NFPA 12B

Standard on

Halon 1211 Fire Extinguishing Systems

1990 Edition

This edition of NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*, was prepared by the Technical Committee on Halogenated Fire Extinguishing Systems and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 21-24, 1990 in San Antonio, TX. It was issued by the Standards Council on July 20, 1990, with an effective date of August 17, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

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

Origin and Development of NFPA 12B

In a regular committee meeting on May 14, 1969, the Chairman appointed a subcommittee of five members under the chairmanship of Mr. Norman W. Lemley which was given the specific charge to review and evaluate data developed and presented to the committee to determine what additional work would be necessary to integrate Halon 1211 into the Standard on Halogenated Fire Extinguishing Agent Systems. The subcommittee concluded that the public would be better served by a separate standard. The tentative Standard No. 12B-T was the result of their work, and was tentatively adopted in May, 1971 at the Annual Meeting.

The 1973 edition was a revision of the tentative standard. More revisions were made in 1977 and 1980.

A new chapter on hand hose line systems was added in the 1985 edition, which was a complete revision of the standard. The 1990 edition correlates NFPA 12B with NFPA 12A.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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

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

Information on referenced publications can be found in Chapter 5 and Appendix B.

Chapter 1 General

1-1 Scope. This standard contains minimum requirements for Halon 1211 fire extinguishing systems. It includes only the essentials to make the standard workable in the hands of those skilled in this field. Portable Halon 1211 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 the purchasing, inspecting, testing, approving, operating, and maintaining of 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 the purchasing, designing, installing, testing, inspecting, approving, listing, operating, and maintaining of halogenated agent extinguishing systems (Halon 1211), in order that such equipment will function as intended throughout its life. Nothing in this standard is intended to restrict new technologies or alternate arrangements provided the level of safety prescribed by this standard is not lowered.

Pre-engineered systems (packaged systems) consist of system components designed to be installed according to pretested limitations as approved or listed by a testing laboratory. Pre-engineered systems may incorporate special nozzles, flow rates, methods of application, nozzle placement, 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:

Chapters 1 through 5 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 the purpose of clarification, the following general terms used with special technical meanings in this standard are defined:

Approved. Acceptable to the "authority having jurisdiction."

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

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

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

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 = 3.785L
cubic decimeter	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa

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

In Canada refer to *Canadian Metric Practice Guide,* CSA Standard Can3-Z
234.1-79

1-5* General Information and Requirements.

1-5.1 The information and requirements in Chapter 1 are generally common to all Halon 1211 (bromochlorodifluoromethane, $CBrClF_2$) systems.

1-5.2* Halon 1211.

1-5.2.1 Halon 1211 is a colorless, faintly sweet-smelling electrically nonconductive gas that is an effective medium for extinguishing fires.

1-5.2.2* According to present knowledge Halon 1211 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 1211 is included in the Montreal Protocol on Substances that Deplete the Ozone Layer signed September 16, 1986. The protocol permits continued availability of halogenated fire extinguishing agents at 1986 production levels.

Halon 1211 fire extinguishing systems are useful within the limits of this standard in extinguishing fires in specific hazards or equipment. Halon 1211 is a stratospheric ozone-depleting substance and should only be used where there is a need for a nonconductive medium, where cleanup of other media presents a problem, and where a more severe toxicology exposure to humans would result from use of another fire extinguishing medium.

1-5.3.2 Some of the more important types of hazards and equipment that Halon 1211 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.

1-5.3.3 Halon 1211 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 1211 total flooding systems. (*See 2-1.1.3 and 2-1.1.4.*)

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

1-5.4 Duration of Protection. It is important that an effective agent concentration not only be achieved but that it be maintained for a sufficient period of time to allow effective emergency action by trained personnel. This is equally important in all classes of fires since a persistent ignition source (e.g., an arc, heat source, oxyacetylene torch or "deep-seated" fire) can lead to a recurrence of the initial event once the agent has dissipated. Halon 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-hr duration but sprinklers may be less effective in controlling many fires. The designer, the buyer and the emergency force in particular should 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. There are two types of systems recognized in this standard:

Total Flooding Systems.

Local Application Systems.

1-5.5.1 Total Flooding System. Consists of a supply of Halon 1211 arranged to discharge into, and fill to the proper concentration, an enclosed space or enclosure about the hazard.

1-5.5.2 Local Application System. Consists of a supply of Halon 1211 arranged to discharge directly on the burning material.

1-5.6 Halon 1211 Systems. A Halon 1211 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 The discharge of Halon 1211 may create hazards to personnel such as dizziness, impaired coordination, reduced visibility, and exposure to toxic decomposition products.

1-6.1.2* Safety Requirements. In any proposed use of Halon 1211 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 and to prevent entry into such atmospheres and 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.

As used in this standard, "clearance" is the air distance between Halon 1211 equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. The minimum clearances listed in Table 1-6.2 are for the purpose of electrical clearances under normal conditions; they are not intended for use as "safe" distances during fixed Halon 1211 system operation.

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

The clearances are based 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. For these higher system voltages it has become common practice to use BIL levels dependent on the degree of protection which is to be obtained. For example, in 230 kv systems, BILS of 1050, 900, 825, 750, and 650 kv have been utilized.

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

Table 1-6.2 Clearance from Halon 1211 Equipment or Live Uninsulated Electrical Components

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

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

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

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

Possible design variations in the clearance required at higher voltages are evident in the table, where a range of BIL values is indicated opposite the various voltages in the high voltage portion of the table. However, the clearance between uninsulated energized parts of the electrical system equipment and any portion of the Halon 1211 system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

1-6.2.1 When the design BIL is not available, and when nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

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.

1-7 Specifications, Plans and Approval.

1-7.1 Specifications. Specifications for Halon 1211 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 this standard to be permitted by the authority having jurisdiction and the type and extent of the approval testing to be performed after installation of the system.

1-7.2 Plans.

1-7.2.1 Plans and calculations shall be submitted for approval to the authority having jurisdiction before installation begins. Their preparation shall be entrusted to none but persons fully experienced and qualified in the design of Halon 1211 extinguishing systems.

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

1-7.2.3 These plans shall contain sufficient detail to enable an evaluation of the hazard(s) and the effectiveness of the system. The detail of the hazards shall include the materials involved in the hazards, the location of the hazards, the enclosure or limits and isolation of the hazards, and the exposures to the hazards.

1-7.2.4 The detail on the system shall include information and calculations on the amount of Halon 1211, container storage pressure; internal volume of the container; the location, type, and flow rate of each nozzle including equivalent orifice area; the location, size, and equivalent lengths of pipe, fittings, and hose; and the location and size of the storage facility. Details of pipe size reduction method and orientation of tees shall be clearly indicated. Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used. Apparatus and devices used shall be identified. Any special features shall be adequately explained.

Exception: Listed pre-engineered systems do not require information on internal volume of container; flow rate of each nozzle including equivalent orifice area; and equivalent length of pipe, fittings, and hose.

1-7.2.5 An as-built instruction and maintenance manual that includes a full sequence of operation and a full set of drawings and calculations shall be maintained in a clearly identified protective enclosure at or near the system control panel.

1-7.3 Approval of Plans.

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

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

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

1-7.4* Approval of Installations.

1-7.4.1 The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. Only listed or approved equipment and devices shall be used in the systems. To determine that the system has been properly installed and will function as specified, the following tests shall be performed.

1-7.4.1.1 The piping shall be pneumatically tested in a closed circuit for a period of 10 minutes at 150 psig (10.3 bar). At the end of 10 minutes, the pressure drop shall not exceed 10 percent of the test pressure. When pressurizing the piping, pressure shall be increased in 50 psi (3.5 bar) increments.

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

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

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

1-7.4.1.3

A. The following mechanical items shall be checked:

1. The piping distribution system shall be inspected to determine that it is in compliance with the system drawings; NFPA 12B, *Halon 1211 Fire Extinguishing Systems*, and

the hydraulic calculations indicated on the computer printout associated with each agent storage container piping and nozzle configuration.

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

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

4. The piping distribution system shall be adequately cleaned and inspected internally to prevent the possibility of any oil or particulate matter soiling the hazard area or affecting the agent distribution due to a reduction in the effective nozzle orifice area.

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

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

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

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

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

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

9. Detectors shall not be located near obstructions or air ventilation and cooling equipment that would appreciably affect their response characteristics. Where applicable, air changes for the protected area shall be taken into consideration. Refer to NFPA 72E, *Standard on Automatic Fire Detectors*, and the manufacturer's recommended guidelines concerning this area.

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

11. Manual pull stations shall be properly installed, readily accessible, and accurately identified.

12. All manual stations used to release Halon shall be properly identified as to their purpose. Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated. Manual stations in this instance shall be clearly identified as to which zone or suppression area they affect.

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

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

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

B. Inspection of Agent and Containers

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

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

3. Containers for the agent to be used during the testing shall be weighed before and after discharge.

4. Adequate quantity of agent to produce the desired specified concentration shall be provided. The actual room volume shall be checked against those indicated on the system drawings to ensure the proper quantity of agent. Fan coastdown and damper closure time shall be taken into consideration.

C. Electrical Checkout

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

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

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

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

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

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

D. Functional Test or Predischarge Test

1. Functional test (predischarge)

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

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

(c) Check each detector for proper response.

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

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

2. System functional operational test

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

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

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

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

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

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

3. Testing of remote monitoring operations, if applicable

(a) Operate one of each type of input device while on standby power. Verify that an alarm signal is received at remote panel after device is operated. Reconnect primary power supply.

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

4. Testing of the control panel primary power source

(a) Verify that the control panel is connected to a dedicated circuit and labeled properly. This panel shall be readily accessible, yet restricted to unauthorized personnel.

(b) A primary power failure shall be tested in accordance with the manufacturer's specification with the system fully operated on standby power for the required design period.

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

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

E. Enclosure Integrity Check. All total flooding systems shall have the enclosure examined or tested to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified Halon 1211 concentration level for the specified holding period. The currently preferred method is using a blower door fan unit and smoke pencil. If quantitative results are recorded these could be useful for comparison at future tests.

F. To determine that the system has been properly installed and will function as specified, the following additional test shall be performed.

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

1-8 Detection, Actuation and Control Systems.

1-8.1* Detection, actuation, alarm and control systems shall be installed, tested, and maintained.

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

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.

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

1-8.2.2 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

1-8.3 Operating Devices.

1-8.3.1 Operating devices shall include Halon 1211 releasing devices or valves, discharge controls, and shutdown equipment, necessary for successful performance 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(s) for actuation shall be located for easy accessibility at all times, including time of fire within the protected area. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of this control shall cause the complete system to operate in its normal fashion.

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

1-8.3.7 Manual controls shall not require a pull of more than 40 lb (178 newtons) nor a movement of more than 14 in. (35.6 cm) to secure operation. At least one manual control for activation shall be located not more than 5 ft (1.5 m) above the floor.

1-8.3.8 Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers the supply and discharge rate shall be designed for releasing all of the remaining containers.

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

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

1-8.4 Control Equipment.

1-8.4.1 Electric Control Equipment. The control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation. The control equipment shall be specifically listed or approved for the number and type of actuating devices utilized and their compatability shall have been listed or approved.

1-8.4.2 Pneumatic Control Equipment. Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity will occur. The control equipment shall be specifically listed or approved for the number and type of actuating devices utilized and their compatability shall have been listed or approved.

1-8.5 Operating Alarms and Indicators.

1-8.5.1 Alarms or indicators or both are used to indicate the operation of the system, hazards to personnel, or failure of any supervised device. The type (audible, visual, or olfactory), number and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment or both shall be approved.

1-8.5.2 Audible and highly visible alarms shall be provided to give positive warning of discharge. The operation of the warning devices shall be continued after Halon discharge, until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

1-8.5.3* Abort switches are generally not recommended. However, where provided, they shall be located only within the protected area and shall be of a type that requires constant manual pressure to cause abort. The abort switch shall not be of a type that would allow the system to be left in an aborted mode without someone present. In all cases the normal manual and emergency manual control shall override the abort function. Operations of the abort function shall result in both audible and distinct visual indication of system impairment. The abort switch shall be clearly recognizable for the purpose intended.

1-8.5.4 Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinctive from alarms indicating operation or hazardous conditions.

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

1-8.5.6 Time delays shall be used only where discharge delay is required for personnel evacuation or to prepare the hazard area for discharge. Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

1-8.6 Unwanted System Operation. Accidental discharge has been recognized as a significant factor in unwanted Halon 1211 emissions. Care must be taken to thoroughly evaluate and correct any factors which may result in unwanted discharges.

1-9 Halon 1211 Supply.

1-9.1 Quantities.

1-9.1.1 The amount of Halon 1211 in the system shall be at least sufficient for the largest single hazard protected or group of hazards which are to be protected simultaneously.

1-9.1.2 Where required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary. The time needed to obtain Halon 1211 for replenishment to restore systems to operating conditions shall be considered a major factor in determining the reserve supply needed.

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

1-9.2* Quality. The Halon 1211 shall comply with the Military Specification MIL-B-38741 (USAF) Bromochlorodifluoromethane, Technical.

A likely source of water contamination would be the presence of free water in the system container before filling with Halon 1211. Containers shall be thoroughly dried before filling, especially after hydrostatic testing.

1-9.3 Storage Container Arrangement.

1-9.3.1 Storage containers and accessories shall be so located and arranged that inspection, testing, recharging and other maintenance is facilitated and interruption to protection is held to a minimum.

1-9.3.2 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.

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

1-9.3.4 Storage containers shall be securely mounted per the manufacturer's listed or approved installation manual. This shall include mounting the container to the appropriate mounting surface.

1-9.4* Storage Containers.

1-9.4.1 The Halon 1211 supply shall be stored in containers designed to hold Halon 1211 in liquefied form at ambient temperatures. Containers shall not be charged to a filling density greater than 85 lb per cu ft (1361 kg/m^3). They shall be superpressurized with dry nitrogen.

1-9.4.2 Each system shall have a permanent nameplate specifying the number, filling weight, and pressurization level of the containers. Each container shall have a permanent nameplate specifying the agent, tare and gross weight in addition to superpressurization level.

A label that will require the proper return of the agent shall be affixed to all new and existing containers. Filled containers must be returned for recycling or recovery of the agent when no longer needed.

1-9.4.3 The Halon 1211 containers used in these systems shall be designed to meet the requirements of the U.S. Department of Transportation or the Canadian Transport Commission[1], if used as shipping containers. If not a shipping container, it shall be designed, fabricated, inspected, certified, and stamped in accordance with Section VIII of the ASME *Unfired Pressure Vessel Code*: independent inspection and certification is recommended. The design pressure shall be suitable for the maximum pressure developed at 130°F (55°C) or at the maximum controlled temperature limit (*see 1-9.4.7*).

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

1-9.4.5 Container Test.

1-9.4.5.1 D.O.T., C.T.C. or similar design Halon 1211 cylinders shall not be recharged without a retest if more than five years have elapsed since the date of the last test and inspection. The retest may consist of a complete visual inspection as described in the *Code of Federal Regulations*, Title 49, Section 173.34(e)(1).

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

1-9.4.5.3 Where external visual inspection indicates that the container has been damaged, additional strength tests shall be required. Caution: If additional tests used include hydrostatic testing, containers should be thoroughly dried before refilling.

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

1-9.4.5.5 When manifolded, containers shall be adequately mounted and suitably supported in a rack which provides for convenient individual servicing or content weighings. Automatic means shall be provided to prevent agent loss from the manifold if the system is operated when any containers are removed for maintenance.

1-9.4.6 In a multiple cylinder system, all cylinders supplying the same manifold outlet for distribution of agent shall be interchangeable and of one select size and charge.

1-9.4.7 Storage temperatures shall not exceed 130°F (55°C) nor be less than −20°F (−29°C) for total flooding systems unless the system is designed for proper operation with storage temperatures outside this range. For local application systems, container storage temperatures shall be within a range from +32°F (0°C) to +130°F (55°C) unless special methods of compensating for changing flow rates are provided. External heating or cooling may be used to keep the temperature within desired ranges.

1-10 Distribution.

1-10.1* Piping.

1-10.1.1* Piping shall be of noncombustible material having physical and chemical characteristics, such that its integrity under stress can be predicted with reliability. Special corrosion-resistant materials or coatings may be required in severely corrosive atmospheres.

[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 the Transportation of Dangerous Commodities by Rail," available from the Queen's Printer, Ottawa, Ontario.

(a) Ferrous piping – Black or galvanized steel pipe shall be either ASTM A-53 seamless or electric resistance welded, grade A or B, or ASTM A-106, grade A, B, or C. ASTM A-120 and ordinary cast-iron pipe shall not be used. The thickness of the pipe wall shall be calculated in accordance with ANSI B-31.1, *Power Piping Code*. The internal pressure for this calculation shall be the maximum storage pressure at the maximum storage temperature (102 lb per cu ft density shall be assumed), but in no case shall be less than the following:

For 150 psig charging pressures, an internal pressure of 240 psi at 130°F (16.56 bar at 54.4°C);

For 360 psig charging pressure, an internal pressure of 500 psi at 130°F (34.5 bar at 54.4°C).

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

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

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

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

1-10.2 Piping Joints.

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

1-10.2.2 Examples of materials used for fittings are:

Malleable iron 300-lb class only .... ASTM A197
Ductile iron 300-lb class or higher .... ASTM A395
Steel .... ASTM A234

Exception: 150-lb class fittings are suitable for 150 psig (11.36 bars) charging pressure systems and they are also suitable for 3/4 in. or smaller pipe sizes on 360 psig (25.84 bars) charging pressure systems.

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, *Power Piping Code*. 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 that will satisfy the requirements of this paragraph.

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

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

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

1-10.2.5.1 Welding shall be performed in accordance with Section IX, Qualifications 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, *Power Piping Code*, shall be consulted for guidance on this matter. Where explosions are likely, the piping shall be attached to supports that are least likely to be displaced.

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

1-10.3.4 In systems where valve arrangement introduces sections of closed piping, such sections shall be equipped with pressure relief devices or the valves shall be designed to prevent entrapment of liquid. Where pressure-operated container valves are used, a means shall be provided to vent any container leakage from the manifold 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 corrosive-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.

1-10.6* System Flow Calculations.

1-10.6.1 As part of the design procedure, system flow calculations shall be performed using a listed calculation method. The system design shall be within the manufacturer's listed limitations.

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

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

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

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

1-11 Inspection, Maintenance and Instructions.

1-11.1* Inspection and Tests.

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

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

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

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

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

1-11.1.6 At least semiannually, the agent quantity and pressure of refillable containers shall be checked. If a container shows a loss in net weight of more than 5 percent or a loss in pressure of more than 10 percent, it shall be refilled or replaced. When the amount of agent in the container is determined by special measuring device in lieu of weighing, these devices shall be listed.

All Halon removed from refillable containers during service or maintenance procedures shall be collected and recycled.

1-11.1.7 Factory-charged nonrefillable containers that do not have a means of pressure indication shall be weighed at least semiannually. If a container shows a loss in net weight of more than 5 percent, it shall be replaced.

All factory-charged nonrefillable containers removed from useful service shall be returned for recyling of the agent.

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

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

1-11.1.9.1 All hoses shall be tested at 2½ times the container pressure at 70°F.

(a) Remove the hose from any attachment.

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

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

(d) Pressure then is applied at a rate-of-pressure rise to reach the test pressure within a minimum of one minute.

The test pressure is to be maintained for one full minute. Observations are then made to note any distortion or leakage.

(e) If the test presssure has not dropped or if the couplings have not moved, the pressure is released. The hose assembly is then considered to have passed the hydrostatic test if no permanent distortion has taken place.

(f) Hose assembly passing the test must be completely dried internally. If heat is used for drying, the temperature must not exceed 150°F (66°C).

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

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

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

1-11.2 Maintenance.

1-11.2.1 These systems shall be maintained in full operating condition at all times. Use, impairment, and restoration of this protection shall be reported promptly to the authority having jurisdiction.

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

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

Chapter 2 Total Flooding Systems

2-1* General Information.

2-1.1 Uses.

2-1.1.1 This type of system may be used where there is a fixed enclosure about the hazard that is adequate to enable the required concentration to be built up and maintained for the required period of time to ensure the effective extinguishment of the fire in the specific combustible materials involved where the ambient temperature is above 30°F (−1°C).

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

2-1.1.3* Halon 1211 total flooding systems shall not be used in normally occupied areas. For the purposes of this standard, a normally occupied area is defined as an area intended for occupancy.

2-1.1.4 Halon 1211 total flooding systems may be used only in normally unoccupied areas where egress of personnel can be accomplished in less than 30 seconds.

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

2-2 Hazard Specifications.

2-2.1 Types of Fires.

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

(a) Fires involving flammable liquids or gases.

(b) Surface fires involving flammable solids.

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

2-2.1.2 Flammable liquid and gas fires are subject to prompt extinguishment when Halon 1211 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 1211. 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 1211 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 1211, 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 1211 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 uncloseable openings shall be kept to a minimum. The authority having jurisdiction may require tests to assure proper performance as defined by this standard.

2-2.2.3* To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures. Where reasonable confinement of agent is not practicable, protection shall be extended to include the adjacent connected hazards or work areas.

2-2.2.4 Forced-air ventilating systems shall be shut down or closed automatically where their continued operation would adversely affect the performance of the Halon 1211 system or result in propagation of the fire.

2-3* Halon 1211 Requirements for Liquid and Gas Fires.

2-3.1 General. The quantity of Halon 1211 for fires involving flammable liquids and gases is based upon normal conditions with the extinguishing system meeting the requirements specified herein.

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

2-3.2 Design Concentrations. In the determination of the design concentration of Halon 1211, 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 1211 concentration may apply, i.e., flame extinguishment or inerting. However, the greater inerting concentrations shall be used where conditions for subsequent reflash or explosion could exist. Specifically, these conditons are when both:

1. The quantity of fuel permitted in the enclosure is sufficient to develop a concentration equal to or greater than one-half of the lower flammable limit throughout the enclosure, and;

2. The volatility of the fuel before the fire is sufficient to reach the lower flammable limit in air (maximum ambient temperature or fuel temperature exceeds the closed cup flash point temperature) or the system response is not rapid enough to detect and extinguish the fire before the volatility of the fuel is increased to a dangerous level as a result of the fire.

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 is 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 seconds 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.

NOTE: Table A-2-3.2.2 provides information on the development of Table 2-3.2.2.

Table 2-3.2.2 Halon 1211 Design Concentrations for Flame Extinguishment In 77°F air at 1 atm (25°C at 1 atm)

Fuel	Minimum Design* Concentration, Percent by Volume
Acetone	5.0
Benzene	5.0
Ethanol	5.0
Ethylene	8.6
Methane	5.0
n-Heptane	5.0
Propane	5.8

*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 69, *Standard on Explosion Prevention Systems*, covering vapor detection and explosion venting andsuppression, shall be consulted. In particular, extreme caution shall be taken following inerting of a rich fuel-air mix ture 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 1211 Requirements for Fires in Solid Materials.

2-4.1 General. Flammable solids may be classed as those that do not develop deep-seated fires, and those that do. Materials 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 plastics without filler materials, surface combustion is the only type that occurs. These fires are readily extinguished with a 5 percent concentration of Halon 1211. Although glowing embers may remain at the surface of the fuel following extinguishment of flames, these embers will usually be completely extinguished within 10 minutes, provided the Halon 1211 concentration is maintained around the fuel for this period of time. It would be appropriate to consider maintaining the agent concentration around the fuel until response by emergency personnel can be achieved.

2-4.3 Deep-Seated Fires.

2-4.3.1 Halon 1211, like other halogenated hydrocarbons, chemically inhibits the propagation of flame. However, although the presence of Halon 1211 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 the complete extinguishment of the fire. (*See A-2-4.*)

2-5 Determination of Halon 1211 Quantity for Total Flooding Systems.

2-5.1 General. The Halon 1211 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 1211 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 1211 vapor at various temperatures. The amount of Halon 1211 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 1211 required, lb (kg)
s = Specific volume superheated Halon 1211, cu ft/lb (m^3/kg)
C = Halon 1211 concentration, % by volume
V = Volume of hazard, cu ft (m^3).

This calculation includes an allowance for normal leakage from a "tight" enclosure due to agent expansion. Since the amount of gas and, therefore, the concentration produced by a given weight of Halon 1211 is greatly affected by the temperature it encounters, the specific volume of superheated Halon 1211 vapor for the lower operating minimum anticipated ambient temperature limit shall be used in the design of a Halon 1211 total flooding system. Table 2-5.2 is a tabulation of the Halon 1211 weight per cu ft (Kg/m^3) of hazard volume required to produce the specified concentration of various hazard temperature conditions.

All Halon 1211 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 2-1.1.2 and 2-1.1.3.

2-5.3* Special Conditions. The design quantity of Halon 1211 shall be adjusted to compensate for any special conditions, such as openings, forced ventilation, altitudes of more than 3000 ft (1000 m) above or below sea level, and pressures other than atmospheric. It shall be the responsibility of the system design 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 1211 to enclosed hazards shall be designed with due consideration for the materials involved, the type of burning expected, and the nature of the enclosure. These factors all may affect the discharge times and rates of application.

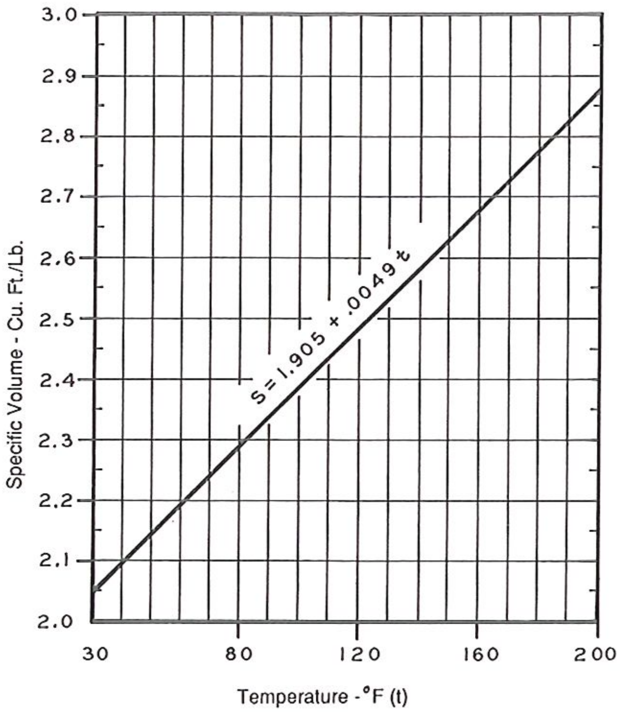


Figure 2-5.2 Specific volume of superheated Halon 1211 vapor (at 1 atmosphere).

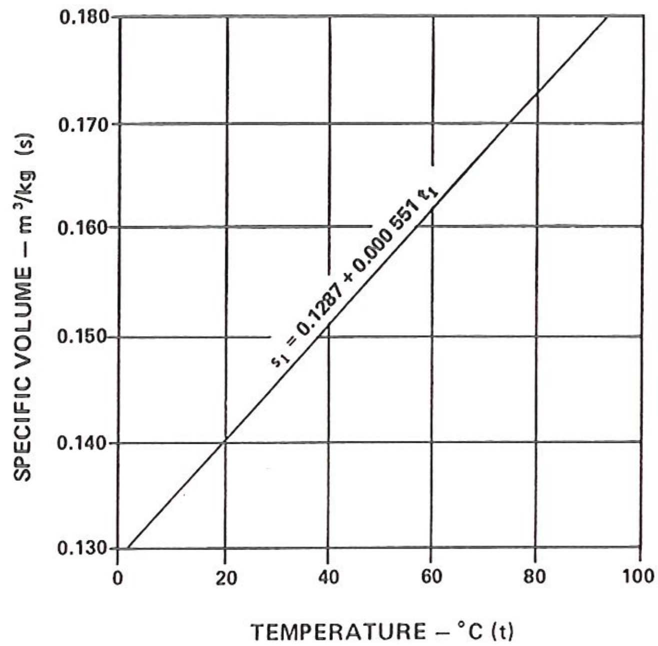


Figure 2-5.2 — Metric. Specific volume of superheated Halon 1211 vapor (at 1 atmosphere)

Table 2-5.2 Halon 1211 Total Flooding Quantity

Temperature t °F.	Halon 1211 Specific Vapor Volume $Ft.^3/Lb.$	Halon 1211 Weight Requirements/$Lbs/Ft.^3$ of Hazard Volume(1) — Halon 1211 Concentration —C— % by Volume(4)							
(2)	(3)	3	4	5	6	7	8	9	10
30	2.052	.0151	.0203	.0256	.0311	.0367	.0424	.0482	.0541
40	2.101	.0147	.0198	.0250	.0304	.0358	.0414	.0471	.0529
50	2.150	.0144	.0194	.0245	.0297	.0350	.0405	.0460	.0517
60	2.199	.0141	.0190	.0239	.0290	.0342	.0396	.0450	.0505
70	2.248	.0137	.0185	.0234	.0284	.0335	.0387	.0440	.0494
80	2.297	.0135	.0181	.0229	.0278	.0328	.0379	.0431	.0484
90	2.346	.0132	.0178	.0224	.0272	.0321	.0371	.0422	.0474
100	2.395	.0129	.0174	.0220	.0266	.0314	.0363	.0413	.0464
110	2.444	.0126	.0171	.0215	.0261	.0308	.0356	.0405	.0455
120	2.493	.0124	.0167	.0211	.0256	.0302	.0349	.0397	.0446
130	2.542	.0122	.0164	.0207	.0251	.0296	.0342	.0389	.0437
140	2.591	.0119	.0161	.0203	.0246	.0291	.0336	.0382	.0429
150	2.640	.0117	.0158	.0199	.0242	.0285	.0330	.0375	.0421
160	2.689	.0115	.0155	.0196	.0237	.0280	.0324	.0368	.0413
170	2.738	.0113	.0152	.0192	.0233	.0275	.0318	.0361	.0406
180	2.787	.0111	.0150	.0189	.0229	.0270	.0312	.0355	.0399
190	2.836	.0109	.0147	.0185	.0225	.0266	.0307	.0349	.0392
200	2.885	.0107	.0145	.0182	.0221	.0261	.0302	.0343	.0385

Table 2-5.2 — Metric Halon 1211 Total Flooding Quantity

Temperature t °C.	Halon 1211 Specific Vapor Volume m^3/kg	Halon 1211 Weight Requirements—Kilograms per Cubic Metre of Hazard Volume[1]							
		Halon 1211 Concentration —C— % by Volume[4]							
(2)	(3)	3	4	5	6	7	8	9	10
0	0.129	0.2403	0.3237	0.4089	0.4959	0.5848	0.6756	0.7684	0.8632
5	0.131	0.2353	0.3169	0.4003	0.4855	0.5725	0.6614	0.7523	0.8452
10	0.134	0.2304	0.3104	0.3921	0.4756	0.5608	0.6479	0.7369	0.8278
15	0.137	0.2258	0.3042	0.3842	0.4660	0.5495	0.6348	0.7220	0.8112
20	0.140	0.2213	0.2982	0.3767	0.4568	0.5387	0.6223	0.7078	0.7952
25	0.142	0.2171	0.2924	0.3694	0.4480	0.5283	0.6103	0.6941	0.7798
30	0.145	0.2130	0.2869	0.3624	0.4395	0.5183	0.5987	0.6810	0.7651
35	0.148	0.2090	0.2816	0.3557	0.4313	0.5086	0.5876	0.6683	0.7508
40	0.151	0.2052	0.2764	0.3492	0.4234	0.4993	0.5769	0.6561	0.7371
45	0.153	0.2015	0.2715	0.3429	0.4159	0.4904	0.5665	0.6443	0.7239
50	0.156	0.1979	0.2667	0.3369	0.4085	0.4817	0.5565	0.6330	0.7111
55	0.159	0.1945	0.2621	0.3310	0.4015	0.4734	0.5469	0.6220	0.6988
60	0.162	0.1912	0.2576	0.3254	0.3946	0.4653	0.5376	0.6114	0.6869
65	0.165	0.1880	0.2533	0.3199	0.3880	0.4576	0.5286	0.6012	0.6754
70	0.167	0.1849	0.2491	0.3147	0.3816	0.4500	0.5199	0.5913	0.6643
75	0.170	0.1819	0.2451	0.3096	0.3754	0.4427	0.5115	0.5817	0.6536
80	0.173	0.1790	0.2412	0.3046	0.3695	0.4357	0.5033	0.5725	0.6431
85	0.176	0.1762	0.2374	0.2999	0.3637	0.4288	0.4954	0.5635	0.6331
90	0.178	0.1735	0.2337	0.2952	0.3581	0.4222	0.4878	0.5548	0.6233
95	0.181	0.1709	0.2302	0.2907	0.3526	0.4158	0.4804	0.5463	0.6138

Notes to Table 2-5.2

(1) *Agent Weight Requirements* ($\frac{W}{V}$ - lb./ft.^{3}) — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperatures 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 1211 vapor at the temperature indicated.

$$s = 1.905 + .0049\ t$$

(4) *Concentration* (C — %) — Volumetric concentration of Halon 1211 in air at the temperature indicated.

Notes to Table 2-5.2 (Metric), for SI Units

(1) *Agent Weight* $\left(\frac{W_1}{V_1} - \text{kg/m}^3\right)$ — Kilograms of agent required per cubic meter.

$$W_1 = \frac{V_1}{s_1}\left(\frac{C}{100 - C}\right)$$

(2) *Temperature* (t_1 — °C.) — The design temperature in the hazard area.

(3) *Specific Volume* (s_1 — m^3/kg) — Specific volume of superheated Halon 1211 vapor at the temperature indicated.

$$s_1 = 0.1287 + 0.000\ 551\ t_1$$

(4) *Concentration* (C — %) Volumetric concentration of Halon 1211 in air at the temperature indicated.

2-6.2* Rate of Application.

2-6.2.1 The minimum design rate of application shall be based on the quantity of agent required for the desired concentration and the time allotted to achieve the desired concentration.

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

This period shall be measured as the interval between the first appearance of liquid at the nozzle and the time when the discharge becomes predominantly gaseous. This point is distinguished by a marked change in both the sound and the appearance of the discharge.

2-6.3 Extended Application Rate.

2-6.3.1 Where leakage is appreciable and the design concentration must be obtained quickly and maintained for an extended period of time, agent quantities provided for leakage compensation may be applied at a reduced rate.

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

2-6.3.3 The initial discharge shall be completed within the limits specified in 2-6.2.2.

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.

2-7 Venting Consideration.

2-7.1 General. Venting of an enclosure may be necessary to relieve pressure buildup due to the discharge of large quantities of Halon 1211. Appropriate pressure relief depends on the injection rate of the Halon 1211 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 1211 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 1211 vapor at 70°F (21°C) to be 2.26 cu ft per lb (0.141 m^3/kg).

$$x = \frac{7.8Q}{\sqrt{P}}$$

x = Free venting area, sq in.
Q = Halon 1211 injection rate, lb per second
P = Allowable strength of enclosure, lb/sq ft

For SI Units

$$x_1 = \frac{242Q_1}{\sqrt{P_1}}$$

x_1 = Free venting area, sq mm
Q_1 = Halon 1211 injection rate, kg/second
P_1 = Allowable strength of enclosure, bars-gauge

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	0.012
Normal Building	140	50†	10	.35	0.024
Vault Building	200	100	20	.70	0.048

*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 with 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 1211 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 applicaton system to distribute the agent evenly throughout the entire volume, locally high concentrations may be experienced. (*See A-1-6.1.*) This concentration shall be 2 percent or less for all normally occupied areas.

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 are 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 1211 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 must be maintained to assure complete extinguishment.

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

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

3-3.2 Rate of Discharge.

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

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

3-3.2.3 The minimum design rate (R_d) shall not be less than the optimum rate (R_o) required for extinguishment (*see Figure 3-3.2.4*). 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 3-3.2.4 together with other performance data that clearly depicts the interrelationship between agent quantity, discharge rate, discharge time, area coverage and the distance of the nozzle from the protected surface.

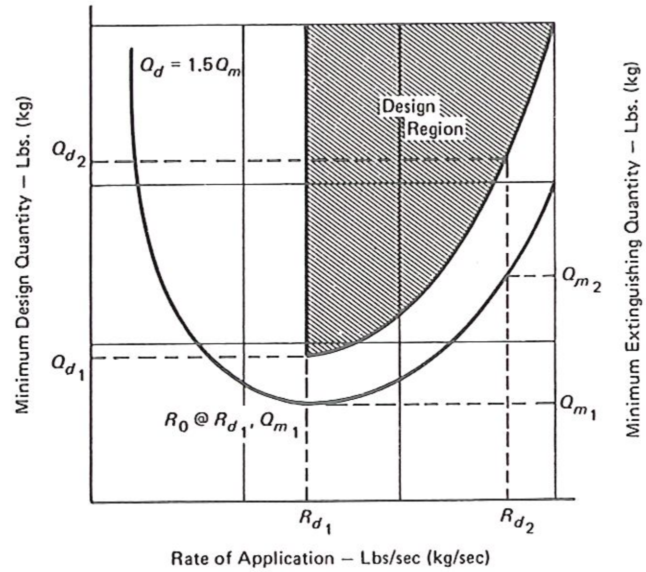


Figure 3-3.2.4 Typical data presentation for local application nozzles.

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 surface protected, 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 projected 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.

Chapter 4 Hand Hose Line Systems

4-1 General Information.

4-1.1 Description. Hand hose line systems consist of a hose reel or rack, hose, and discharge nozzle assembly connected by fixed piping to a supply of Halon 1211. A separate Halon 1211 supply may be provided for hand hose line use or Halon 1211 may be piped from a central storage unit. A central storage unit shall not be used to supply a fixed system and hose line system protecting the same hazard.

4-1.2 Uses. Hand hose line systems may be used to supplement fixed fire protection systems or to supplement first aid fire extinguishers for the protection of specific hazards for which Halon 1211 is a suitable extinguishing agent. These systems shall not be used as substitutes for other fixed Halon 1211 fire extinguishing systems equipped with fixed nozzles, except where the hazard cannot adequately or economically be provided with fixed protection. The decision as to whether hose lines are applicable to the particular hazard shall rest with the authority having jurisdiction (*see A-1-6.1*).

4-1.3 General Requirements. Hand hose line systems shall be installed and maintained in accordance with the applicable requirements of Chapter 1 except as outlined below.

4-1.4 Safety Requirements. All personnel who are to use hand hose line systems shall be properly trained in fire fighting techniques applicable to the equipment and in procedures for safe use. Exposure of personnel to Halon 1211 concentrations of more than 4 percent may be hazardous. Breathing apparatus shall be used by personnel if the supply of Halon 1211 available to hand hose line systems is sufficient to produce a concentration of 4 percent or greater in any area accessible to hand hose lines (*see Section 4-6*).

4-2 Hazard Specifications.

4-2.1 Hand hose line systems may be used to combat fires in all hazards covered under Chapter 1, except those which are inaccessible and beyond the scope of manual fire fighting.

4-3 Location and Spacing.

4-3.1 Location. Hand hose line stations shall be placed such that they are easily accessible and within reach of the most distant hazard which they are expected to protect. In general, they shall not be located such that they are exposed to the hazard.

4-3.2 Spacing. If multiple hose stations are used, they shall be spaced so that any area within the hazard may be covered by one or more hose lines.

4-4 Halon 1211 Requirements.

4-4.1 Rate and Duration of Discharge. The rate and duration of discharge and consequently the amount of Halon 1211 shall be determined by the type and potential size of the hazard. A hand hose line shall have a sufficient quantity of Halon 1211 to permit its use for at least 30 seconds.

4-4.2 Provision for Use by Inexperienced Personnel. The possibility of these hose lines being used by inexperienced personnel shall be considered and adequate provision made so that there will be a sufficient supply of Halon 1211 to enable them to effect extinguishment of the hazards that they are likely to encounter.

4-4.3 Simultaneous Use of Hose Lines. Where simultaneous use of two or more hose lines is possible, a sufficient quantity of Halon 1211 shall be available to supply the maximum number of nozzles that are likely to be used at any one time for at least 30 seconds.

4-5 Equipment Specifications.

4-5.1 Hose. Hose lines shall have a bursting pressure at least two times the maximum operating pressure at maximum storage temperature.

4-5.2 Discharge Nozzle Assembly. Hose lines shall be equipped with a discharge nozzle assembly which can be easily handled by one adult and which contains a quick-opening shutoff valve to control the flow of Halon 1211 through the nozzle and a suitable handle for directing the discharge. The attachment of the discharge nozzle assembly to the hose by means of a swivel connection is desirable for providing easier manipulation.

4-5.3 Hose Line Storage. The hose shall be coiled on a hose reel or rack such that it will be ready for immediate use without the necessity of coupling and such that it may be uncoiled with a minimum of delay. If installed outdoors, it shall be protected against the weather.

4-5.4 Charging the Hose Line. Operation of hand hose line systems depends upon manual actuation and manual manipulation of a discharge nozzle. Speed and simplicity of operation is, therefore, essential for successful extinguishment.

4-5.4.1 All controls for actuating the system shall be located in the immediate vicinity of the hose reel.

4-5.4.2 The Halon 1211 supply shall be located as close to the hose reel as possible so that Halon 1211 will be supplied to the hose line with a minimum of delay after actuation.

4-5.4.3 Except when in actual use, pressure shall not be permitted to remain in the hose line.

4-6 Training. Successful extinguishment of fire with and safe utilization of, hand hose lines is greatly dependent upon the individual ability and technique of the operator. All personnel who are likely to use this equipment at the time of a fire shall be properly trained in its operation and safe use in the fire fighting techniques applicable to this equipment.

4-7 Maintenance. All system hoses shall be examined annually for damage. If visual examination shows any deficiencies, the hoses shall be replaced or tested as follows:

At least every 5 years all hoses shall be tested at 2,500 psi (173 bars) for high-pressure systems and at 900 psi (62 bars) for low-pressure systems.

(a) Remove the hose from any attachments.

(b) The hose assembly is then to be placed in a protective device, whose design will permit visual observation of the test.

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

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

(e) If the test pressure has not dropped or if the couplings have not moved, the pressure is released. The hose assembly is then considered to have passed the hydrostatic test if no permanent distortion has taken place.

(f) Hose assemblies passing the test must be completely dried internally. If heat is used for drying, the temperature must not exceed 150°F (66°C).

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

Chapter 5 Referenced Publications

5-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document. These references are listed separately to facilitate updating to the latest edition by the user.

5-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 69-1986, *Standard on Explosion Prevention Systems*

NFPA 70-1990, *National Electrical Code*

NFPA 72-1990, *Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems*

NFPA 72E-1990, *Standard on Automatic Fire Detectors.*

5-1.2 Other Publications.

5-1.2.1 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

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

ANSI B36.10M-1985, *Welded and Seamless Wrought Steel Pipe (ISO64)*

ANSI/UL 536-1989, *Flexible Metal Hose.*

5-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A53-89, *Specifications for Welded and Seamless Steel Pipe*

ASTM A106-89, *Specifications for Seamless Carbon Steel Pipe for High-Temperature Service*

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

ASTM A234-89, *Specifications for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

ASTM A395-88, *Specifications for Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures*

ASTM B88-89, *Specifications for Seamless Copper Water Tube*

ASTM E380-89, *Standard for Metric Practice.*

5-1.2.3 ASME Code. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code — 1980.*

Appendix A

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

A-1-5 Halogenated Extinguishing Agents.

A halogenated compound is one 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 1211.

Halon 1211 is bromochlorodifluoromethane, $CBrClF_2$.

Under normal conditions, Halon 1211 is a colorless gas with a faintly sweet smell and having a density about 5 times that of air. It can be readily liquefied by compression for storage in closed vessels. A list of the physical properties of both the vapor and the liquid is given in Table A-1-5.2(a). The variation of vapor pressure with temperature is shown in Figure A-1-5.2. The variation of liquid density with temperature is given in Table A-1-5.2(b).

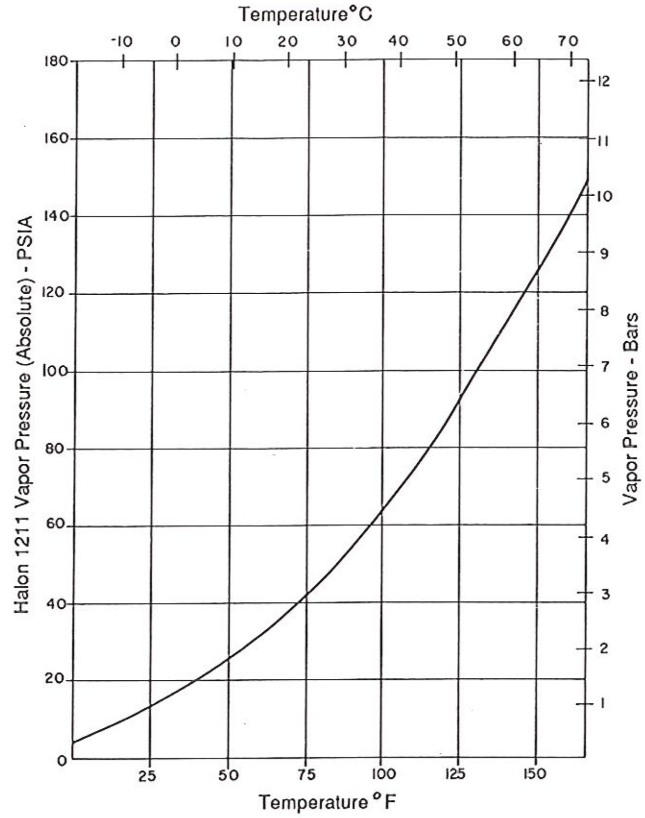


Figure A-1-5.2 Vapor Pressure of Halon 1211 vs. Temperature.

Table A-1-5.2(a) Physical Properties of Halon 1211

Molecular Weight	165.38
Boiling Point at 1 atm., °F	26.0
Boiling Point at 1 atm., °C	-3.4
Freezing Point, °F	-256.0
Freezing Point, °C	-160.5
Critical Temperature, °F	309.0
Critical Temperature, °C	153.8
Critical Pressure, psia	595.4
Critical Pressure, bars	42.06
Critical Pressure, atm.	38.7
Critical Volume, cu ft./lb.	0.0225
Critical Volume, m^3/kg	0.001 41
Critical Density, lb./cu. ft.	44.5
Critical Density, kg/m^3	713.0
Specific Heat, Vapor, 1 atm., 77°F, BTU/lb./°F	0.108
Specific Heat, Vapor, 1 atm., 25°C, kJ/kg/°C	0.452
Specific Heat, Liquid @ 77°F, BTU/lb./°F	0.185
Specific Heat, Liquid @ 25°C, kJ/kg/°C	0.775
Heat of Vaporization at BPt, BTU/lb.	57.0
Heat of Vaporization at BPt, kJ/kg	132.6
Heat of Vaporization at BPt, cal/g	32.0
Molar Heat Capacity, cal/g/mol/°C	30.5
Liquid Viscosity @ 77°F (25°C), centipoise	0.34
Vapor Viscosity @ 77°F (25°C) centipoise	0.013
Surface Tension @ 77°F (25°C), dyne/cm	16.5

Table A-1-5.2(b) Halon 1211 Liquid Density

Temp., °C	Density, kg/m^3	Temp., °F	Density, lb/ft^3
-60	2060	-80	129.2
-40	2020	-40	126.1
-20	1970	0	121.7
0	1900	40	116.7
20	1830	70	113.4
40	1750	80	111.7
60	1670	120	106.8
80	1580	160	101.1
100	1470	200	94.9

A-1-5.2.2 Fire Extinguishing Characteristics.

Halon 1211 is particularly effective against flammable liquid fires, but also has a very good performance against most solid combustible materials, and is safe against fires involving electrical equipment. It should not be used on fires of active metals and metal hydrides, nor against burning materials that contain their own oxidizer. Although its boiling point is 26°F (−4°C), it is capable of being discharged from a hand extinguisher as a liquid jet with an effective throw.

The extinguishing action of most common agents is through the physical processes of cooling and diluting. The chemical extinguishants are much more effective because of their ability to interfere with the combustion processes. They act by removing active species that are involved in the chain reactions: a process known as chain breaking. All the halogens are active in this way, but bromine is very much more effective than either chlorine or fluorine, and it is probable that Halon 1211 owes its high efficiency mainly to the presence of a bromine atom in the molecule.

The mechanism by which bromine inhibits combustion is not completely understood, nor indeed are the combustion processes themselves. However, a number of possible reactions have been proposed. The most active species in hydrocarbon combustion are oxygen and hydrogen atoms, and hydroxyl radicals (O, H and OH). One possible mechanism assumes the removal of H atoms and the formation of H_2 molecules (this cannot happen by direct combination of two atoms since the energy released is sufficient to cause dissociation of the newly formed molecule):

$$H + HBr \rightarrow H_2 + Br$$

Another proposed system involves a reaction with OH radicals:

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

The variation of vapor pressure with temperature is shown in Figure A-1-5.2 and may be calculated from:

$$\log_{10} p = 5.199 - \frac{964.9}{t + 243.3}$$

where p is the pressure in psia and t is the temperature in °C.

The variation of liquid density with temperature is shown in Table A-1-5.2(b).

In either case, the Br atom can react with some organic radical:

$$RH + Br \rightarrow + HBr$$

In this way, chain carriers are removed from the system, while the inhibiting HBr is continuously regenerated. In hydrocarbon combustion, the removal of H or OH would be equally effective, as they are involved in an equilibrium reaction.

$$OH + CO \rightleftharpoons H + CO_2$$

A-1-6.1 Hazards to Personnel.

The discharge of Halon 1211 to extinguish a fire may create a hazard to personnel from the natural Halon 1211 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. Personnel should not attempt to remain in an area following the discharge of the system.

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.

Natural or undecomposed Halon 1211. Undecomposed Halon 1211 has been studied in humans and found to produce minimal, if any, central nervous system effects at concentrations below four percent for exposures of approximately one-minute duration. At concentrations above four percent effects such as dizziness, impaired coordination and reduced mental acuity become definite with exposure of a few minutes duration; however, these effects are not incapacitating for exposure of one minute or less. With the first thirty seconds of exposure to Halon 1211 little effect is noticed, even when concentrations above four percent are inhaled. At these levels this amount of time appears necessary for the body to absorb a sufficient quantity of agent to bring about the onset of effects. At concentrations of the order of five to ten percent there is the risk of unconsciousness and possible death if the exposure is prolonged.

The effects of exposure to Halon 1211 may persist for a short time following exposure; however, recovery may be expected to be rapid and complete. Halon 1211 would not be expected to accumulate in the body even with repeated exposures.

Halon 1211 is colorless and has a faintly sweet odor. The 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 long 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 three percent, voice characteristics are changed due to the increased density of the air/agent mixture.

In total flooding systems, the high density of Halon 1211 vapor (5.7 times that of air) requires the use of discharge nozzles that will achieve a well-mixed atmosphere in order to avoid local pockets of high concentrations. It is also possible to develop local pockets of higher concentrations in pits or low-lying areas adjacent to local application systems. Once mixed into the air, the agent will not settle out.

(a) Decomposition Products of Halon 1211.

Although Halon 1211 vapor has a low toxicity, its decomposition products can be hazardous. The most accepted theory is that the vapor must decompose before Halon 1211 can inhibit the combustion reactions (*see A-1-5.2.2*). The decomposition takes place on exposure to a flame, or to a hot surface 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, HCl, HBr), and free halogens (Cl_2, Br_2), with small amounts of the carbonyl halides (COF_2, $COCl_2$, $COBr_2$).

Approximate lethal concentration values for 15-minute exposures to some of these compounds are given in Column 1 of Table A-1-6.1. Column 2 of Table A-1-6.1 gives the concentrations of these materials that have been quoted as "dangerous for short exposures" by Sax.[11]

Table A-1-6.1 Decomposition Products of Halon 1211

Compound	ALC for 15 Minute Exposure, ppm by Volume in Air	Dangerous Concentration, ppm by Volume in Air
Hydrogen Bromide (HBr)	4750	—
Hydrogen Chloride (HCl)	4750	1000 – 2000
Hydrogen Fluoride (HF)	2500	50 – 250
Bromine (Br_2)	550	50**
Chlorine (Cl_2)	350	50
Fluorine (F_2)	375	—
Carbonyl Bromide ($COBr_2$)	100 – 150***	—
Carbonyl Chloride ($COCl_2$)	100 – 150	50
Carbonyl Fluoride (COF_2)	1500	—

** Value for chlorine; value for bromine is not available.
***Value for carbonyl chloride, $COCl_2$; value for carbonyl bromide is not available.

The decomposition products of Halon 1211 have a characteristic sharp acrid odor, even in concentrations of only a few parts per million. This characteristic provides a built-in warning system for the agent, but at the same time creates a noxious, irritating atmosphere for those who must enter the hazard following a fire.

The amount of Halon 1211 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, two n-heptane fires were burned in a 2.5 sq ft (0.23 m^2) tray in a 2500 cu ft (71 m^3) room. The first fire was extinguished by Halon 1211 in 10 seconds. On analysis, the air in the room was found to contain:

HCl + HBr	50 ppm
HF	10 ppm
Cl_2 + Br_2	2.5 ppm
$COCl_2$	Not detected (i.e. less than 0.25 ppm)

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 or breakdown products must be minimized. In most cases the area would be untenable for human occupancy due to 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 1211 may include the following:

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

(b) Provision of the necessary additional or emergency lighting, or both, and directional signs to ensure quick, safe evacuation.

(c) Provision of alarms within such areas that will operate immediately upon detection of a 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 entering the protected area that a Halon 1211 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 1211 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 1211 is heavier than air.

(j) Prohibition against smoking by persons until the atmosphere has been purged of Halon 1211.

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

A-1-7.4

When a full discharge test is conducted, the following procedures are recommended.

A. Planning for the Acceptance Test.

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

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

B. Conducting the Discharge Test

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

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

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

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

(b) A stopwatch.

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

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

1. Halon 1211 should not be used as a test agent. Availability of Halon 1211 is limited by the Montreal Protocol on Substances that Deplete the Ozone Layer. Use of Halon 1211 as a test agent further reduces availability for fire extinguishing purposes. As such this standard recommends that Halon 1211 should not be used as a test agent. Alternate test agents should be considered.

2. Where permitted by the authority having jurisdiction, Halon 122 or other agents are sometimes used in acceptance testing of new Halon 1211 systems. Where Halon 122 or other agents are used, the authority having jurisdiction should assure that they provide a meaningful test of the system.

Known differences between Halon 1211 and Halon 122 include:

(a) Halon 122 causes less turbulence than Halon 1211.

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

(c) Halon 122 mixes with the atmosphere less readily than Halon 1211.

(d) The toxicity of Halon 122 is greater than Halon 1211.

(e) The vapor density of Halon 122 is less than Halon 1211.

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

(g) The test cylinder for Halon 122 is loaded to 82 percent by weight of the Halon 1211 charge.

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

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

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

3. Replacement 1211 should be on hand and the replacement containers should be weighed at the site.

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

1. The protected enclosure should be prepared as follows:

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

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

(c) All ceiling tiles should be installed.

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

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

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

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

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

E. Total Flooding Test. For total flooding systems, a listed or approved concentration meter should be used and calibrated in strict accordance with the manufacturer's instructions. The meters should be checked for accuracy by means of a known sample. Concentration readings should be taken at the point of the highest combustible being protected or at a level equivalent to 75 percent of the height of the enclosure, whichever is greater. The sampling points shall not be located less than 12 in. (305 mm) from the ceiling unless the combustibles being protected extend within the area, in which case special design consideration may be necessary. If more than one space or compartment is being simultaneously protected, a sampling point should be located in each space in accordance with the above criteria. (The minimum design concentration for the hazard should be achieved at all sampling points in the enclosure within one minute after the end of the initial discharge.) For flammable liquids and gases, the minimum specified concentration need not be maintained for an extended period. For surface fire hazards other than flammable liquids and gases, 80 percent of the minimum design concentration should be maintained for a period of 10 minutes after the initial discharge or as required by the authority having jurisdiction. Hazards involving deep-seated combustibles require maintenance of the design concentrations for longer periods of time (*see 2-4*). Where an inerting concentration is required, a more stringent test may be necessary. Halon 1211 total flooding systems are not intended for normally occupied areas (*see 2-1.1.3*). 110-volt, 60-cycle power should be available for operating a recordable-type analyzer. The power to the analyzer should remain on when the fire extinguisher system is activated.

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

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

3. Actuate the system for discharge.

4. Concentration will be reported for the time period that the authority having jurisdiction has determined to be appropriate for that particular occupancy-.Caution: There should be no smoking in or around the test area during and after the discharge.

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

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

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

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

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

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

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

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

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

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

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

G. The results of the test should be documented in report form for each member of the test team. This report should include, but not necessarily be limited to the following:

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

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

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

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

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

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

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

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

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

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

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

A-1-8.1 The halon electrical control system should meet the requirements of NFPA 72, *Standard for the Installation, Maintenance and Use of Protective Signaling Systems*. The control unit should be listed as a local alarm panel for use as a releasing device. It is desirable to connect the halon control unit to a constantly manned facility in accordance with the appropriate NFPA signaling system standards. To accomplish this, as a minimum a common alarm and common trouble signal from the halon control unit should be transmitted to a constantly attended location.

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

A-1-9.2 Quality. Specification MIL-B-38741 requires a technical purity of Halon 1211 as shown in Table A-1-9.2.

Table A-1-9.2 Requirements for Halon 1211 Bromochlorodifluoromethane Specification MIL-B-38741

Property	Requirement
Bromochlorodifluorormethane percent by volume, minimum	99.0
Boiling Point, degrees Centigrade at 760 mm Hg	−4 ± 1 (24.8 ± 1.8°F)
Acid Halides & Free Halogens, ppm (by weight), maximum	3.0
Nonvolatile Residue, grams/100 ml, maximum	0.02
Suspended Matter or Sediment	None
Color (Platinum-Cobalt Color Standard)	Equal or Less than #15
Moisture percent by weight, maximum	0.002

(a) Description.

Halon 1211 is a liquefied gas with a boiling point at 26°F (−3.4°C). At 68°F (20°C) the pressure in the container is about 25 psig (1.72 bars gage).

The container, as with all liquefied gases, should be kept away from heat.

The material is chemically stable and finds its main application as an extinguishing agent for Class B and C fires, i.e., fires of burning liquids and electrical fires. It is of low toxicity.

The liquid is clear and colorless. It vaporizes readily and has the following physical properties:

Boiling Point	−3.4°C
Freezing Point	Below −80°C
Liquid Density	1830 kg/m^3 at 20°C
Critical Constants:	
Temperature	154°C
Pressure	595 $lb/in.^2$ absolute (42.06 bars)
Density	713 kg/m^3
Molecular Weight	165.4
Formula	$C \cdot Br \cdot Cl \cdot F_2$

1 lb of Halon 1211 converted into vapor at 68°F (20°C) occupies 2.3 cu ft (1 kg = 0.14 m^3).

(b) Composition.

The material consists essentially of bromochlorodifluoromethane, the principal impurities being other halogenated methanes.

A-1-9.4 Storage Containers.

Storage containers for Halon 1211 must be capable of withstanding the total pressure exerted by the Halon 1211 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 1211, or manifolded cylinders for larger installations.

Specially designed containers, such as spheres, are also used, particularly in high-rate discharge systems. For very *large systems, bulk storage tanks may be used, provided the design requirements of the ASME Unfired Pressure Vessel Code* are followed.

Each container must be equipped with a discharge valve capable of discharging liquid Halon 1211 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 1211.

Nitrogen Superpressurization. Halon 1211 has a vapor pressure of approximately 25 psig (2.74 bars) at 70°F (21°C), which is insufficient to ensure a rapid discharge from a system. At very low temperatures, the vapor pressure is negligible. Also, if a system was operated simply by the vapor pressure of the agent, the liquid would boil off in the pipelines and a very poor discharge would result. The pressure behind the discharge nozzles should not in fact be allowed to fall below 30 psig (3.08 bars). This is achieved, together with a satisfactory discharge, by superpressurizing the Halon 1211 container with nitrogen.

When the container is superpressurized, some of the nitrogen goes into solution in the Halon 1211. The amount of nitrogen lost in this way can be estimated from Figure A-1-9.4(a), which shows the percentage, by weight, of nitrogen in solution at various pressures and at 75°F (24°C).

Filling Density. The filling density of the agent in the container is expressed in terms of lb of agent per cu ft of volume. This relationship is independent of temperature. It is also convenient to express this relationship as a fill ratio, which is the simple ratio of the volume of the liquid to the volume of the container. In a closed vessel, this ratio will vary with the temperature.

The maximum temperature at which a Halon 1211 system will be operated is well below the critical temperature, so there is little change in liquid density over the normal operating temperature range and it is possible to design for a fill ratio as high as 90 percent. However, unless a flow of nitrogen is maintained into the container during a discharge, there will be a considerable drop in pressure. It is, therefore, normally convenient to design for a fill ratio of 75 percent or less.

Figure A-1-9.4(b) shows the pressure-temperature relationships for vessels filled with Halon 1211 at four different fill ratios, and at two different initial levels of superpressurization. In Figure A-1-9.4(c), the same information has been plotted as filling density. The curve for a filling density of 100 lb/cu ft (1602 kg/m^3) gives values very slightly below those for the maximum filling density of 102 lb/cu ft (1634 kg/m^3). On the fill ratio curves, this corresponds to a 90 percent fill at 68°F (20°C). The other fill ratio curves, at 75 percent, 50 percent and 33 percent correspond, at 68°F (20°C), with filling densities of 86, 57 and 38 lb/cu ft (1378, 913 and 609 kg/m^3).

A-1-10.1 Piping. Although halon systems are not subjected to continous 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. Stress is to be calculated as shown in ANSI B31.1, *Power Piping Code*, Section 104.

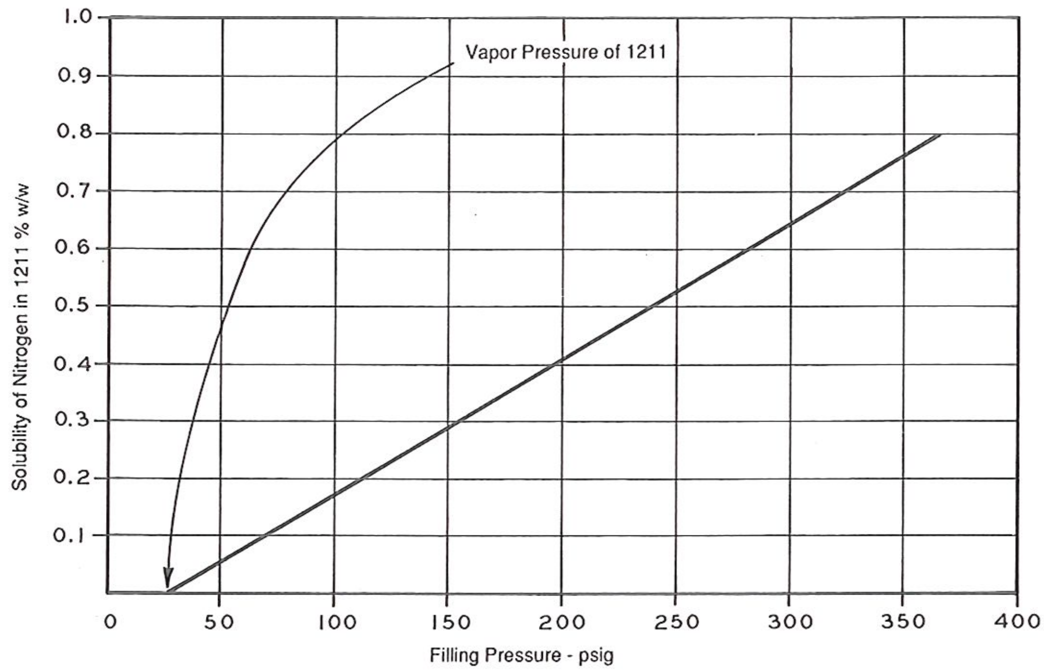


Figure A-1-9.4(a) Solubility of nitrogen in Halon 1211 at various pressures and 24°C (75°F).

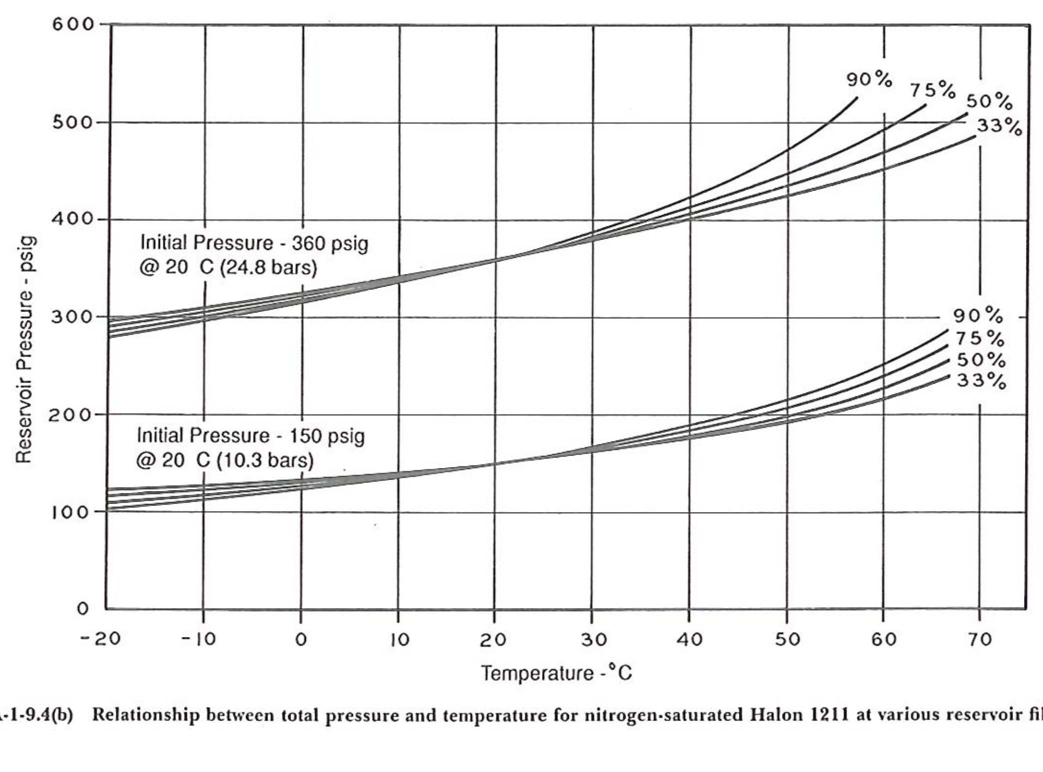


Figure A-1-9.4(b) Relationship between total pressure and temperature for nitrogen-saturated Halon 1211 at various reservoir fill ratios.

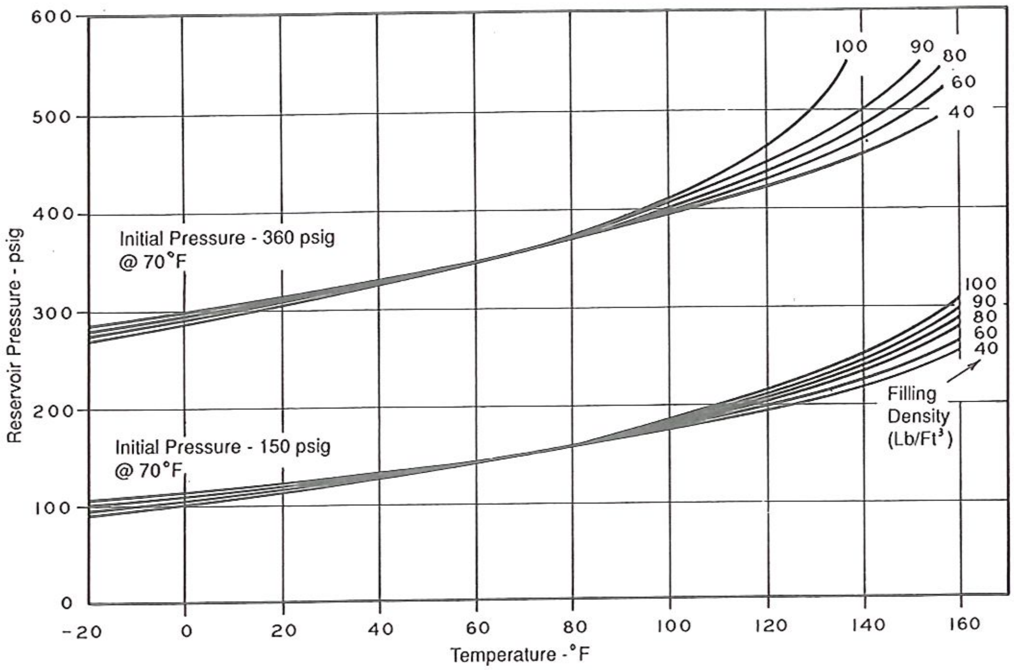


Figure A-1-9.4(c) Relationship between total pressure and temperature for nitrogen-saturated Halon 1211 at various reservoir filling densities.

A-1-10.1.1 The *Power Piping Code* referred to in the body of this standard utilizes the minimum tensile strength of the piping material as the basis for determining the maximum allowable stress value. The minimum tensile strength is de-rated by a factor of 4 and then multiplied by a joint efficiency factor. The result is the maximum allowable stress value for the pipe. The following piping meets or exceeds the strength requirements of 1-10.1.1(a) and is based upon maximum storage temperatures of 130°F (54.4°C).

For 150 psig storage pressures, Schedule 40 pipe may be used as follows:

A-53 grade A, B, seamless or ERW, sizes 1/8 in. thru 8 in., threaded or welded connections.

For 360 psig storage pressures, Schedule 40 pipe may be used as follows:

A-53 grade A, B, seamless, sizes 1/8 in. thru 8 in., threaded or welded connections.

A-53 grade A, ERW, sizes 1/8 in. thru 6 in., threaded or welded connections.

A-1-10.5 Discharge Nozzles. The discharge rate from a nozzle varies very little with the temperature of the agent, provided that the pressure behind the nozzle is the same. This is probably because the effect of the reduced liquid viscosity is compensated for by the reduced nitrogen solubility. The deviation from the curves in Figure 1-10.6.2(a) is negligible over the temperature range 55 to 115°F (13 to 46°C). Outside this range, the data from the curves may still be sufficiently accurate for a preliminary design calculation.

A-1-10.6 System Flow Calculations.

Piping must be designed to handle the required flow of agent, and must be sized according to Figure 1-10.6.2(a) or 1-10.6.2(b) so that a minimum design pressure of 30 psig (3.08 bars) is maintained at the nozzle.

Two sources of pressure drop exist:

(a) A drop in storage pressure occurs as the liquid Halon 1211 fills the piping system initially. The change in the storage pressure can be estimated from the following formula:

$$P_T = (P_{Ti} - P_V)\ \frac{(1 - V_c - V_s)}{V_c + V_p}$$

Where:

P_t = change in the container pressure due to the filling of the piping with Halon 1211

P_{Ti} = initial charged pressure of the container

P_v = vapor pressure of Halon 1211

V_c = internal volume of the vapor space of the container, dip tube included at initial start

V_s = internal volume of the portion of the dip tube above the liquid level in the container, in.^{3} (m^3)

V_p = internal volume of the external piping and distribution system, in.^{3} (m^3)

Internal volume figures for steel pipe and copper tubing are given in Tables A-1-10.6(a) and A-1-10.6(b).

(b) Friction losses occur as the liquid Halon 1211 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

Table A-1-10.6(a) Internal Volume of Steel Pipe Cubic Inches per Foot of Length

Nominal Pipe Diameter in.	Schedule 40	Schedule 80
1/4	1.244	0.864
3/8	2.298	1.693
1/2	3.646	2.817
3/4	6.411	5.184
1	10.368	8.623
1 1/4	17.971	15.396
1 1/2	24.433	21.168
2	40.262	35.424
2 1/2	57.453	50.859
3	88.712	79.262
3 1/2	118.642	106.655
4	152.763	137.962

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 valves are given in Tables A-1-10.6(c) and A-1-10.6(d).

Changes in elevation are accounted for by subtracting 0.79 psi for each ft (0.0054 bar/m) above the storage container (or by adding, if below) from the total available pressure drop.

Table A-1-10.6(b) Internal Volume of Copper Tubing

Size inches	Type	Actual Inside Diameter-inches	Internal Volume cu/in/ft
1/4	M	—	—
	L	0.315	0.935
	K	0.305	0.877
3/8	M	0.450	1.909
	L	0.430	1.743
	K	0.402	1.523
1/2	M	0.569	3.051
	L	0.545	2.799
	K	0.527	2.618
3/4	M	0.811	6.199
	L	0.785	5.808
	K	0.745	5.231
1	M	1.055	10.490
	L	1.025	9.902
	K	0.995	9.331
1 1/4	M	1.291	15.708
	L	1.265	15.082
	K	1.245	14.609
1 1/2	M	1.527	21.976
	L	1.505	21.347
	K	1.481	20.672
2	M	2.009	38.039
	L	1.985	37.136
	K	1.959	36.169
2 1/2	M	2.495	58.669
	L	2.465	57.267
	K	2.435	55.882
3	M	2.981	83.752
	L	2.945	81.741
	K	2.907	79.645
3 1/2	M	3.459	112.76
	L	3.425	110.56
	K	3.385	107.99
4	M	3.935	145.94
	L	3.905	143.72
	K	3.857	140.21

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

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

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

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

A-1-11.1 Inspection. The entire fire extinguishing system should be completely inspected at least annually. More frequent general inspections are recommended. Regular service contracts with the manufacturer or installing company are recommended.

In the annual inspection particular attention should be given to:

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

1. Detection and Actuation System.

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

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

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

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

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

2. Containers.

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

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

3. Piping and Nozzles.

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

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

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

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

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

4. Auxiliary Equipment.

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

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

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

From a performance viewpoint, a total flooding system is designed to develop a concentration of Halon 1211 that will extinguish fires in combustible materials located in an enclosed space. It must also maintain an effective concentration until the maximum temperature has been reduced below the reignition point.

The concentration of Halon 1211 required will depend on the type of combustible material involved. This has been determined for many surface-type fires, particularly those involving liquids and gases. For deep-seated fires, the critical concentration required for extinguishment is less definite, and has in general been established by practical test work.

It is important that an effective agent concentration not only be achieved but that it be maintained for a sufficient period of time to allow effective emergency action by trained personnel. This is equally important in all classes of fires since a persistent ignition source (e.g., an arc, heat source, oxyacetylene torch, or deep-seated fire) can lead to a recurrence of the initial event once the agent has dissipated. Halon 1211 extinguishing systems normally provide protection for a period of minutes but are exceptionally effective for certain applications. Water supplies for standard sprinklers, on the other hand, are normally designed to provide protection for an extended period of time. The designer, buyer, and emergency force in particular need to closely review the advantages and limitations of available systems as applied to the specific situation at hand, the residual risks being assumed, and the proper emergency procedures.

A-2-1.1.2 The discharge of a minimum extinguishing concentration of Halon 1211 into enclosures containing operating diesel engines not drawing combustion air from outside the space creates a special problem. Experience has shown the engine may continue to operate resulting in a decrease in agent concentration and extensive decomposition of the halon.

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

A-2-2.2.3 Halon 1211 installed under a computer floor only is not acceptable, as NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, requires total room flooding and prohibits underfloor protection only. Halon 1211 is not permitted in the normally occupied above floor space.

A-2-3 Halon 1211 Requirements for Surface Fires. Two basic types of extinguishment data have been obtained for Halon 1211:

1. Flame extinguishment data, which determines the agent concentration necessary to extinguish a flame of a particular fuel.

2. Inerting data, which determines the minimum premixed agent concentration to suppress propagation of a flame front at the "flammability peak," or stoichiometric fuel/air composition.

Flame extinguishment data generally relates closest to the concentration actually required in a fire extinguishing system. The apparatus recommended for these measurements is a cup burner method similar to that described in References (1), (5), and (6) (*see Appendix B*). Liquid fuels are examined at two temperatures:

1. Ambient: 77°F (25°C), or approximately 41°F (5°C) above ASTM open-cup flash point of the fuel, whichever is higher, and

2. Elevated: approximately 41°F (5°C) below the boiling point of the fuel, or 392°F (200°C), whichever is lower.

Gaseous fuels are examined at two temperatures, 77°F (25°C) and 302°F (150°C). A 20 percent safety factor is added to experimental threshold concentrations.

Design concentrations less than 5 percent Halon 1211 are not used for flame extinguishment. Measured flame extinguishment data plus safety factor which is less than 5 percent should be increased to 5 percent minimum because the potential array of fuels likely to be involved in every real fire requires the higher concentration.

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

In inerting measurements, a fuel/air mixture is contained in a test chamber, and an ignition source is activated. If the mixture cannot support a flame front, the mixture is considered to be nonflammable. Typical results may be plotted as shown in Figure A-2-3.

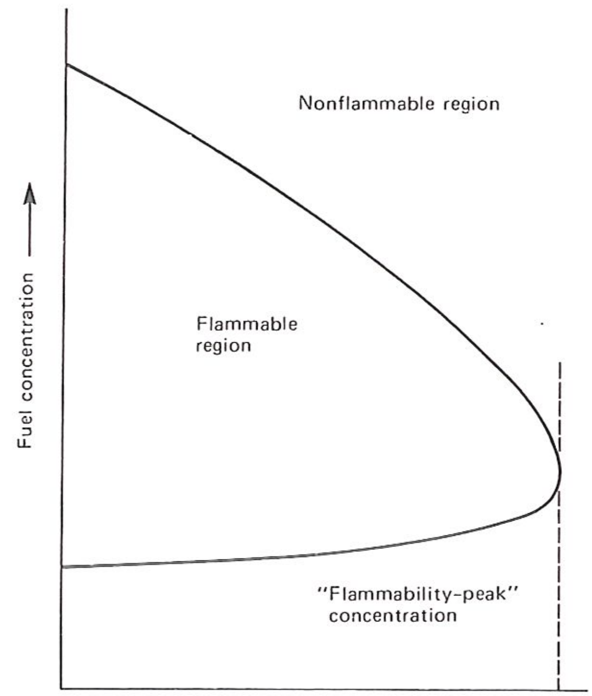


Figure A-2-3 Typical flammability-peak presentation.

The normal flammability range which exists when no agent is present is shown at the left-hand side of the graph. As Halon 1211 is added to the system, the flammability range is reduced until it finally disappears entirely. The agent concentration at which this occurs is called the "flammability peak" concentration. All fuel/air mixtures containing concentrations of agent equal to or greater than the flammability peak value are nonflammable, hence the term "inter."

The results in Table A-2-3.2.3 were measured using a spherical vessel described in Reference (3) (*see Appendix B*).

Table A-2-3.2.2 Development of Halon 1211 Design Concentrations for Flame Extinguishment In 77°F Air at 1 atm (25°C at 1 atm)

	Concentration in Air in Volume Percent							
Fuel	Average*		Safety Factor		Total	Design***	Ref**
Acetone	3.6	+	0.7	=	4.3	5.0	(5)(6)(7)
Benzene	2.9	+	0.6	=	3.5	5.0	(5)(6)(7)
Ethanol	4.2	+	0.8	=	5.0	5.0	(5)(6)(7)
Ethylene	7.2	+	1.4	=	8.6	8.6	(5)(6)(7)
Methane	3.5	+	0.7	=	4.2	5.0	(5)(6)(7)
n-Heptane	4.1	+	0.8	=	4.9	5.0	(5)(6)(7)
Propane	4.8	+	1.0	=	5.8	5.8	(5)(6)(7)

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

** For references see Appendix B.

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

Table A-2-3.2.3 Halon 1211 Design Concentrations for Inerting

Fuel	Minimum Conc.* % by Volume
Benzene	5.0
Ethylene	13.2
Hydrogen	35.7
Methane	10.9
Propane	7.7

*For references see Reference (4), Appendix B.

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

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

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

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

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

For SI Units

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

K = kelvin = °C + 273.15

To account for possible stratification effects, which might create localized explosive pockets, the fuel quantity as determined above should be divided by an appropriate safety factor. Table A-2-3 lists quantities for several fuels, to which an arbitrary safety factor of 2 has been applied. Greater safety factors may be required by individual situations.

Table A-2-3 Quantity of Fuel Required to Achieve ½ of Lower Explosive Limit in Air at 1.0 atm and 70°F (21°C)

Material	Fuel Quantity, lbs. per cu. ft. enclosed volume	kg/m^3
n-Butane	.0014	0.0224
Isobutane	.0016	0.0256
Carbon disulfide	.00099	0.0159
Carbon monoxide	.0045	0.0721
Ethane	.0012	0.0192
Ethyl alcohol	.0018	0.0288
Ethylene	.0020	0.0320
n-Heptane	.0016	0.0256
Hydrogen	.00011	0.0018
Methane	.0011	0.0176
Propane	.0013	0.0208

A-2-3.2.6 NFPA 68 should be used for guidance on explosion venting.

A-2-4 Fires in Solid Materials.

Two types of fires can occur in solid fuels: one in which volatile gases resulting from heating or decomposition of the fuel surface are the source of combustion; and another in which oxidation occurs at the surface of, or within, the mass of fuel. The former is commonly referred to as "flaming" combustion while the latter is often called "smoldering" or "glowing" combustion. The two types of fires frequently occur concurrently, although one type of burning may precede the other. For example, a wood fire may start as flaming combustion and become smoldering as burning progresses. Conversely, spontaneous ignition in a pile of oily rags may begin as a smoldering fire and break into flames at some later point. Flaming combustion, because it occurs in the vapor phase, is promptly extinguished with low levels of Halon 1211, a vapor-phase, flame-inhibiting extinguishant. In the absence of smoldering combustion, the flame will stay out.

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

For the purposes of this standard, smoldering fires are divided into two classes: (1) where the smoldering is not "deep-seated," and (2) "deep-seated" fires. The difference is only a matter of degree, and the distinction is a functional one: if a 5 percent concentration of Halon 1211 will not extinguish a fire within 10 minutes of application, it may be considered to be deep seated. In practice, experiments have shown a rather sharp dividing line between the two. Deep-seated fires usually require much higher concentrations than 10 percent and much longer soaking times than 10 minutes.

Whether a fire will become deep seated depends in part upon the length of time it has been burning before application of extinguishing agent. This time is usually called the "preburn" time. Underwriters Laboratories wood crib fires (1A) and stacks of wood pallets have been readily extinguished with less than 5 percent Halon 1211 maintained for less than 10 minutes following discharge. In these tests, a 10-minute preburn was allowed. In many cases, a fire may be prevented from becoming a deep-seated smoldering fire through prompt detection and rapid extinguishment.

Once the fire has become deep seated, it may be necessary to maintain a concentration of 10 percent for 20 minutes to completely extinguish that particular fire. Since, for a given fire situation, the soaking time required for complete extinguishment varies with the concentration, concentration-soak time combinations of 35 percent for 10 minutes, or 5 percent for 30 minutes, might produce the same effect as the exposure mentioned above.

Another important variable which bears on whether a fire will become deep seated or not is the fuel configuration. While wood cribs and pallets are easily extinguished with 5 percent Halon 1211, vertical wood panels closely spaced and parallel require about 25 percent concentrations for 30 to 40 minutes for extinguishment, as a result of slow heat dissipation through re-radiation between the surfaces. Fires in boxes of excelsior and in piles of shredded paper also require about 20 percent Halon 1211 for extinguishment. In these situations, heat tends to be retained in the fuel array, rather than being dissipated to the suroundings. Radiation is an important mechanism for heat removal from smoldering fires.

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

To date no firm basis has been developed to predict the agent requirements for a deep-seated fire. In a practical sense, the use of a Halon 1211 system for control or extinguishment of a deep-seated fire is usually unattractive. Long soaking times are usually difficult to maintain without an extended agent discharge due to leakage of agent from even the smallest openings in the enclosure and at high agent concentrations these systems become relatively expensive. The use of Halon 1211 systems will generally be limited to solid combustibles which cannot or are not allowed to become deep seated.

The deep seated potential of a solid material in a given situation can be established positively only by experiment.

The information given in this standard may assist the authority having jurisdiction to decide whether such experimentation is necessary.

A-2-5.2 Total Flooding Quantity.

The volume of Halon 1211 required to develop a given concentration will be greater than the final volume remaining in the enclosure. In most cases, Halon 1211 must be applied in a manner that promotes progressive mixing of the atmosphere. The displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents, as Halon 1211 is injected. Some Halon 1211 is therefore lost with the vented atmosphere. This loss is greater at high concentrations.

For the purposes of this standard, it is assumed that the Halon 1211/air mixture lost in this manner contains the final design concentration of Halon 1211. This represents the worst case from a theoretical standpoint, and provides a built-in safety factor to compensate for non-ideal discharge arrangements.

A-2-5.3 Special Conditions.

Effects of Ventilation.

Halon 1211 discharged into a ventilated enclosure for total flooding is subject to loss of agent in the effluent ventilating air. A greater amount of agent may be required to develop a given concentration, and continuous agent discharge is required to maintain the concentration at a given constant level.

Beginning with an enclosure containing pure air, the Halon 1211 discharge rate required to develop a given concentration of agent at any given time after start of discharge is as follows:

$$R = \frac{0.01\ CE}{S\left[1 - e^{-\frac{ET}{V}}\right]}$$

Where R = Halon 1211 discharge rate, lb per sec (kg/s)
C = Halon 1211 concentration, percent by volume
E = Ventilation rate, cu ft per sec (m^3/s)
V = Enclosure volume, cu ft (m^3)
T = Time, sec
e = Natural logarithm base, 2.71828
S = Specific volume of Halon 1211 vapor at the design temperature (cu ft/lb) (m^3/kg)
.01 = Factor used because the units of Halon 1211 concentration are (vol. %)

The above formula cannot be used where the Halon discharge rate (R), when converted to cubic feet per second, is greater than the ventilation rate (E). The method of calculation described in 2-5.2 should be used in these cases.

The Halon 1211 discharge rate necessary to maintain a given concentration of agent is given by the equation:

$$R = \frac{0.01\ CE}{S}$$

After agent discharge is stopped, the concentration-vs-time relationship is as follows:

$$C = C_o e^{-\frac{E}{V}T}$$

Where C_o = Agent concentration at end of discharge, percent by volume.
T = Time after stopping discharge, in seconds. Other variables as described above.

EXAMPLE 1: In a 10,000cu ft enclosure which is ventilated with two air changes per minute, calculate the discharge rate and quantity of Halon 1211 required to develop a 5 percent concentration in 10 seconds.

$$V = 10{,}000 \text{ cu ft}$$

$$E = \frac{2 \times 10{,}000}{60} = 333 \text{ cu ft/sec}$$

$$R = \frac{0.01\ CE}{S\left[1 - e^{-\frac{ET}{V}}\right]}$$

$$= \frac{0.01\ (5)\ (333)}{2.26\left[1 - 3^{-\frac{(333)\ (10)}{10{,}000}}\right]}$$

$$= \frac{7.35}{(1-.717)}$$

$$= 25.9 \text{ lb/sec}$$

$$Q = RT = (25.9)(10) = 259 \text{ lb}$$

EXAMPLE 2: After achieving a 5 percent concentration of Halon 1211 in the above example, calculate the continuous discharge rate necessary to maintain the agent concentration at 5 percent:

$$R = \frac{0.01\ (333)\ (5)}{2.26}$$

$$= 7.37 \text{ lb/sec}$$

Leakage of Halon 1211 through Enclosure Openings.

Halon 1211 discharged into an enclosure for total flooding will result in an air/agent mixture which has a higher specific gravity than the air surrounding the enclosure. Therefore, any opening in the walls of the enclosure will allow the heavier air/agent mixture to flow out of the enclosure, being replaced with lighter outside air flowing into the enclosure through the same opening. The rate at which agent is lost through openings will depend upon the height and width of the opening, the location of the opening in the wall, and the concentration of agent in the enclosure.

Fresh air entering the enclosure will collect toward the top, forming an interface between the air/agent mixture and fresh air. As leakage proceeds, the interface will move toward the bottom of the opening. The space below the interface will contain essentially the original extinguishing concentration of agent, whereas the upper space will be completely unprotected. The rate at which the interface moves downward increases with increasing concentrations of agent, so that simply injecting an overdose of agent initially will not provide an extended period of protection. Where extended protection in the upper portions of an enclosure is necessary, either extended discharge of agent throughout the entire protection time, or continuous mechanical mixing of the enclosure contents (e.g., with a fan) is recommended. The following sections provide methods for calculating:

1. The rate required for continuous extended discharge of agent to maintain a constant concentration of Halon 1211.

2. The protection time which can be obtained by applying an overdose of agent initially to an enclosure which provides for mechanical mixing.

3. The time required for the interface to reach the midpoint of the enclosure height.

Nomenclature:

C = Concentration of Halon 1211 in enclosure at any given time, and by volume.
C_o = Initial concentration of Halon 1211 in enclosure, percent by volume.
d = Overall height of the enclosure, ft (m).
g_c = Gravitational acceleration = 32.2 ft/sec^2 (9.81 m/sec^2)
H = Height of opening, ft (m).
K = Orifice discharge coefficient. (Assumed equal to 0.66 for normal doors, windows, etc.)
R_f = Halon 1211 discharge rate, lb/sec (kg/sec)
T = Period of extended protection (from end of initial discharge), sec.
V = Volume of enclosure, ft^3 (m^3).
W = Width of opening, ft (m).
G = A geometric constant, equal to $\frac{KW}{3V}\sqrt{2g_cH^3}$.

Extended Agent Discharge. Halon 1211 is continually added at a rate which will just compensate for leakage out of the enclosure. The makeup rate is dependent upon the agent concentration and the height and width of the opening. The agent must be discharged in such a way that uniform mixing of agent and air is obtained.

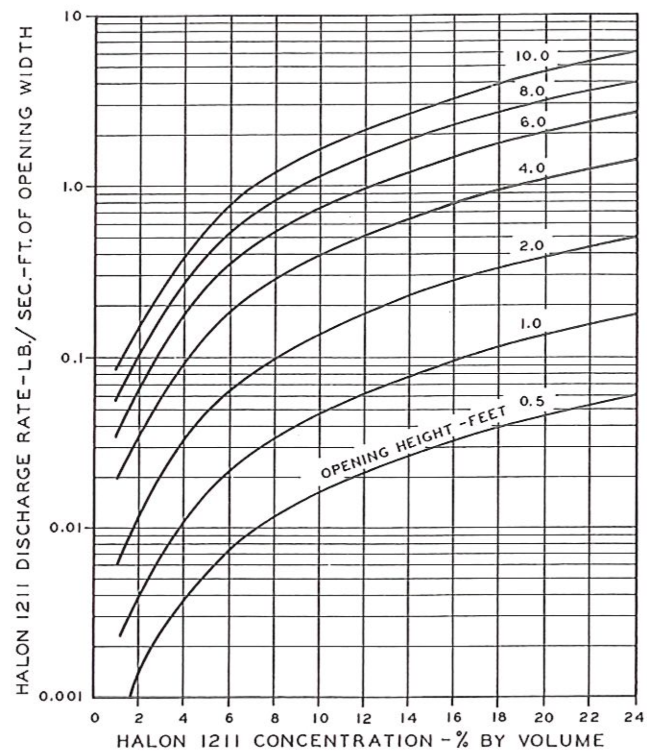
Figure A-2-5.3(a) gives the Halon 1211 makeup rate per unit opening width required to maintain a specified concentration in the enclosure, for various values of opening height.

EXAMPLE: Calculate the Halon 1211 makeup rate required to maintain a concentration of 5 percent by volume in an enclosure, one wall of which has an opening 4 ft wide by 6 ft high:

From Figure A-2-5.3(a), R/W = 0.25 lb/sec/ft
R = (0.25) (4) = 1.00 lb/sec

It may be convenient to know that this calculation can also be made directly, without reference to the figure, from this formula:

$$a = (R/W) = 0.00145\ H^{1.53}Co^{1.51}$$



FOR SI UNITS
1 ft = 0.305 m
1 lb/sec/ft = 1.49 kg/sec/m

Figure A-2-5.3(a) Extended discharge rate of Halon 1211 to maintain control concentrations in enclosures with unclosable openings.

The concentration that will be achieved, after a certain time, by any other discharge rate can be calculated from:

$$t = \frac{V}{E} \log \frac{(C_o)}{(C)}$$

$$\text{where } E = \frac{a\ (100 - C)}{pH\ (C)} A$$

t = time, sec
a = rate, lb/sec/ft of opening width
p = vapor density, lb per cu ft
A = area of opening, sq ft

Enclosure with Mechanical Mixing. An adequate overdose of Halon 1211 is provided initially so that, at the end of the desired protection period, a pre-established minimum concentration of agent still exists. The necessary initial concentration depends upon the extended protection time required, the height and width of the opening, and the volume of the enclosure.

Figures A-2-5.3(b), A-2-5.3(c), and A-2-5.3(d) relate the initial agent concentration required to the soaking time for variables of G, a function of enclosure and opening dimensions.

$$G = \frac{KW}{3V}\sqrt{2g_cH^3}$$

Each figure is for a different value of the final minimum concentration which is to be permitted.

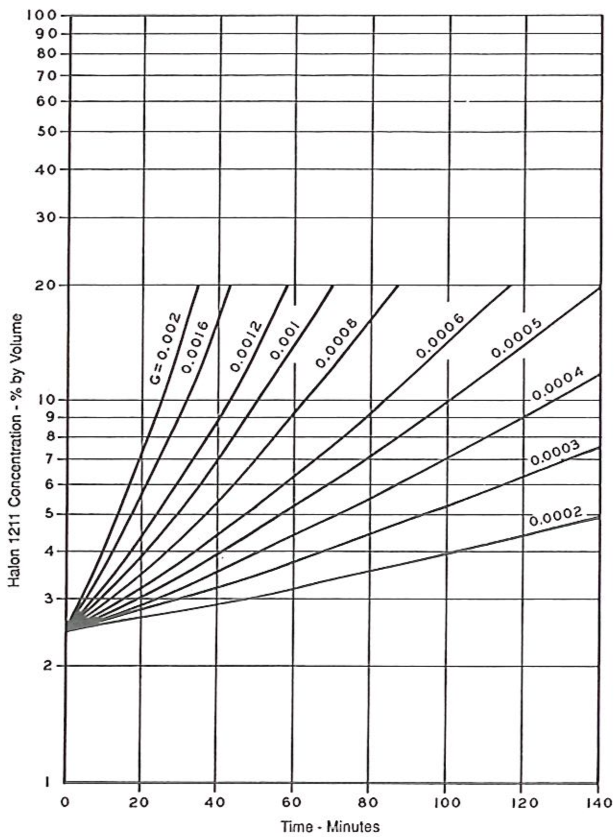


Figure A-2-5.3(b) Initial amounts of Halon 1211 to produce a 2.5% residual concentration in enclosures equipped for mechanical mixing.

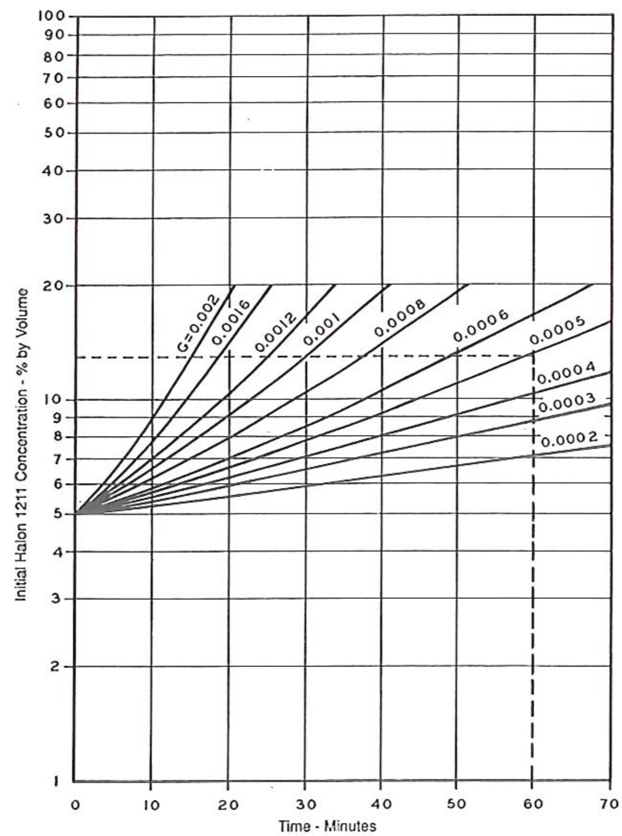


Figure A-2-5.3(c) Initial amounts of Halon 1211 to produce a 5% residual concentration in enclosures equipped for mechanical mixing.

Descending Interface: The design concentration of Halon 1211 is established in the enclosure initially. The time required for the interface to reach halfway down the enclosure height is shown in Figure A-2-5.3(e) as a function of agent concentration and geometrical constant G (defined above).

EXAMPLE: Calculate the time required for the interface of a 5 percent Halon 1211/air mixture to reach the center of a 100,000 cu ft enclosure which has an opening 4 ft wide by 6 ft high along one wall:

$$\text{Calculate } G = \frac{KW}{3V}\sqrt{2g_cH^3}$$

$$= \frac{(0.66)(4)}{(3)(100{,}000)}\sqrt{(2)(32.2)(6)^3}$$

$$= .001$$

From Figure A-2-5.3(e), T = 20 minutes.

EXAMPLE: Calculate the initial concentration of agent required for a final residual concentration of 5 percent after 1 hr, in a 100,000 cu ft enclosure having an opening 4 ft wide by 6 ft high along one wall:

V = 10,000 cu ft
W = 4 ft
H = 6 ft
C_f = 5%
T = 1 hr = 60 min

$$\text{Calculate } G = \frac{KW}{3V}\sqrt{2g_cH^3}$$

$$= \frac{(0.66)(2)}{(3)(100{,}000)}\sqrt{(2)(32.2)(6)^3}$$

$$= .005$$

From Figure A-2-5.3(c), C_o = 13%.

A-2-6.2 Rate of Application.

The minimum rates established are considered adequate respectivelyfor the usual surface or deep-seated fire. However, where the spread of fire may be faster than normal for the type of fire, or where high values or vital machinery or equipment are involved, rates higher than the minimums may, and, in many cases, should be used. Where a hazard contains material that will produce both surface and deep-seated fires, the rate of application should be at least the minimum required for surface fires. Having selected a rate suitable to the hazard, the tables and infor-

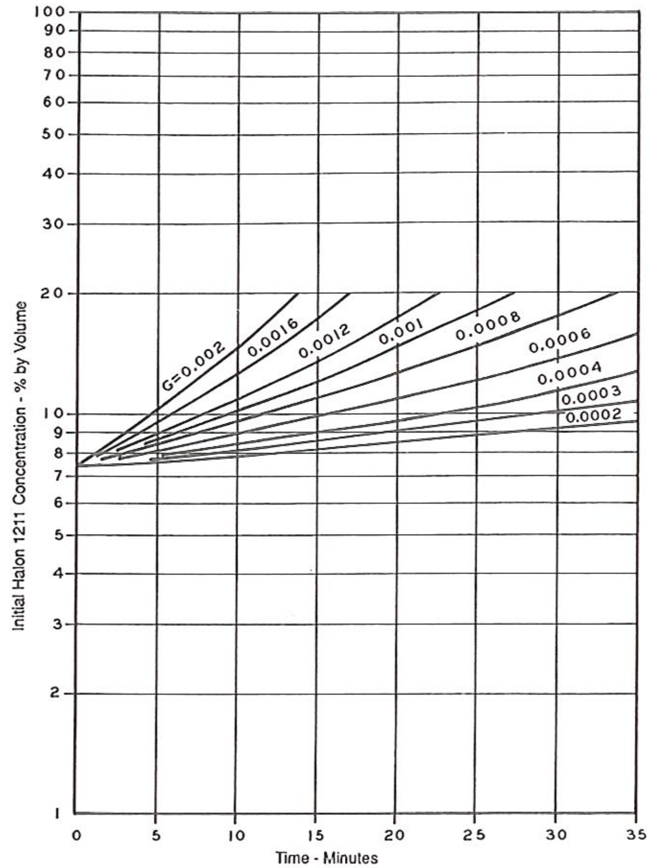


Figure A-2-5.3(d) Initial amounts of Halon 1211 to produce a 7.5% residual concentration in enclosures equipped for mechanical mixing.

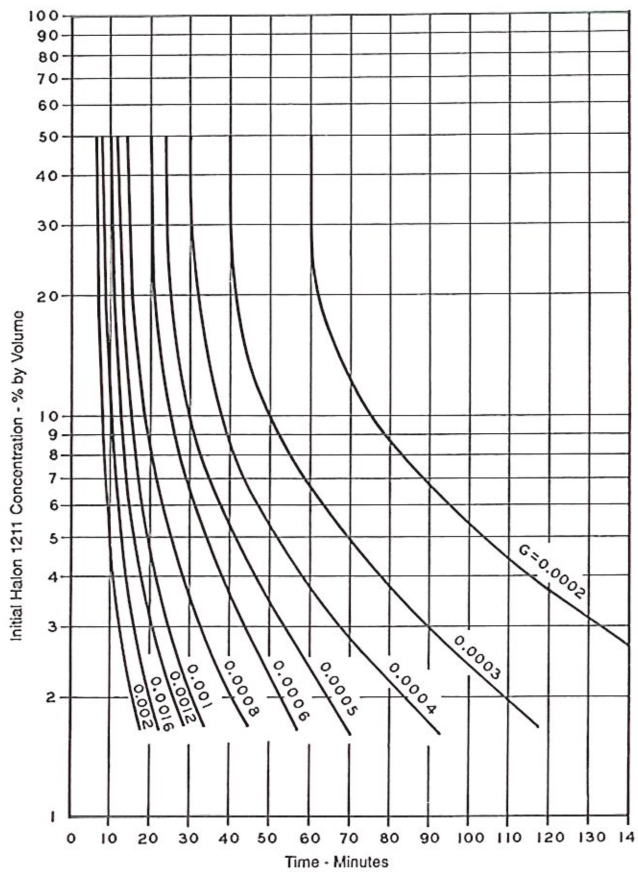


Figure A-2-5.3(e) Time required for interface between effluxing Halon 1211/air mixtures and influxing air to descend to the center of enclosures not equipped for mechanical mixing.

mation given in the standard should be used, or such special engineering as is required should be carried out, to obtain the proper combination of container releases, supply piping, and orifice sizes that will produce this desired rate.

A-2-6.5.2 For a given type of nozzle selection of the appropriate nozzle discharge rate is critical to reducing the potential of damage due to discharging agent. Careful consideration of ceiling type and construction, nozzle discharge characteristics and installation methods is necessary. Maximum flow rates should be based on manufacturers' recommendations.

A-3-1 General Information on Local Application Systems.

A local application Halon 1211 system is designed to apply the agent directly to a fire which may occur in an area or space which has no immediate enclosure surrounding it. Such systems must be designed to deliver Halon 1211 to the hazard being protected in such a manner that the agent will cover all burning surfaces during the discharge of the system.

The flow rate and discharge times will depend on the type of fuel involved, the nature of the hazard, and the location and spacing of the Halon 1211 nozzles.

The important factors to be considered in the design of a local application system are the rate of agent flow, the distance and area limitations of the nozzles, the quantity of Halon 1211 required, and the agent distribution system. The steps necessary to design the system are as follows:

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

2. Based upon the configuration of the hazard, lay out the nozzles to cover the hazard within the limitations shown in the nozzle listings. Based upon the spacing or area coverage, determine the flow rate range within which each nozzle must discharge in order to achieve extinguishment. These parameters will be presented in listing information in a tabular form or by curves similar to those shown in Figures 3-3.2.4, A-3-3(a), A-3-3(b), and A-3-3(c).

In overhead applications the exact shape and relationship of the curves will vary with specific nozzles or hazard sizes. It is essential that in each case information be obtained for the system under consideration. Actual curves may not be symmetrical as shown in Figure A-3-3(a).

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

4. Locate the agent storage container(s), lay out the piping and select the appropriate pipe and nozzle sizes to produce the required rates of Halon 1211 flow.

A-3-3 Halon 1211 Requirements.

The agent requirements for a Halon 1211 local application system do not lend themselves to quantifiable generalization.

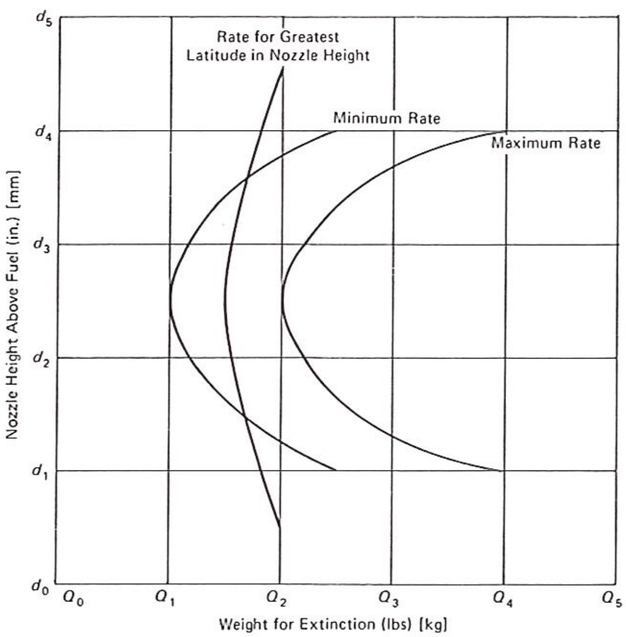


Figure A-3-3(a) Typical agent weight/nozzle height relationship for overhead local application systems.

The effectiveness of a local application system is heavily influenced by the design of the delivery hardware, especially the nozzles. Since each nozzle design has its own performance peculiarities with respect to flow rate and area coverage at various distances from the protected surface, it is essential that nozzles used for this application be limited to those that have been tested and have had their performance parameters listed by a testing laboratory. It is felt that some nozzle characteristics, such as discharge velocities, discharge turbulence, droplet size formation and the companion rate of vaporization influence the effectiveness of a given nozzle as much as mass flow rate and area coverage. Until these characteristics are completely understood and found to be reproducible and predictable, only those nozzles that have been tested within the performance requirements of the anticipated application should be used.

However, in recent experimentation with the Halon 1211 local application systems, a relationship has been found between the agent rate density (Q_m/A) where A is the surface area of the hazard, (*see 3-3.2.3*) and the extinguishment time. The testing was performed with nozzles located in such a manner to provide proper area coverage and no fuel splashing in testing conducted in accordance with the provisions of UL Standard 711, *Classification, Rating and Fire Testing of Class A, B and C Fire Extinguishers and for Class D Extinguishers or Agents for Use on Combustible Metals.*

Typical results of this work conducted with a single nozzle system are shown in Figures A-3-3(d) and A-3-3(e) for overhead application and A-3-3(f) for tankside application. These are examples of the general case shown in Figures A-3-3(a) through A-3-3(c) respectively. In overhead application, the data shown there is a rate density Q_m/A, which allows for the greatest latitude in nozzle height above the hazard so as to eliminate splashing and ensure extinction. The curves also show that there is an optimum nozzle height above the hazard. The height/rate density relationship becomes important where a decreasing freeboard is likely. The information given in Figures A-3-3(d), A-3-3(e), and A-3-3(f) will vary with individual nozzle design, type of fuel, etc., and these figures should not be used as design criteria.

In overhead application freeboard will affect nozzle height selection as shown in Figure A-3-3(g), for a given constant rate density Q_m/A.

In the case of tankside protection, freeboard will affect nozzle selection. It has also been found that nozzle placement should be at the same height as the top of the tank.

Based on this work, systems designed for areas less than 15 sq ft (1.4 m^2) should be designed for 4 seconds or less extinction.

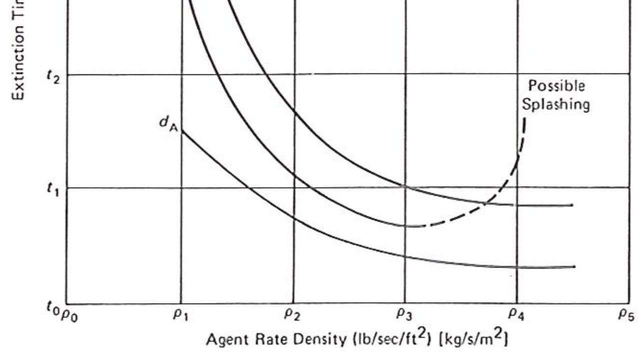


Figure A-3-3(b) Typical agent rate density/extinction time relationship for overhead local application nozzles.

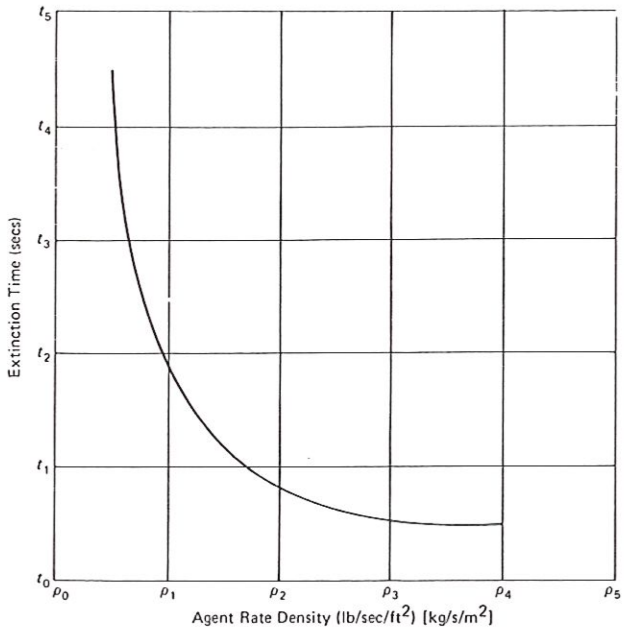


Figure A-3-3(c) **Typical agent rate density/extinction time relationship for tankside local application systems.**

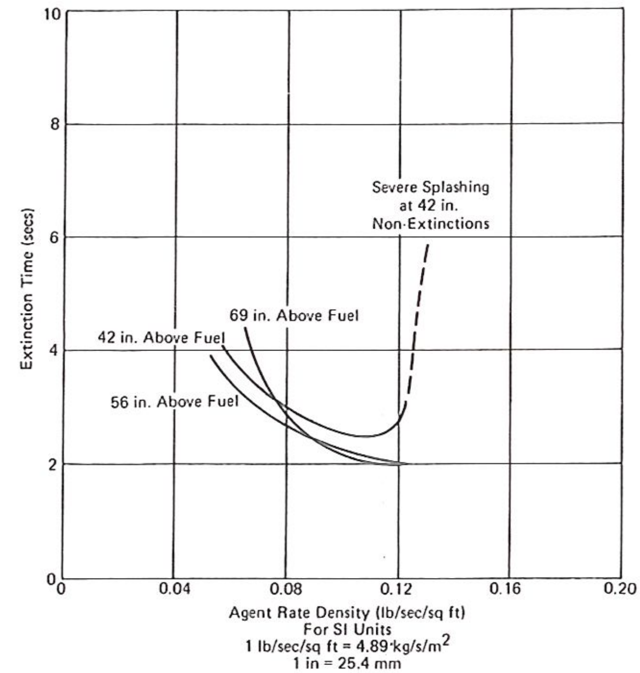


Figure A-3-3(e) **Example of actual results obtained with an overhead nozzle on a 10 sq ft (0.93 m^2) n-Heptane fire with 6-in. (152-mm) freeboard plotted as in Figure A-3-3(b). CAUTION: Actual results will vary with nozzle design, type of fuel, configuration of hazard, etc. This figure should not be used as design criteria.**

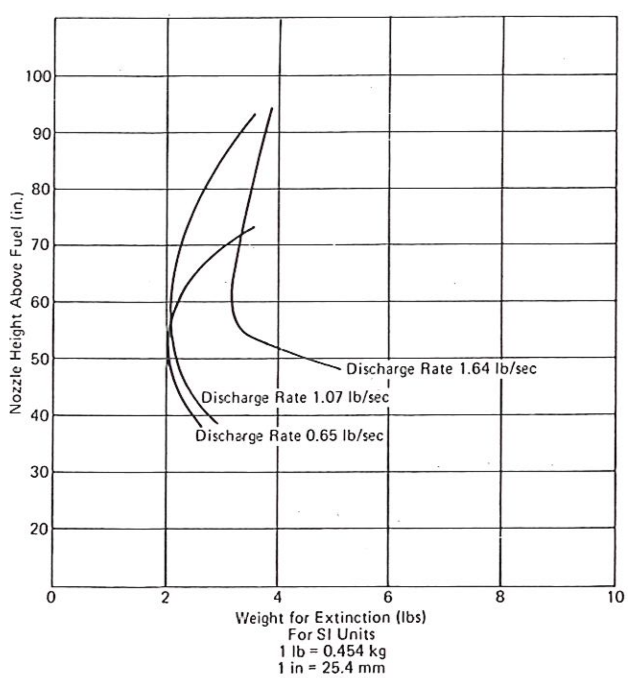


Figure A-3-3(d) **Example of actual results obtained with an overhead nozzle on a 10 sq ft (0.93 m^2) n-Heptane fire with 6-in. (152-mm) freeboard plotted as in Figure A-3-3(a). CAUTION: Actual results will vary with nozzle design, type of fuel, configuration of hazard, etc. This figure should not be used as design criteria.**

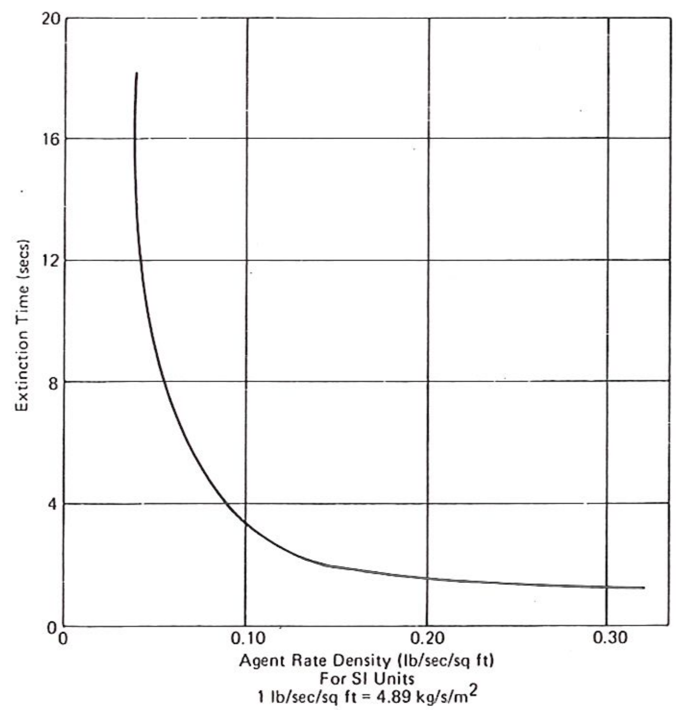


Figure A-3-3(f) **Example of actual results obtained with a tankside nozzle on a 10 sq ft (0.93 m^2) n-Heptane fire with 6-in. (152-mm) freeboard plotted as in Figure A-3-3(c). CAUTION: Actual results will vary with nozzle design, type of fuel, configuration of hazard, etc. This figure should not be used as design criteria.**

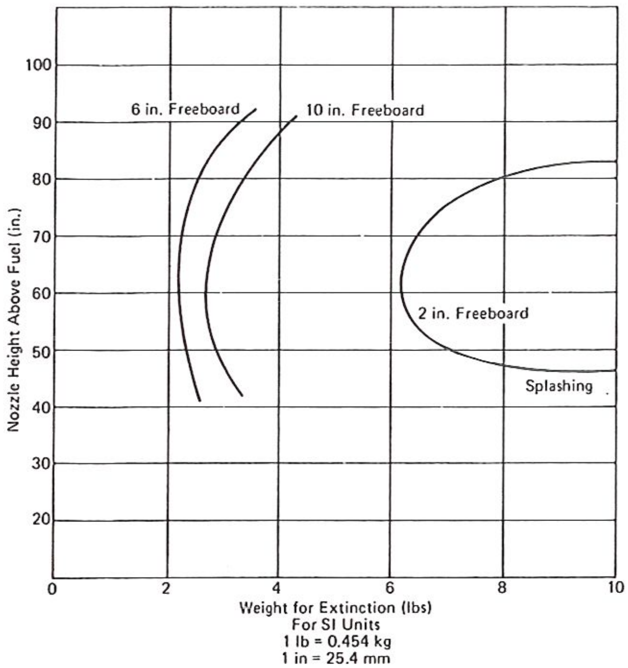


Figure A-3-3(g) Example of actual results obtained with an overhead nozzle on a 10 sq ft (0.93 m²) n-Heptane fire with variable freeboard plotted as in Figure A-3-3(a) but with constant rate of 1.07 lb/seconds (0.49 kg/sec). CAUTION: Actual results will vary with nozzle design, type of fuel, configuration of hazard, etc. This figure should not be used as design criteria.

A-3-3.1.3 When the liquid Halon 1211 flows through the pipeline, a certain amount of the agent will be vaporized if the piping is at a higher temperature than the agent. Since the agent discharge is usually under 10 seconds and the heat transfer is essentially due to conduction, the amount of agent vaporized in the piping is usually quite small. In order to calculate this amount, and accordingly the amount of the agent increase necessary to compensate for this effect, the following relationship is used:

where:

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

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

Due to the very short discharge times for the Halon 1211 systems, it can be assumed that the temperature of the pipe and the temperature of the agent remain constant throughout the discharge. The temperature of the agent for this calculation will be its temperature in the storage container before the discharge is initiated. The temperature of the piping will normally be the ambient temperature in the area where the piping is located. Table A-3-3.1.3 lists the latent heat of vaporization (h) for Halon 1211 at various temperatures.

Table A-3-3.1.3 Latent Heat of Vaporization for Halon 1211

Temperature		Latent Heat (h)	
°F	°C	Btu/lb	kJ/kg
32	0	57.6	134
40	4	56.9	132
50	10	56.1	130
60	16	55.3	129
70	21	54.4	127
80	27	53.5	124
90	32	52.6	122
100	38	51.7	120
110	43	50.7	118
120	49	49.7	116
130	54	48.7	113

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document. These references are listed separately to facilitate updating to the latest edition by the user.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10-1990, *Standard for Portable Fire Extinguishers*

NFPA 12A-1989, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 68-1990, *Guide for Explosion Venting*

NFPA 69-1986, *Standard on Explosion Prevention Systems*

NFPA 72H-1988, *Guide for Testing Procedures for Local, Auxiliary, Remote Station and Proprietary Protective Signaling Systems*

NFPA 77-1988, *Recommended Practice on Static Electricity*

B-1.2 Other Publications.

B-1.2.1 Flame Extinguishment and Inerting References.

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

2. Ford, C. L., "An Overview of Halon 1301 Systems," *Halogenated Fire Suppressants*, ACS Symposium, Series No. 16 (1975), pp. 1-63.

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

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

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

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

7. Data on file at the NFPA.

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