharging may be retained in service for a maximum of 20 years from the date of the last test and inspection. At the end of 20 years, they shall be emptied, retested and subject to a complete visual inspection and remarked before returning to service.

1-9.5.5.3 Where the authority having jurisdiction determines that the container has been subjected to unacceptable corrosion, shock or vibration, a visual inspection and a test for strength of the container can be required.

1-9.5.5.4 Nondestructive test methods such as hydrostatic testing shall be used. Containers shall be thoroughly dried before filling, especially after hydrostatic testing.

1-9.5.6 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.

1-9.5.7 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.

1-9.5.8 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. Examples of materials for piping and the standards covering these materials are:

Ferrous Piping: Black or Galvanized Steel Pipe: ASTM A-53, or A-106, ANSI B36.10.

Nonferrous piping (Drawn, Seamless), Copper: ASTM B-88.

Flexible Metallic Hose: ANSI B140.

The above listed materials do not preclude the use of other materials such as stainless steel or other pipe or tubing, which will also satisfy the requirements of this section. See A-1-10.1 for stress calculations.

Schedule 40 steel pipe up to 4 in. nominal pipe size conforming to the above specifications is satisfactory for both the 360 psig (25.84 bars) and 600 psig (42.38 bars) charging pressures specified in this standard.

Type M copper tubing conforming to the above specification is satisfactory for all 360 psig (24.84 bars) charging pressure.

For 600 psig (42.38 bars) charging pressures Type M is satisfactory for nominal sizes up to ¾ in., Type L up to 1½ in. size and Type K up to 2½ in. size.

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 Examples of materials used for fittings are:

Malleable Iron 300 lb class only—ASTM A-197
Ductile Iron 300 lb class or higher—ASTM A-395
Steel—ASTM A-234

Exception: For ¾ in. or smaller pipe sizes, 150 lb class fittings are acceptable.

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. The above listed materials do not preclude the use of other materials which will satisfy the requirements of this section.

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 B2.1. 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 Piping shall be blown out before nozzles or discharge devices are installed.

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 but which will 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 so located they will not injure personnel.

1-10.6* Pipe and Orifice Size Determination.

1-10.6.1 System flow calculations shall be based upon the methods given in this section or any other method approved or listed by a testing laboratory.

1-10.6.2 Pipe sizes and orifice areas shall be selected to deliver the required rate of flow at each nozzle.

1-10.6.3* Flow shall be calculated on the basis of an average container pressure during discharge, taking into account the original pressurization level, storage filling density, and percent in piping for 70°F (21°C) storage temperature as shown in Figure A-1-10.6.3(d).

1-10.6.4* The percent of agent in piping is defined by the following equation and shall not exceed 100 percent of the charged weight.

$$\text{percent in piping} = 100 \frac{\Sigma_1^n (Vp)\,(\bar{\rho})}{W}$$

Where:

Σ_1^n = Summation of (Vp) ($\bar{\rho}$) values for all pipeline sections.

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

$\bar{\rho}$ = 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).

1-10.6.5* A balanced system is one in which:

(a) Actual pipe length from container to each nozzle is equal to within 10 percent of the longest pipe length, and

(b) Equivalent pipe length from container to each nozzle is equal to within ± 10 percent, and

(c) Design flow rate at each nozzle is equal.

For balanced piping systems, Figures A-1-10.6.5(a) and A-1-10.6.5(b) may be used to calculate the pressure drop. When these curves are used a multiplication factor is applied to this pressure drop to correct for the percent in piping and filling density in accordance with Figures A-1-10.6.5(c) and A-1-10.6.5(d)

1-10.6.6* For unbalanced piping systems, pressure drop shall be calculated by means of the two-phase equation given below or by any other method approved by the authority having jurisdiction. This two-phase equation may also be used for calculating pressure drop in balanced piping systems.

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

Where

Q = Flow rate, lbs./second

D = Inside pipe diameter, inches

L = Equivalent length of pipe, feet

Y & Z = Factors depending on density and pressure

NOTE 1: This flow equation contains a friction factor based on commercial steel pipe.

NOTE 2: Pressure drops calculated by this means will be most accurate when the calculated terminal pressure equals one-half of the average container pressure during discharge.

1-10.6.7* Nozzle orifice sizes shall be selected to achieve the design flow rate. The discharge characteristics of the nozzle shall be provided in the manufacturer's listed design manual.

1-10.6.8* 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 discharge 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.

1-11.1.7 Factory charged nonrefillable containers which 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.

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

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(b).

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 which may contain 10 percent Halon 1301 shall be evacuated immediately upon discharge of the agent. Where egress cannot be accomplished within 1 min, 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 sec. Where egress cannot be accomplished within 30 sec 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 which 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. These openings shall be compensated for by additional quantities of agent according to the design procedures outlined in A-2-5.3. The authority having jurisdiction may require tests to assure proper performance as defined by this standard.

2-2.2.3 To prevent fire from spreading through openings to adjacent hazards or work areas and to make up for leakage of the agent, openings shall be compensated for with automatic closures, screening nozzles or additional agent, and shall be arranged to operate simultaneously with system discharge. The agent required by screening nozzles shall be in addition to the normal requirement for total flooding. Where reasonable confinement of agent is impracticable, protection shall be extended to include the adjacent hazards or work areas.

2-2.2.4 For deep-seated fires, forced air ventilating systems shall be shut down or closed with the start of agent discharge; or, additional compensating gas shall be provided. (*See A-2-5.3.*)

2-2.2.5 For surface fires, forced air ventilation may also be required to be shut down or closed with the start of agent discharge; or, additional compensating gas may need to be provided. (*See A-2-5.3.*)

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 upon normal conditions with the extinguishing system meeting the requirements specified herein.

2-3.2 Flammable Materials.

2-3.2.1 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. (*See 2-5.3.*)

NOTE: A-2-3 contains additional guidelines for determining which concentration level to use for a particular hazard.

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 it can be shown that a probable explosive atmosphere cannot exist in the hazard either before or as a result of the fire. An explosion potential is improbable when either of the following conditions apply:

1. The quantity of fuel permitted in the enclosure is less than that required to develop a maximum concentration equal to one-half of the lower flammable limit. Additional information is given in A-2-1 and A-2-3.

2. The volatility of the fuel before the fire is too low to reach the lower flammable limit in air (maximum ambient temperature or fuel temperature does not exceed the closed cup flash point temperature), and fire may be expected to burn less than 30 sec before extinguishment.

(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. (*See A-2-3.*)

(c) *Special Fire Considerations.* 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.

Table 2-3.2.2
Halon 1301 Design Concentrations for Flame Extinguishment
(In 25°C air 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* Inerting.

(a) *Applicability of Inerting Concentrations.* Inerting concentrations shall be used when the conditions of 2-3.2.2 are not or cannot be met. Such concentrations are sufficient to "inert" the atmosphere against all proportions of fuel in air. Specifically, they shall be used in the following situations:

1. The quantity of fuel in the enclosure is greater than that permitted in 2-3.2.2(a)(1); and

2. The volatility of the fuel is greater than that permitted in 2-3.2.2(a)(2) or

3. 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.

NOTE: Table A-2-3.2.3 gives minimum design concentrations for inerting several flammable liquids and gases.

2-3.2.4 Design flame extinguishment concentrations not given in 2-3.2.2 shall be obtained by test plus a 20 percent safety factor. Minimum design concentrations shall be 5 percent. Design inerting concentrations shall be determined by test plus a 10 percent safety factor.

2-3.2.5 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.

2-3.2.6 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 Explosion Venting*, 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 which do not develop deep-seated fires, and those which do. Materials which do not become deep-seated undergo surface combustion only and may be treated much as a flammable liquid fire. Most materials which 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 unfilled plastics (without filler materials), surface combustion is the only type that occurs. These fires are readily extinguished with low concentrations (e.g., 5 percent) of Halon 1301. Although glowing embers may remain at the surface of the fuel following extinguishment of flames, these embers will be completely extinguished within a short time (e.g., 10 min), provided the Halon 1301 concentration is maintained around the fuel for this time (called "soaking" time).

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 time during which 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 (*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 unclosable openings, forced ventilation or other special conditions which 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).

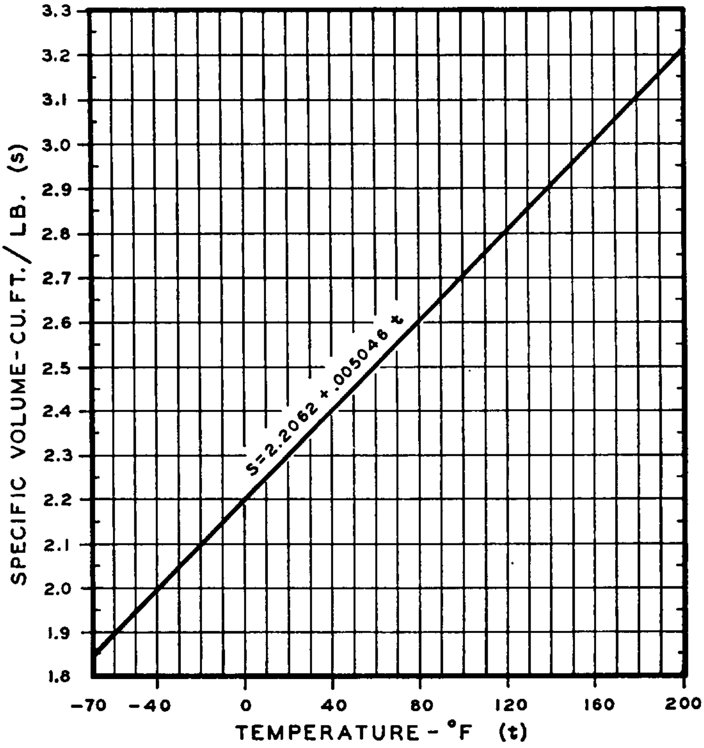


Figure 2-5.2. Specific volume of superheated Halon 1301 vapor (at 1 atmosphere).

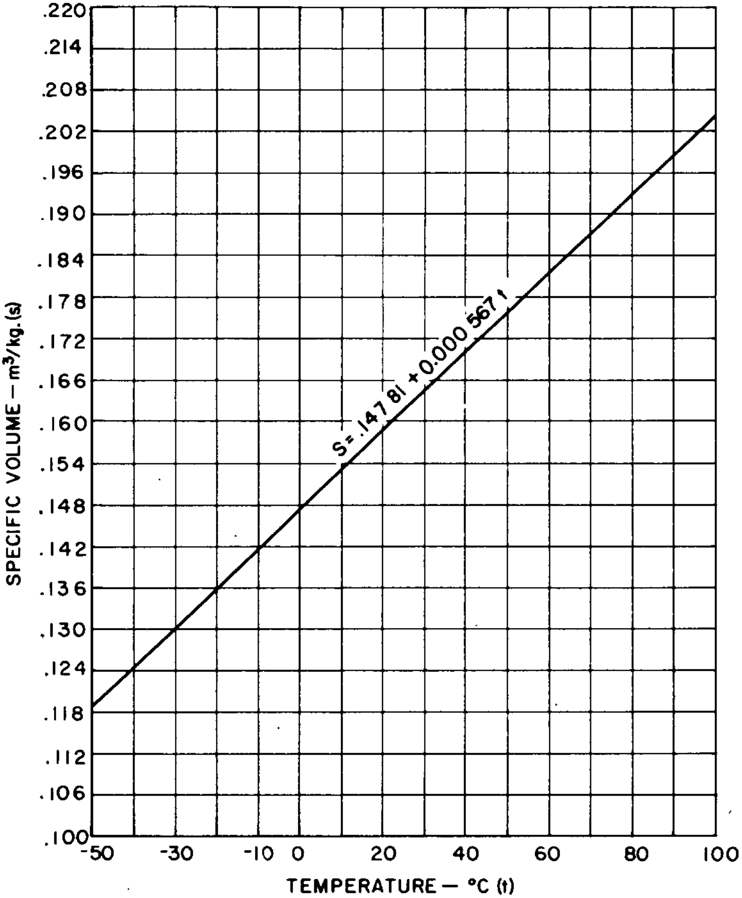


Figure 2-5.2 (Metric). Specific volume of superheated Halon 1301 vapor (at 1 atmosphere).

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 unclosable 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.

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 sec or a shorter time if practicable, unless a longer discharge time is specifically permitted 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.

Table 2-5.2
Halon 1301 Total Flooding Quantity

Temperature t °F (2)	Halon 1301 Specific Vapor Volume ft. 3/lb. (3)	Halon 1301 Weight Requirements of Hazard Volume (1) [lb./ft.³]							
		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

Table 2-5.2 (cont.)
Halon 1301 Total Flooding Quantity

Temperature t °F (2)	Halon 1301 Specific Vapor Volume ft. 3/lb. (3)	Halon 1301 Weight Requirements of Hazard Volume (1) [lb./ft.^{3}]							
		Halon 1301 Concentration—C—% By Volume(4)							
		3	4	5	6	7	8	9	10
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) Agent Weight Requirements $\left(\frac{W}{V}\text{—lb./ft.}^3\right)$—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) Temperature (t—°F)—The design temperature in the hazard area.

(3) Specific Volume (s—ft.^{3}/lb.)—Specific volume of superheated Halon 1301 vapor may be approximated by the formula:

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

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

Table 2-5.2—Metric
Halon 1301 Total Flooding Quantity

Temperature t °C (2)	Halon 1301 Specific Vapor Volume m³/kg. (3)	Halon 1301 Weight Requirements of Hazard Volume (1) [kg/m³] 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

Table 2-5.2 — Metric (cont.)
Halon 1301 Total Flooding Quantity

Temperature t °C (2)	Halon 1301 Specific Vapor Volume m³/kg. (3)	Halon 1301 Weight Requirements of Hazard Volume (1) [kg/m³] Halon 1301 Concentration—C—% By Volume (4)							
		3	4	5	6	7	8	9	10
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) Agent Weight Requirements $\left(\frac{W}{V}\text{—kg/m}^3\right)$—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) Temperature (t—°C)—The design temperature in the hazard area.
(3) Specific Volume (s—m³/kg)—Specific volume of superheated Halon 1301 vapor may be approximated by the formula:

$$s = 0.147\,81 + .000\,567t$$
where t = temperature, °C

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

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

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 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.

2-6.5.3 In rooms with suspended ceiling tiles, tiles within a 4-ft (1.2-m) radius of nozzles shall be suitably clipped or retained to prevent lifting during discharge.

2-7 Venting Consideration.

2-7.1. General. Venting of an enclosure may be necessary to relieve pressure build-up due to the discharge of large quantities of Halon 1301. Appropriate pressure relief depends on the injection rate of the Halon 1301 and enclosure strength.

2-7.2 Pressure Relief Venting.

2-7.2.1 Porosity and leakages such as around doors, windows and dampers, though not readily apparent or easily calculated, will usually provide sufficient relief for Halon 1301 flooding systems without need for additional venting. Record storage rooms, refrigerated spaces and duct work also generally need no additional venting.

2-7.2.2 For very tight enclosures, the area necessary for free venting may be calculated from the following formula, taking the specific volume of Halon 1301 vapor at 70 °F to be 2.56 cu ft per lb (0.160 m^3/kg at 21 °C):

$$x = \frac{13.2\,Q}{\sqrt{p}}$$

x = Free venting area, sq in.

Q = Halon 1301 injection rate, lb/sec.

p = Allowable strength of enclosure, lb/sq ft.

For SI Units:

$$x = \frac{410\,Q}{\sqrt{p}}$$

x = Free venting area, sq mm.

Q = Halon 1301 injection rate, kg/s.

p = Allowable strength of enclosure, bars-gage.

2-7.2.3 In many instances, particularly when hazardous materials are involved, relief openings are already provided for explosion venting. These and other available openings often provide adequate venting.

2-7.2.4 Table 2-7.2.4, based on general construction practices, provides a guide for considering the normal strength and allowable pressures of average enclosures.

Table 2-7.2.4
Strength and Allowable Pressures for Average Enclosures

		Pressure			
Type Construction	**Windage miles/hour**	**lb/sq. ft.**	**In Water**	**psi**	**bars gauge**
Light Building	100	25*	5	.175	.012
Normal Building	140	50†	10	.35	.024
Vault Building	200	100	20	.70	.048

* Venting sash remains closed.
† Venting sash designed to open freely.

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 pipe lines 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 (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.

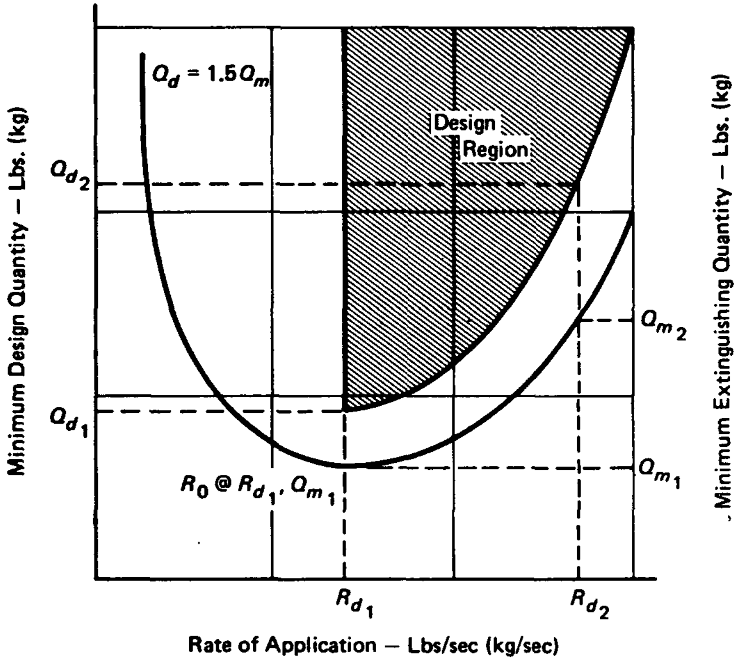


Figure 3-3.2.3 Typical data presentation for local application nozzles.

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 so as 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 so as 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.

Appendix A

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

A-1-5 Halogenated Extinguishing Agents. A halogenated compound is one which 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) is also a gas, is chemically inert, nonflammable and extremely low in toxicity. Carbon tetrachloride (CCl_4) is a volatile liquid which 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 which 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 which 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:

$$CBrF_3 \rightarrow CF_3 \cdot + Br \cdot$$

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

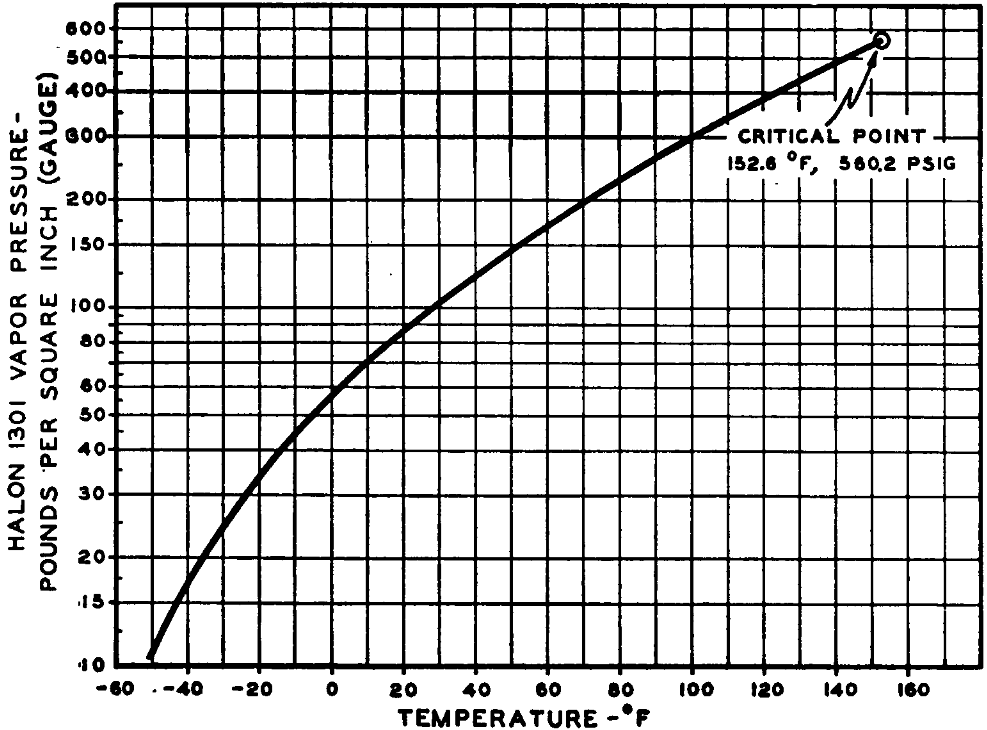


Figure A-1-5.2 Vapor pressure of Halon 1301 vs. temperature.

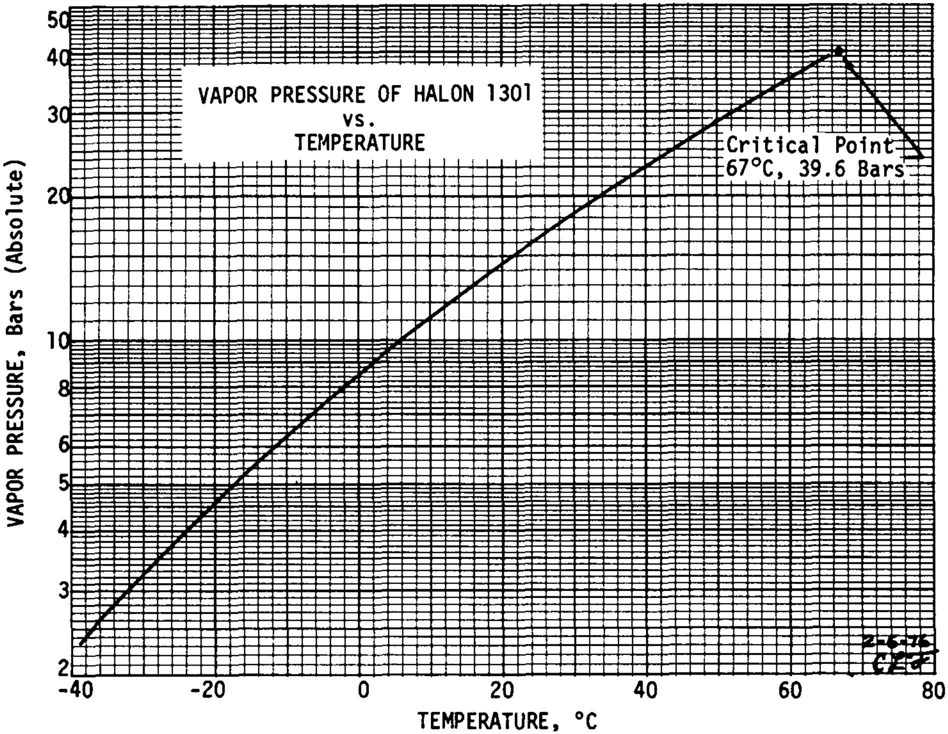


Figure A-1-5.2 (Metric)

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

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

$$R\text{-}H + Br\cdot \rightarrow R\cdot + HBr$$

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

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

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

The "ionic" theory supposes that the uninhibited combustion process includes a step in which O_2-ions are formed by the capture of electrons which come from ionization of hydrocarbon molecules. Since bromine atoms have a much higher cross section for the capture of slow electrons than has O_2, the bromine inhibits the reaction by removing the electrons that are needed for activation of the oxygen.

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-min 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-min exposures and large doses of injected adrenalin, the threshold for sensitization is in the 7.5 to 10 percent range.[3,4,5]

In other studies on dogs, a certain critical blood level was associated with inspired levels needed to sensitize the heart.[6] With exposure to Halon 1301, a relatively insoluble fluorocarbon, blood concentrations rise rapidly, equilibrate within 5-10 min, and fall rapidly upon cessation of exposure. There is no accumulation of Halon 1301 as indicated by similar blood concentration at 5-10 min and at 60 min of exposure. When dogs exposed to Halon 1301 for 60 min are given a large dose of adrenalin, the threshold for cardiac sensitization remains the same as for 5-min exposures—7.5 to 10.0 percent. In addition, studies have shown that sensitization is only a temporary effect, since adrenalin injections given 10 min after exposure to known sensitizing levels have not resulted in arrhythmias.[7]

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.[8]

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

*See B-1-5 for references.

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-hr Ames Test at levels of 40 percent, no evidence of mutagenicity was seen in Salmonella typhimurium bacteria with or without metabolic activation.[9] Pregnant rats exposed to Halon 1301 at levels as high as 5 percent exhibited no embryotoxic or teratogenic effects.[10]

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.[11] 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 min have not actually lost consciousness.[3, 11] 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.[12] In recent studies at the Medical College of Wisconsin [13], exposure to Halon 1301 up to 7.1 percent for 30 min 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 min
7-10 percent -1 min
10-15 percent -30 sec
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 in order 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, $COBr_2$).

Approximate lethal concentration values for 15-min exposures to some of these compounds are given in Column 1 of Table A-1-6.1. Column 2 gives the concentrations of these materials that have been quoted as "dangerous for short exposures" by Sax†.

†Sax, N. Irving: Dangerous Properties of Industrial Materials; Fourth Edition; Section 12; Reinhold Publishing Corporation; New York, NY; 1975.

Table A-1-6.1
Approximate Lethal Concentrations for Predominate Halon 1301 Decomposition Products

Compound	ALC for 15-Minute Exposure ppm by Volume in Air	Dangerous Concentration* ppm by Volume in Air
Hydrogen Fluoride, HF	2500	50–250
Hydrogen Bromide, HBr	4750	—
Bromine, Br_2	550	50***
Carbonyl Fluoride, COF_2	1500	—
Carbonyl Bromide, $COBr_2$	100–150**	—

*Sax, N. Irving; Dangerous Properties of Industrial Materials; Fourth Edition; Section 12; Reinhold Publishing Corporation; New York, NY; 1975.

**Value is for carbonyl chloride, $COCl_2$ (phosgene); value for carbonyl bromide is not available.

***Value is for chlorine (Cl_2); value for bromine is not available.

The decomposition products of Halon 1301 have a charateristic 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 sec produced only 12 ppm HF. A similar test having an extinguishment time of 10 sec produced an average HF level of 250¼ppm over a 9-min 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 of 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(a) Approval of Installations. To determine that the system has been properly installed and will function as specified, the following additional tests should be performed:

1. A test for continuity of piping with free unobstructed flow, such as a "puff" test with compressed air or carbon dioxide.

2. When conditions prevail that make it difficult to determine if the system will perform as designed, a full discharge test should be made. During such a test, measurements are made of discharge time agent concentrations achieved, agent distribution throughout the hazard area, and agent holding time.

(b) A system should have all other functional tests performed prior to making a discharge test to assure that a discharge test will not require repeating.

Where permitted by the authority having jurisdiction, substitute test agents are sometimes used in acceptance testing of new halon systems. Where a substitute test agent is used, the authority having jurisdiction should assure that the substitute provides a meaningful test of the system.

Factors to be considered include:

1. Discharge time.
2. Concentration achieved.
3. Agent distribution (mixing).
4. Hold time.

If the toxicity of the test agent used is such that there is a hazard to test personnel, appropriate precaution should be taken. Personnel should either be provided with breathing apparatus or be excluded from the test enclosure during the test. Provision should be made for safe ventilation of the test agent after the test.

The amount of agent used in the test should be determined prior to the test so that the relationship of the test agent concentration to Halon 1301 can be determined. Containers charged with a substitute test gas should be distinctly identified. The authority having jurisdiction should assure that, after the test, all systems containers are properly filled with Halon 1301.

NOTE: Presently Halon 122 (dichlorodifluoromethane) is the predominant substitute test agent being used. The test cylinder for Halon 122 (dichlorodifluoromethane) is loaded to 82 percent by weight of the Halon 1301 charge. Reference to the test agent manufacturer's bulletins is important.

A-1-9.2 Quality. Specification MIL-M-12218C requires a technical purity of Halon 1301 as shown in Table A-1-9.2.

Table A-1-9.2
Requirements for Halon 1301 (Bromotrifluoromethane)
Specification MIL-M-12218C*

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
Fixed Gases in Vapor Phase of Shipping Cylinder, expressed as air, percent by volume	1.5
Boiling Point, °C at 760 mm Hg	-57.75
Boiling Range, °C, 5 to 85 percent distilled	0.3
High-Boiling Impurities, grams/100 ml, maximum	0.05
Suspended Matter or Sediment	None visible

*May be obtained from: Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

A-1-9.5 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, or manifolded cylinders 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.

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-1-9.5(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-1-9.5(b) (360 psig) and A-1-9.5(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.

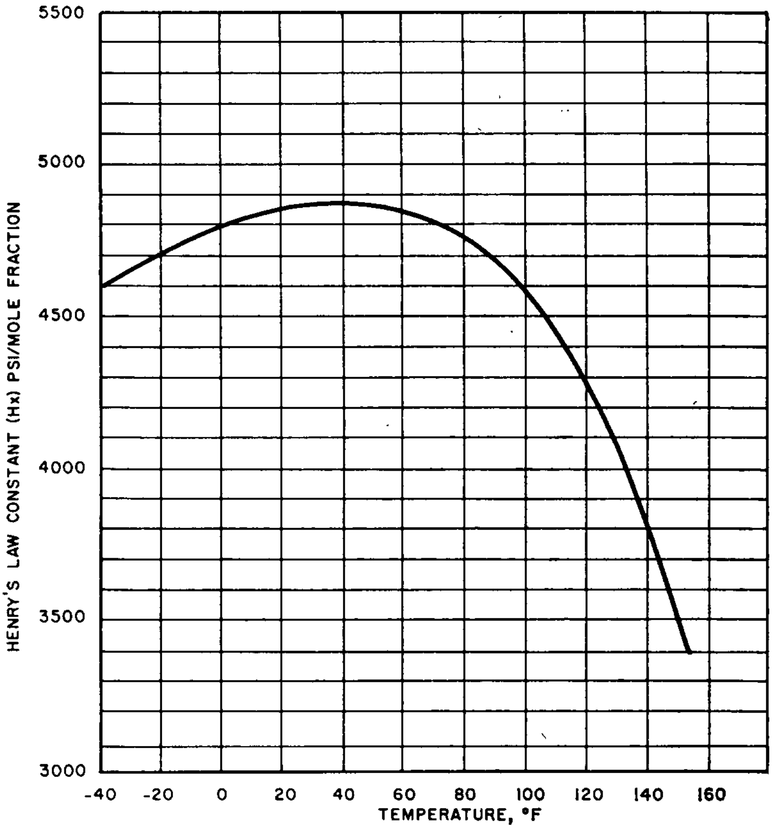


Figure A-1-9.5(a) Henry's Law Constant for Nitrogen Solubility in Liquid Halon 1301.

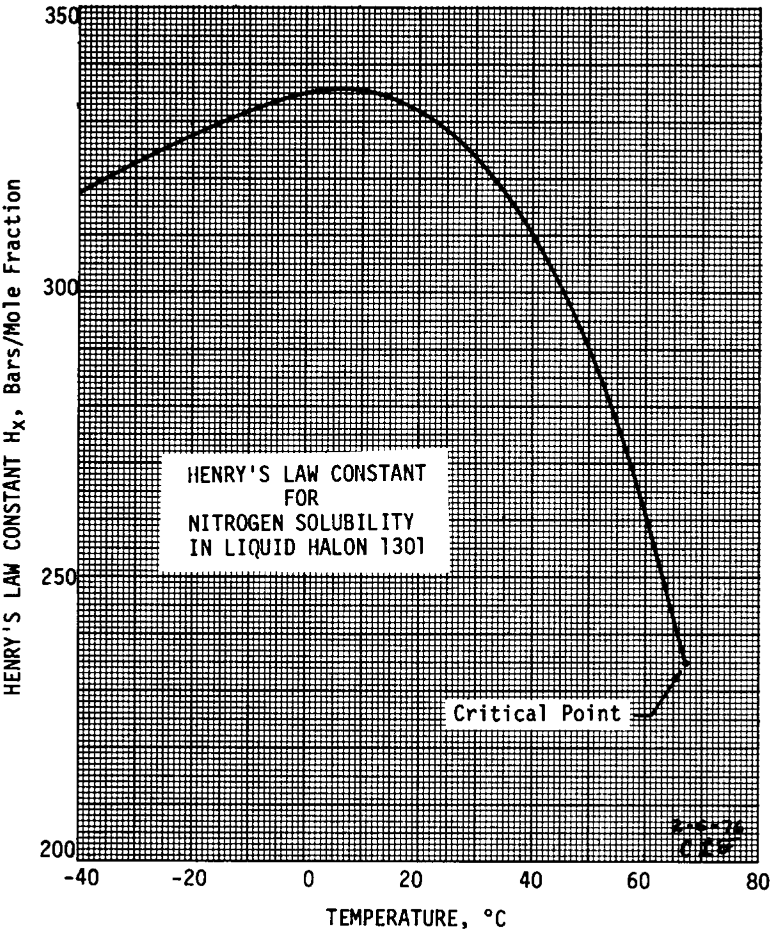


Figure A-1-9.5(a) (Metric)

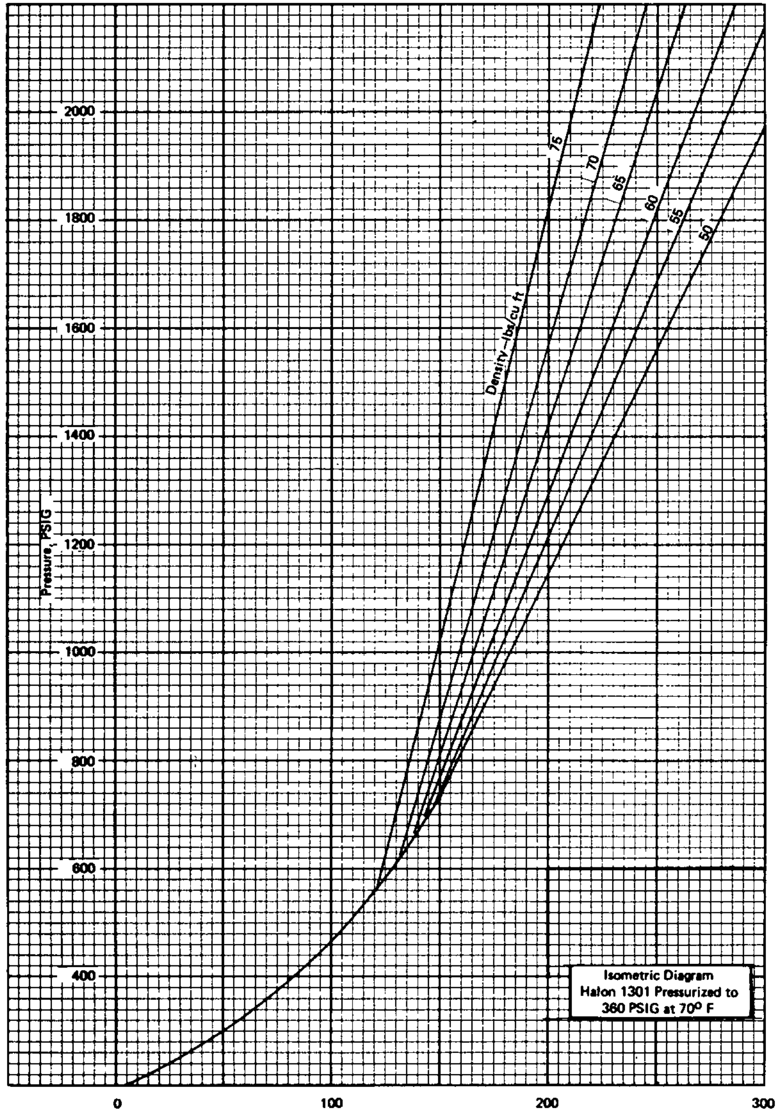


Figure A-1-9.5(b) Isometric diagram. Halon 1301 pressurized to 360 psig at 70°F.

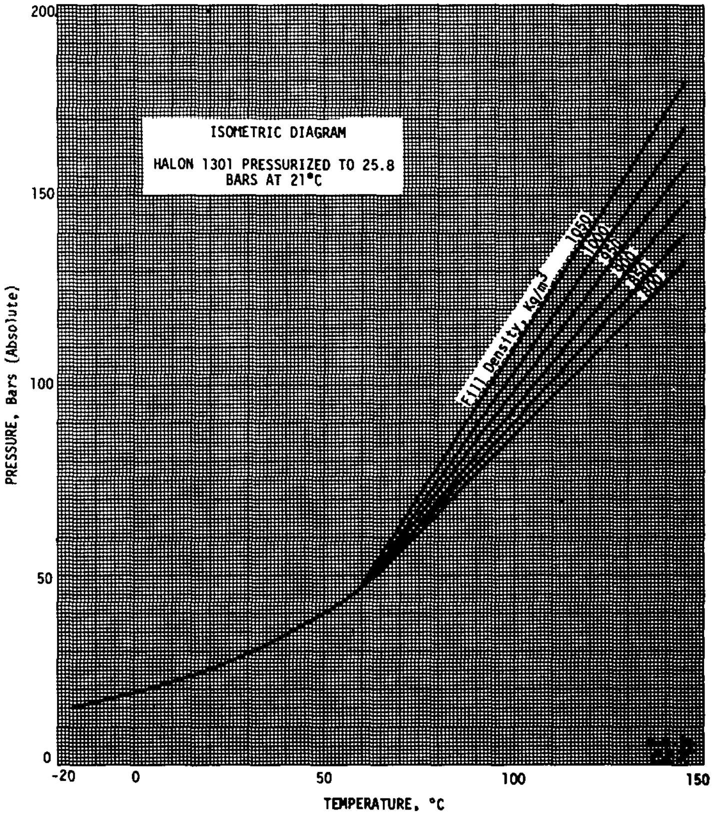


Figure A-1-9.5(b) (Metric)

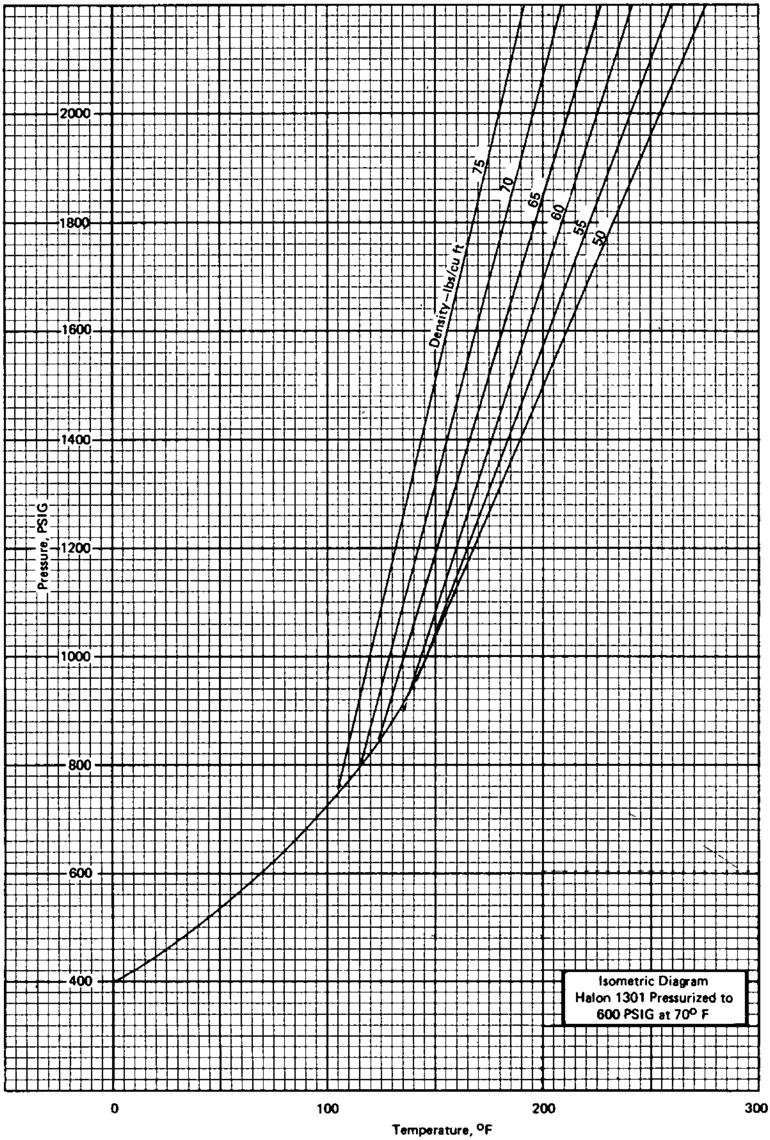


Figure A-1-9.5(c) Isometric diagram. Halon 1301 pressurized to 600 psig at 70° F.

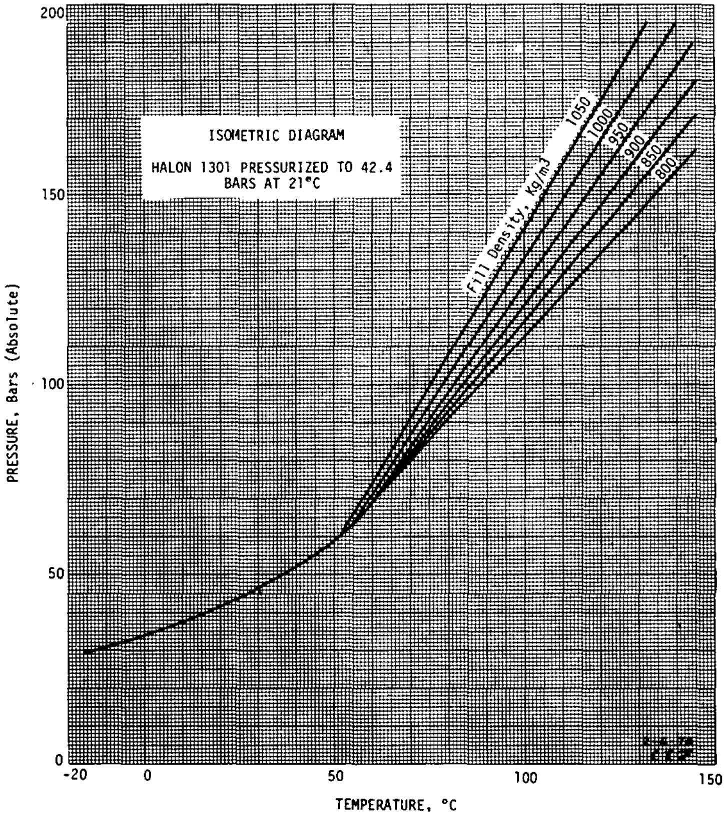
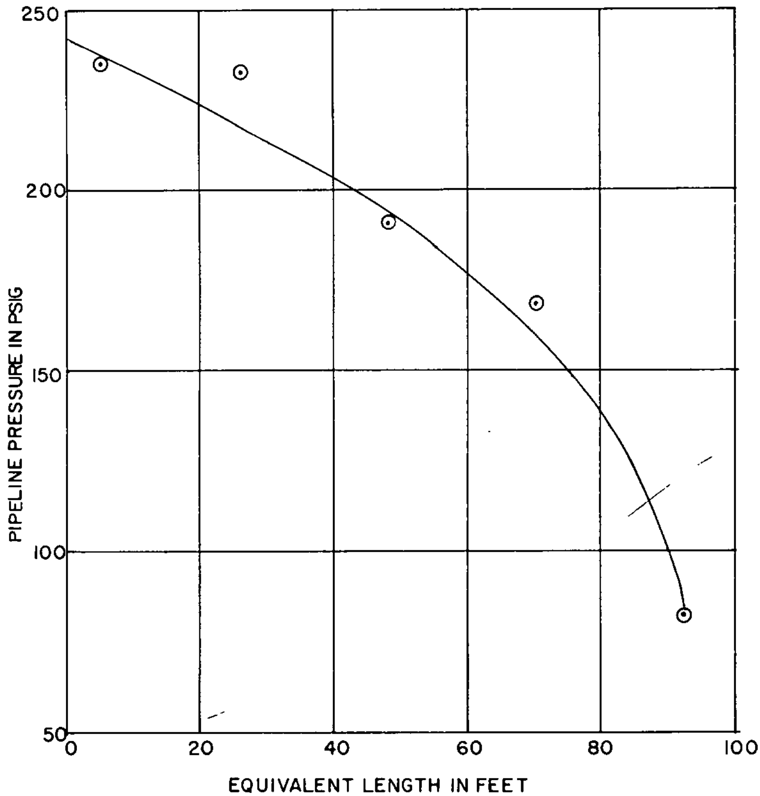


Figure A-1-9.5(c) (Metric)

A.1.10.6 Piping Flow Characteristics. 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. This causes the pressure drop to be nonlinear with an increasing rate of pressure drop as the line pressure is reduced by pipe line friction. A typical example is illustrated in Figure A-1-10.6.



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

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).

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
⅜	0.6	1.3	0.8	2.7	0.3
½	0.8	1.7	1.0	3.4	0.4
¾	1.0	2.2	1.4	4.5	0.5
1	1.3	2.8	1.8	5.7	0.6
1¼	1.7	3.7	2.3	7.5	0.8
1½	2.0	4.3	2.7	8.7	0.9
2	2.6	5.5	3.5	11.2	1.2
2½	3.1	6.6	4.1	13.4	1.4
3	3.8	8.2	5.1	16.6	1.8
4	5.0	10.7	6.7	21.8	2.4
5	6.3	13.4	8.4	27.4	3.0
6	7.6	16.2	10.1	32.8	3.5

Table 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
⅜	0.2	0.7	0.5	1.6	0.3
½	0.3	0.8	0.7	2.1	0.4
¾	0.4	1.1	0.9	2.8	0.5
1	0.5	1.4	1.1	3.5	0.6
1¼	0.7	1.8	1.5	4.6	0.8
1½	0.8	2.1	1.7	5.4	0.9
2	1.0	2.8	2.2	6.9	1.2
2½	1.2	3.3	2.7	8.2	1.4
3	1.5	4.1	3.3	10.2	1.8
4	2.0	5.4	4.4	13.4	2.4
5	2.5	6.7	5.5	16.8	3.0
6	3.0	8.1	6.6	20.2	3.5

Changes in elevation are accounted for by the following equation:

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

where

ΔP = Pressure drop, psi.

ρ = Pipe line density of agent at point of elevation change, lbs./cu. ft.

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

A-1-10.6.3 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 600 psig storage 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 on 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 during discharge. The effect of this is to reduce 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.

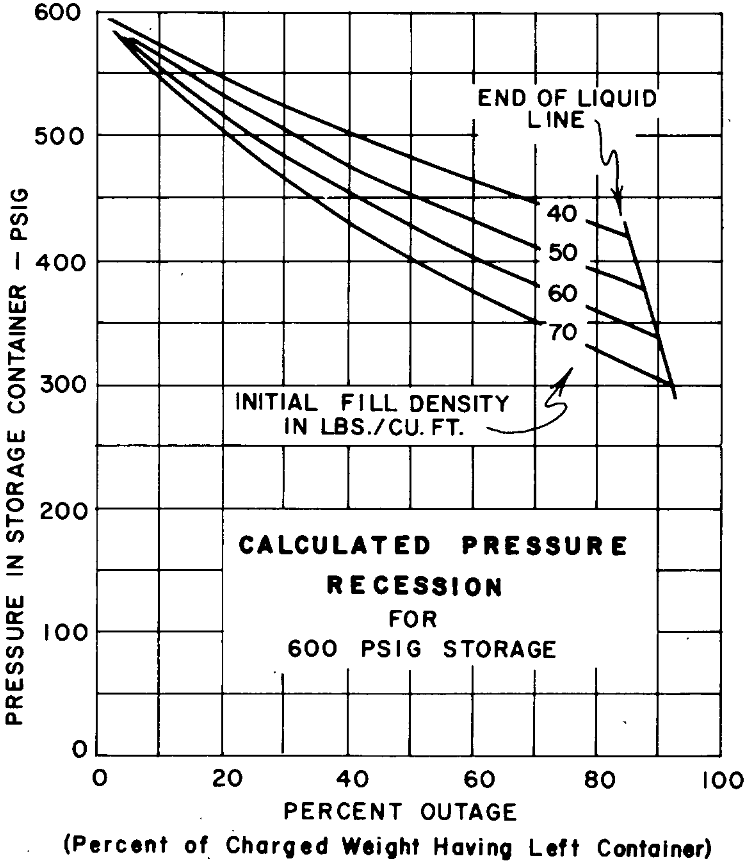


Figure A-1-10.6.3(a) Calculated pressure recession for 600 psig storage.

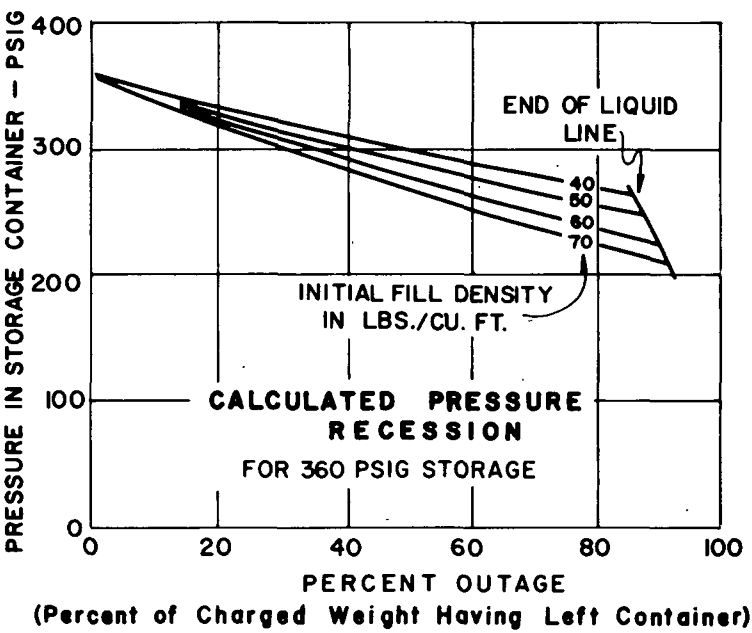


Figure A-1-10.6.3(b) Calculated pressure recession for 360 psig storage.

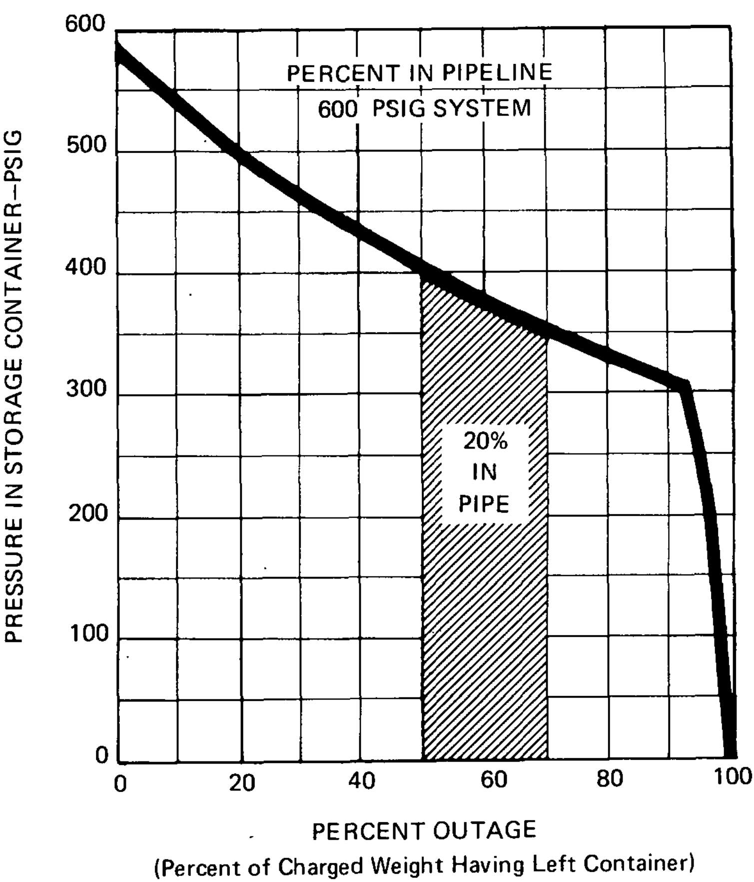


Figure A-1-10.6.3(c)

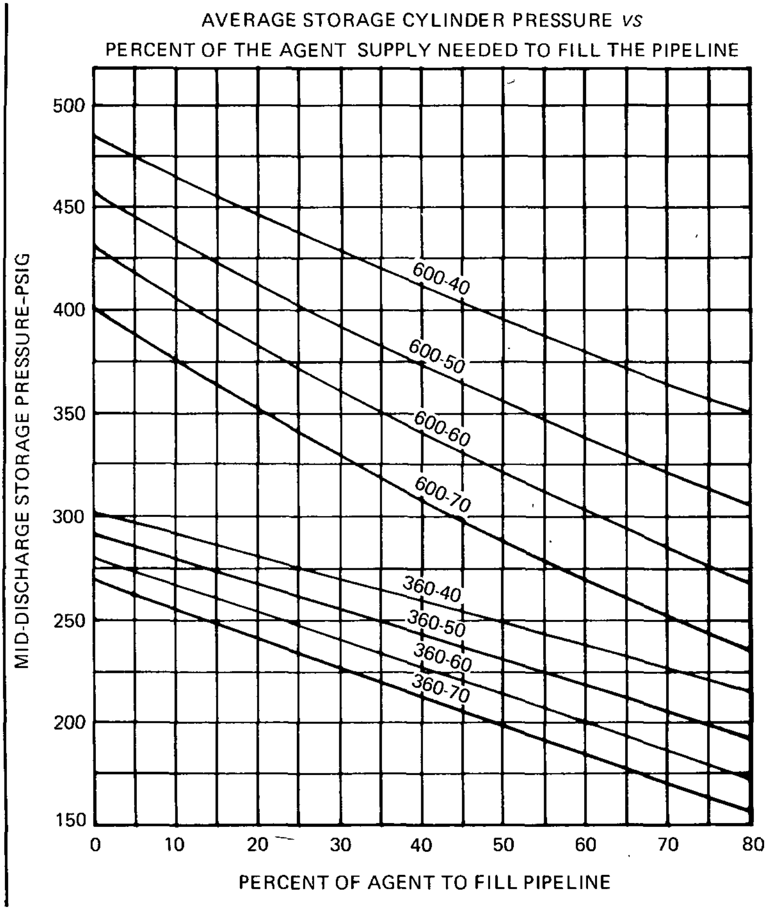


Figure A-1-10.6.3(d)

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.

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	20
600	50	7320	34
600	40	7390	28
360	40	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.	ft^3/ft	Schedule 80 Inside Diameter in.	ft^3/ft
¼	0.364	0.0007	0.302	0.0005
⅜	0.493	0.0013	0.423	0.0010
½	0.622	0.0021	0.546	0.0016
¾	0.824	0.0037	0.742	0.0030
1	1.049	0.0060	0.957	0.0050
1¼	1.380	0.0104	1.278	0.0089
1½	1.610	0.0141	1.500	0.0123
2	2.067	0.0233	1.939	0.0205
2½	2.469	0.0332	2.323	0.0294
3	3.068	0.0513	2.900	0.0459
3½	3.548	0.0687	3.364	0.0617
4	4.026	0.0884	3.826	0.0798

Table 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

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 Figure A-1-10.6.4(b) for the 360 psig systems.

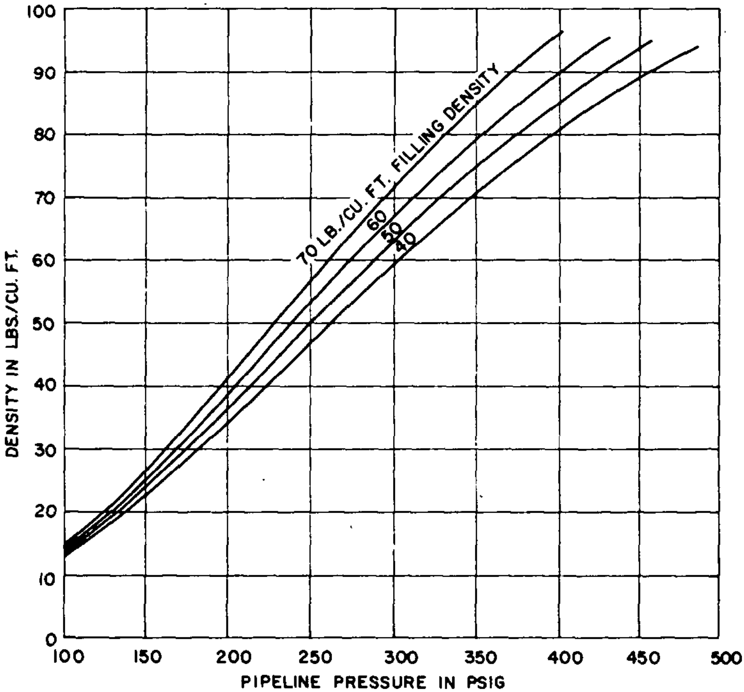


Figure A-1-10.6.4(a) Pipeline density for 600 psig systems based on constant enthalpy expansion.

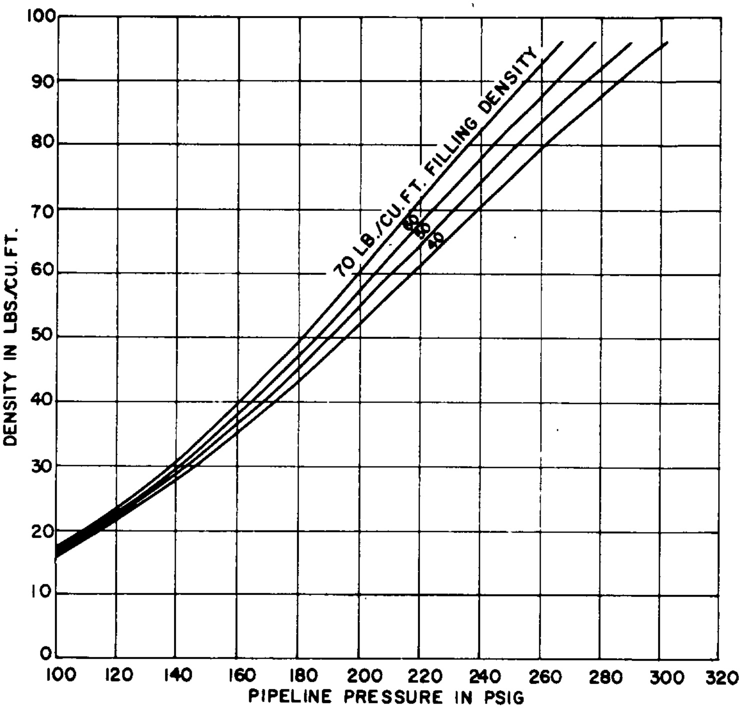


Figure A-1-10.6.4(b) Pipeline density for 360 psig systems based on constant enthalpy expansion.

A-1-10.6.5 Sample Calculation for a Balanced System. An 80-lb supply of agent is to be discharged in 10 sec 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.

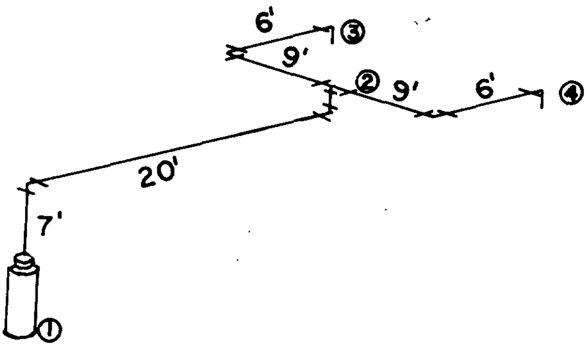


Figure A-1-10.6.5

Calculated Solution

Section	Pipe	L*	EQL*	Elevation	Rate lbs/sec	Start Psig	End Psig
1-2	1" Sch. 40	27'	58'	7'	8	243	191
2-3	¾" Sch. 40	15'	19'	0	4	191	177
2-4	¾" Sch. 40	15'	19'	0	4	191	177

*The terms L and EQL are actual piping length and equivalent piping length respectively. Equivalent length (EQL) is the sum of the actual length (L) plus the equivalent pipe represented by fitting valves and other components affecting flow. Section 1-2, for example, includes 31 ft equivalent length allowance for the cylinder valve, dip tube flexible connector and elbows.

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

$$V_p = (27 \times .0060) + 2(15 \times .0037) = 0.273 \text{ cu ft}$$

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

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

(3) 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 is 243 psig.

(4) Determine Rate of Pressure Drop. Using Figure A-1-10.6.5(a), the uncorrected rate of pressure drop in Section 1-2 is 0.78 psi/ft and that in Sections 2-3 and 2-4 is 0.68 psi/ft. The correction factor from Figure A-1-10.6.5(d) is 1.05. The corrected rate of pressure drop in Section 1-2 is 1.05 x 0.78 = .819 psi/ft, while that for Sections 2-3 and 2-4 is 1.05 x 0.68 = .714 psi/ft.

(5) Calculate Terminal Pressures. 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:

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

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 79 lb/cu ft fill density curve. The pressure loss due to the 7 ft increase in elevation is:

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

The pressure drop due to friction for Section 1-2 is 58 ft x .819 psi/ft = 48 psi. The total pressure loss in Section 1-2 is therefore 48 psi + 4 psi = 52 psi. Pressure at point 2 is 243-52 = 191 psig. The pressure drop due to friction in Sections 2-3 and 2-4 is 19 ft x .714 psi per ft = 14 psi. There is no elevation change in the sections, so the terminal pressure at each nozzle is 191-14 = 177 psig. Since the nozzle pressures are not less than 50 percent of the average container pressure during discharge, the estimated pipe sizes are adequate.

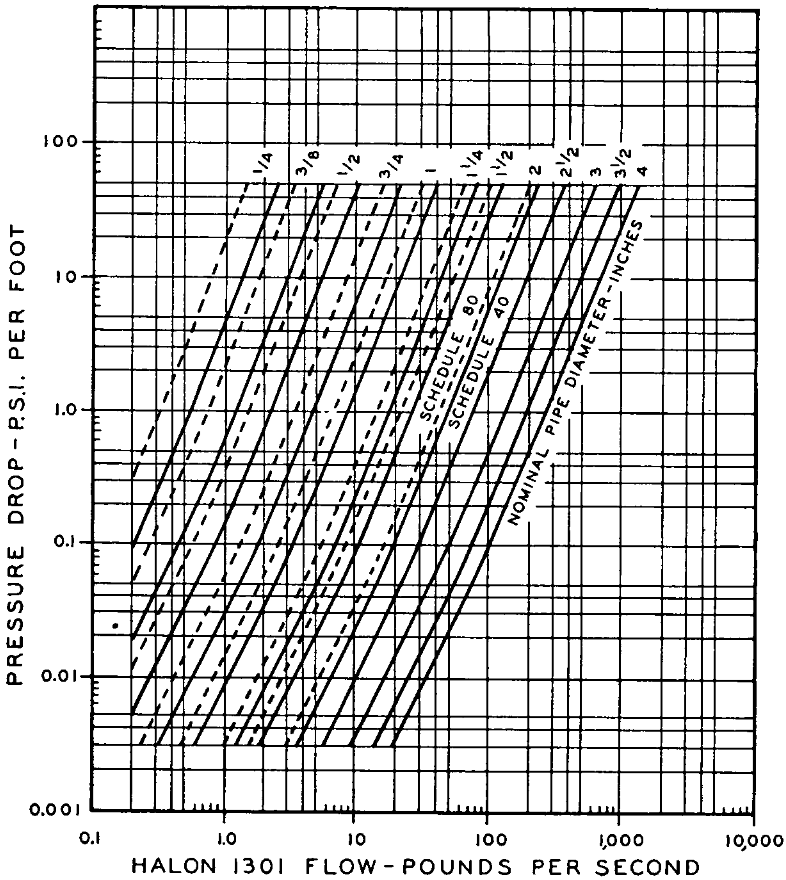


Figure A-1-10.6.5(a) Pressure drop vs. flow in steel pipe.

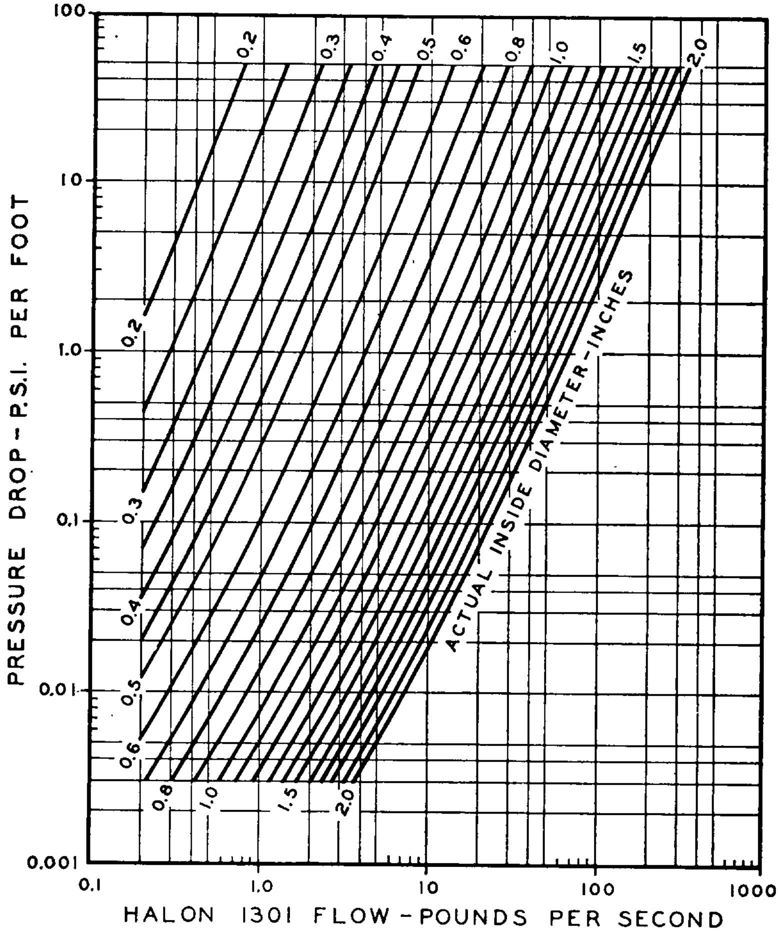


Figure A-1-10.6.5(b) Pressure drop vs. flow in copper tubing.

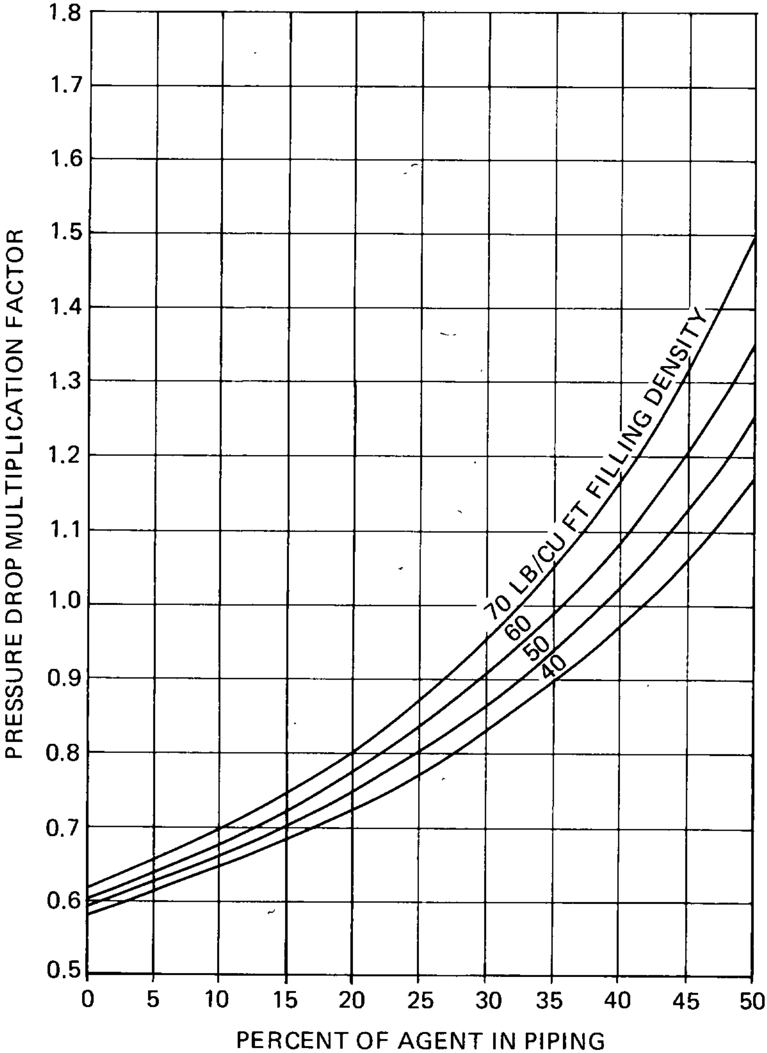


Figure A-1-10.6.5(c) Factor for 600 psig systems.

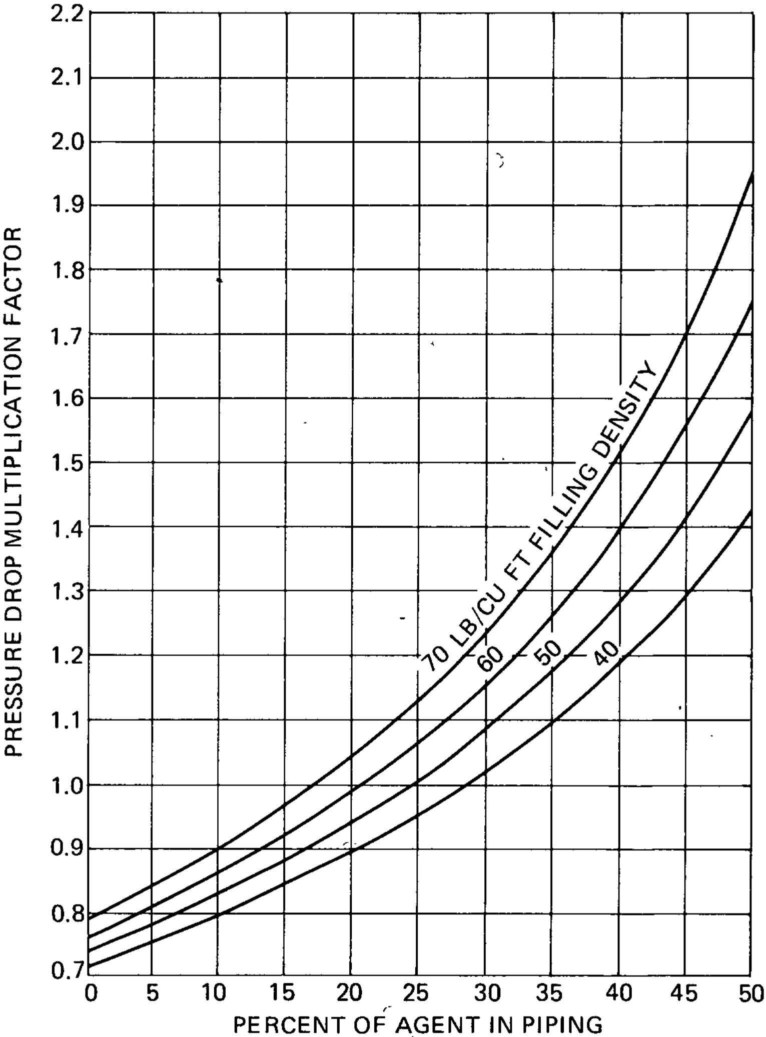


Figure A-1-10.6.5(d) Factor for 360 psig systems.

A-1-10.6.6(a) The two-phase flow equation as given in 1-10.6.6 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 = $+7.97/D^4$
D = I.D. of pipe, in.
L = Equivalent length of section, ft
Q = Flow rate, lbs/sec

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-1-10.6.6(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-1-10.6.6(e), (f), (g) and (h) are for the 360 psig systems with the same filling densities.

As an example of the use of this method of calculating pressure drop, refer to the balanced system of Figure A-1-10.6.5. Using the same storage parameters, the percent in piping can be estimated to be 19.5 percent as determined in the original example. The starting pressure will then be 243 psig. The solution will deviate slightly from the original as tabulated below.

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) **Elevation Correction.**

The first section starts with a rise in elevation of 7 ft from Figure A-1-10.6.4(b). The density at 243 psig (the average starting pressure) is about 832 lbs/cu ft. Loss in pressure due to elevation is then:

PSI = 7(83)/144 = 4.04

New start psig = 243 − 4 = 239

(3) **Determine Y_1 from Table A-1-10-6.6(e).**

For a starting pressure of 239 psig:

$Y_1 = 2819$

$Z_1 = 0.173$

(4) **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.

$$Y_2 = 5670$$

(5) **Determine Terminal Pressure.**

The terminal pressure of Section 1-2 is 200 psig from Table A-1-10.6.6(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 $Y_2 = 5670 + 132 = 5797$

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

(6) **Section 2-3.**

For the next section:

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

$Y_2 = 6626$

Terminal pressure = 182 psig

$Z_2 = 0.652$

$Z_2 = 6631 + 17.3\ (.652 - .485)(4)^2$

$Y_2 = 6631 + 46 = 6677$

Terminal pressure is between 182 and 181 psig; use 181 psig.

Table A-1-10.6.6 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

(b) Sample Calculation for an Unbalanced System. A 200 lb supply is to be discharged through the piping system shown in Figure A-1-10.6.6. The agent is stored in two containers pressurized to 600 psig with a filling density of 60 lb/cu ft. The piping terminates at nozzles 5, 6, and 7 each requiring a different flow rate to discharge the desired quantity of agent into each part of the hazard.

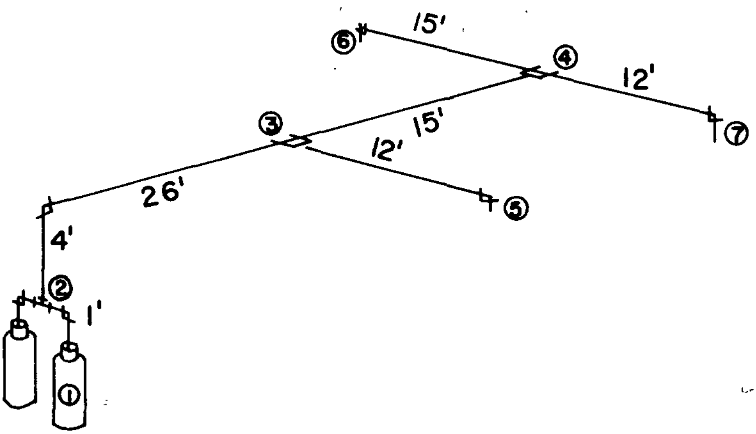


Figure A-1-10.6.6.

Calculated Solution

Section	Pipe	L	EQL	Elevation	Rate	Start Psig	End Psig
1-2	1" Sch. 40	1	19	3	10	385	365
2-3	1¼" Sch. 40	30	41	4	20	365	324
3-4	1" Sch. 40	15	17	0	14	324	283
3-5	¾" Sch. 40	12	19	0	6	324	296
4-6	1" Sch. 40	15	25	0	9	283	255
4-7	¾" Sch. 40	12	19	0	5	283	260

(1) **Determine Piping Volume.**
$V_p = (32 \times .006) + (30 \times .0104) + (24 \times .0037) = 0.5928$ cu ft

(2) **Estimate Percent in Piping.**

$$\% \text{ in piping} = \frac{7250}{(200/0.5928) + 20} = 20$$

(3) **Average Container Pressure During Discharge.**
[From Figure A-1-10.6.3(d)] Average Pressure = 385 psig

(4) **Section 1-2.**

Since the agent is supplied in two containers, only one flow path is considered. Half of the total system flow rate is used up to the junction point.

Elevation Correction: From the 60 lb/cu ft fill density curve in Figure A-1-10.6.4(a) the average density at 385 psig is 87 lbs per cu ft. The elevation correction is the 87 x 3/144 = 1.8 psi. The corrected starting pressure is 383 psig.

Terminal Pressure: From Table A-1-10.6.6(b) find Y and Z for a starting pressure of 383 psig. Find A and B pipe size factors from Table A-1-10.6.6.

$Y_1 = 4325 \quad Z_1 = .099$(383 psig)

$Y_2 = 4325 + 19\,(10^2/1.302 + 6.59\,(Z_2 - .099)\,(10)^2$

$Y_2 = 5784$ at 366 psig

$Z_2 = .148$

$Y_2 = 5784 + 6.59\,(.148 - .099)(10)^2 = 5816$

$P_2 = 366$ psig

(5) Section 2-3.

Elevation Correction is 4(83)/144 = 2 psi

$P_1 = 365 - 2 = 363$

Terminal Pressure:

$Y_1 = 6029 \qquad Z_1 = .158$

$Y_2 = 6029 + 41\,(20^2/5.495 + 2.2\,(Z_2 - 0.158)(20)^2$

$Y_2 = 9014 + 880\,(Z_2 - 0.158)$

Using $Y_2 = 9014$, $P = 325$ and $Z_2 = .266$

$Y_2 = 9014 + 880\,(.266 - .158) = 9109$

$P_2 = 324$

(6) Section 3-4.

Since the remaining sections contain no elevation change, the final Y and Z factors calculated for the preceding section may be used as the starting point for the following section. Thus, for Section 3-4,

$Y_2 = 9109 + 17(14)^2/1.302 + 6.59\,(Z_2 - 0.266)(14)^2$

$Y_2 = 11668 + 1292\,(Z_2 - 0.266)$

$Z_2 = .412$

$Y_2 = 11668 + 1292\,(.412 - .266) = 11857$

$P_2 = 283$

(7) Remaining Section.

In the same way the terminal pressures for the remaining nozzle Section 3-5, 4-6 and 4-7 are determined to be 296, 255 and 260 psig respectively. These pressures are well in excess of one half the 385 psig starting pressure. This indicates that the percent in the piping may be more than the initial 20 percent estimate. This should be established by calculating the quantity of agent in the piping section using the equation given in 1-10-6.5. 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.

(8) Orifice Size.

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 manufacturers' design manual.

Table A-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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-1-10.6.6(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 ultimate device which delivers the agent to the hazard area. Its function is twofold: (1) it distributes the agent in an optimum manner in the hazard, and (2) it controls the system discharge rates. The maximum nozzle flow rate is controlled by the flow which 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 which will be 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 (this is 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:

$$PSI_{velocity} = 3.63 \times Q^2 / p D^4$$

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.