

## Report of Committee on Halogenated Fire Extinguishing Agent Systems

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SCOPE: To develop standards, recommended practices, or manuals on fixed fire extinguishing systems utilizing bromotrifluoromethane and other similar halogenated extinguishing agents, covering the installation, maintenance, and use of such systems.

*This report has been submitted to letter ballot of the Committee which consists of 15 members of whom 13 have voted affirmatively and 2 (Geo. Chamberlain and Alfred J. Millington) have not returned ballots as of the date of this report. Mr. Suchomel has objected to the absence of a specific warning on contamination of food by discharge of these systems. This omission will be given careful consideration at the next meeting of the Committee. Several of the Committee members have made editorial comments which will be incorporated into the standard after full Committee consideration and prior to the time it is submitted for official adoption.*

The Committee has completed work on a proposed Tentative Standard for Halogenated Fire Extinguishing Agent Systems—Halon 1301. This draft of a major extinguishing system standard, was prepared with only one year of work by the Committee, and we will devote some effort to polishing certain portions of the standard during the forthcoming year. It was the strong feeling of the Committee that we should submit a Tentative Standard for approval at the earliest possible date even though we recognized that certain areas of the standard were not yet technically perfect.

The standard follows the same successful arrangement used

by the Carbon Dioxide and Dry Chemical Committees in the preparation of NFPA Standards 12 and 17 respectively. We feel this will make for easier use and adoption. We encourage the study of this proposed Tentative Standard by all concerned and hope that we will get a maximum of feed-back information so that we will be able to propose a revised text for official adoption at the next NFPA Annual Meeting.

**Proposed Tentative Standard on**  
**Halogenated Fire Extinguishing Agent Systems—**  
**Halon 1301**

NFPA No. 12A-T-1968

**Introduction**

**1. Purpose.** This Standard is prepared for use and guidance of those charged with the purchasing, designing, installing, testing, inspecting, approving, listing, operating, and maintaining halogenated agent extinguishing systems (Halon 1301), in order that such equipment will function as intended throughout its life.

Pre-engineered systems (packaged systems) consist of system components designed to be installed according to pretested limitations as approved or listed by a nationally recognized 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 since they are designed for very specific hazards. 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.

**2. Scope.** This standard contains minimum requirements for halogenated agent fire extinguishing systems. It includes only the necessary essentials to make the Standard workable in the hands of those skilled in this field. Portable halogenated agent extinguishers are covered in NFPA No. 10, Installation of Portable Fire Extinguishers, and No. 10A, Maintenance and Use of 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 this equipment to consult with an experienced and competent fire protection engineer in order to effectively discharge their respective duties.

**3. Arrangement.** This Standard is arranged as follows:

Introduction.

Chapter 1—General Information and Requirements.

Chapter 2—Total Flooding Systems.

Chapter 3—Local Application Systems.

Appendix—Explanatory.

Chapters 1 through 3 constitute the body of the Standard and contain the rules and regulations necessary for properly designing, installing, inspecting, testing, approving, operating, and maintaining halogenated agent fire extinguishing systems.

The Appendix contains educational and informative material that will aid in understanding and applying this Standard.

**4. Definitions.** For purpose of clarification, the following general terms used with special technical meanings in this Standard are defined:

**APPROVED** refers to approval by the authority having jurisdiction.

**AUTHORITY HAVING JURISDICTION:** The "authority having jurisdiction" is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure.

**NOTE:** The phrase "authority having jurisdiction" is used in NFPA standards in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local, or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction."

In many circumstances the property owner or his delegated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer, or a departmental official may be the "authority having jurisdiction."

**LISTED** refers to the listing for the use intended, of devices and materials that have been examined by and meet the recognized standards of such testing laboratories as the Factory Mutual Engineering Corporation, the Underwriters' Laboratories, Inc., and Underwriters' Laboratories of Canada. All equipment shall bear a label or some other identifying mark.

**SHALL** is intended to indicate requirements.

**SHOULD** is intended to indicate recommendations 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.

## CHAPTER I. GENERAL INFORMATION AND REQUIREMENTS

### 1100. General Information.

**1110. Scope.** Chapter 1 contains general information, and the design and installation requirements for all features that are generally common to all Halon 1301 (bromotrifluoromethane  $\text{CBrF}_3$ ) systems.

**\*1120. Halon 1301.** Halon 1301 is a colorless, odorless, electrically nonconductive gas that is an effective medium for extinguishing fires.

1121. According to present knowledge Halon 1301 extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. The extinguishing effect due to cooling, or dilution of oxygen or fuel vapor concentration, is minor.

**1130. Use and Limitations.** Halon 1301 fire extinguishing systems are useful within the limits of this Standard in extinguishing fires in specific hazards or equipment, and in occupancies where an electrically nonconductive medium is essential or desirable, where cleanup or other media presents a problem, or where weight vs. extinguishing potential is a factor.

1131. Some of the more important types of hazards and equipment that Halon 1301 systems may satisfactorily protect include:

1. Gaseous and liquid flammable materials.
2. Electrical hazards such as transformers, oil switches and circuit breakers, and rotating equipment.
3. Engines utilizing gasoline and other flammable fuels.
4. Ordinary combustibles such as paper, wood, and textiles.
5. Hazardous solids.

1132. Halon 1301 should not be used to extinguish fires involving the following materials:

1. Chemicals containing their own oxygen supply such as cellulose nitrate.
2. Reactive metals such as sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium.
3. Metal hydrides.

**1140. Types of Systems.** There are two types of systems recognized in this standard:

- Total Flooding Systems.
- Local Application Systems.

1141. A Total Flooding System consists of a supply of Halon 1301 arranged to discharge into, and fill to the proper concentration, an enclosed space or enclosure about the hazard.

1142. A Local Application System consists of a supply of Halon 1301 arranged to discharge directly on the burning material.

**\*1200. Personnel Safety.**

**1210. Hazards to Personnel.** The discharge of Halon 1301 may create hazards to personnel—such as oxygen deficiency and toxic decomposition products.

1211. Safety Requirements. In any proposed use of Halon 1301 where there is a possibility that men may be trapped in or enter into atmospheres made hazardous, suitable safeguards shall be provided to ensure prompt evacuation of and to prevent entry into such atmospheres and also to provide means for prompt rescue of any trapped personnel. Such safety items as personnel training, warning signs, discharge alarms, predischage alarms and breathing apparatus shall be considered.

**1220. Electrical Clearances.** All system components shall be so located as to maintain standard electrical clearances from live parts. See Appendix A for Table of Clearances.

**1300. Specifications, Plans and Approvals.**

**1310. Purchasing Specifications.** Specifications for Halon 1301 fire extinguishing systems shall be prepared with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction. To ensure a satisfactory system, the following items should be included in the specifications.

1311. The specifications should designate the authority having jurisdiction and indicate whether plans are required.

1312. The specifications should state that the installation shall conform to this Standard and meet the approval of the authority having jurisdiction.

1313. The specifications should include the specific tests that may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

1314. These specifications should require the provision of equipment listed for the use intended.

**1320. Plans.** Where plans are required, they shall be prepared with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction.

1321. These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so they can be easily reproduced.

1322. These plans shall contain sufficient detail to enable the authority having jurisdiction to evaluate the hazard or hazards and to evaluate the effectiveness of the system. The detail on the hazards shall include the materials involved in the hazards, the location of the hazards, the enclosure or limits and isolation of the hazards, and the exposures to the hazard.

1323. The detail on the system shall include information and calculations on the amount of Halon 1301; container storage pressure; the location and flow rate of each nozzle including equivalent orifice area; the location, size and equivalent lengths of pipe, fittings and hose; and the location and size of the storage facility. Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used. Sufficient information shall be indicated to identify properly the apparatus and devices used. Any special features should be adequately explained.

**1330. Approval of Plans.** Plans and calculations shall be submitted for approval before work starts.

1331. When field conditions necessitate any material change from approved plans, the change must be approved.

1332. When such material changes from approved plans are made, corrected "as installed" plans shall be supplied to the owner and the authority having jurisdiction.

**1340. Approval of Installations.** The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests shall be adequate to determine that the system has been properly installed and will function as intended. Only listed or approved equipment and devices shall be used in the systems.

1341. Such tests should include a test for tightness up to the selector valve, and for continuity of piping with free unobstructed flow beyond the selector valve. The labeling of devices with proper designations and instructions shall be checked. Operational tests

should be conducted on all devices except cylinder valves in multi-cylinder systems. Where conditions prevail that make it difficult to determine adequately the system requirements of design, a suitable discharge test or concentration analysis should be made (see 1313).

#### **1400. Operation and Control of Systems.**

**1410. Methods of Actuation.** Systems shall be classified as manual or automatic in accordance with the method of actuation.

1411. A manual system is one which is actuated by a person, although it may have other features that are automatic.

1412. An automatic system is one which is actuated by automatic means. Such systems shall also have means for manual actuation.

**1420. Detection of Fires.** Fires or conditions likely to produce fire may be detected by visual (human senses) or by automatic means.

1421. Reliance on visual detection may be used only with permission of the authority having jurisdiction, except in manually actuated systems where fire or conditions likely to produce fire can be readily detected by such means.

1422. 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.

1423. An adequate and reliable source of energy shall be used in detection systems.

#### **1430. AUTOMATIC DETECTION AND OPERATION IS RECOMMENDED.**

**1440. Operating Devices.** Operating devices include Halon 1301 releasing devices or valves, discharge controls, and shutdown equipment, all of which are necessary for successful performance of the system.

1441. Operation shall be by listed or approved mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

1442. 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  $-20^{\circ}\text{F}$  to  $150^{\circ}\text{F}$  or marked to indicate temperature limitations.

1443. 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.

1444. The normal manual control for actuation shall be located so as to be conveniently and easily accessible at all times including the time of fire. This control shall cause the complete system to operate in its normal fashion.

1445. All automatically operated valves controlling the release and distribution shall be provided with approved independent means for emergency manual operation. If the means for manual actuation of the system required in 1422 provides approved positive operation independent of the automatic actuation, it may be used as an emergency means. The emergency means, preferably mechanical, shall be easily accessible and located close to the valves controlled. If possible, the system should be designed so that emergency actuation can be accomplished from one location. This does not require an emergency manual control on "reserve" containers to be connected to the selector valves.

1446. Manual controls shall not require a pull of more than 40 pounds (force) nor a movement of more than 14 inches to secure operation.

1447. Where gas pressure from system supply containers is used as a means for releasing remaining containers and the supply consists of three or more containers, not less than two containers shall be used for such operation.

1448. All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation.

1449. All manual operating devices shall be identified as to the hazard they protect.

**1450. Supervision.** Supervision of automatic systems is required where the possible loss because of any delay in actuation may be high and/or where the detection or control systems are so extensive and complex that they cannot be readily checked by visual or other inspection. When supervision is provided it should be so arranged that there will be immediate indication of failure. The extent and type of supervision shall be approved by the authority having jurisdiction.

**1460. Operating Alarms and Indicators.** Alarms and/or indicators may be needed to indicate the operation of a system, hazards to personnel, or failure of any supervised device or equipment. Such devices should be of such a type and should be provided in such numbers and at such locations as are necessary to accomplish satisfactorily their purpose subject to approval of the authority having jurisdiction. They may be audible, visual, or olfactory.

1461. A positive alarm or indicator should be provided to show that the system has operated.

1462. An alarm should be provided to indicate the operation of automatic systems in case an immediate personnel response is desired.

1463. Alarms should be provided to give positive warning of discharge where hazard to personnel may exist. Such alarms should function to warn against personnel entry into hazardous areas as long as such hazards exist or until such hazards are properly recognized (see 1200).

1464. 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.

#### **1500. Halon 1301 Supply.**

**1510. Quantities.** The amount of Halon 1301 in the system shall be at least sufficient for the largest single hazard protected or group of hazards which are to be protected simultaneously.

1511. Where uninterrupted protection is required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary.

1512. Both primary and reserve supplies for fixed storage shall be permanently connected to the piping and arranged for easy changeover, except where the authority having jurisdiction permits unconnected reserve.

**1520. Quality.** The Halon 1301 quality shall comply with Government Specification MIL-M-12218.

**1530. Replenishment.** The time needed to obtain Halon for replenishment to restore systems to operating condition shall be considered as a major factor in determining the reserve supply needed.

**1540. Storage Container Arrangement.** 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.

1541. Storage containers shall be located as near as possible to the hazard or hazards they protect, but they should not be located where they will be exposed to a fire or explosion in these hazards.

1542. Storage containers should not be located so as to be subject to severe weather conditions or be subject to mechanical, chemical, or other damage.

1543. When excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

**\*1550. Storage Containers.** The Halon 1301 supply shall be stored in containers designed to hold Halon 1301 in liquefied form at atmospheric temperatures.

Containers shall be charged to a filling density between 50 to 75 pounds per cubic feet and super-pressurized with dry nitrogen to 600 psig  $\pm 5\%$ , or 360 psig  $\pm 5\%$  total pressure at 70°F. Containers shall be distinctively and permanently marked with the type and quantity of agent contained therein, together with the degree of super-pressurization.

1551. The Halon 1301 containers used in these systems shall be designed for use at minimum working pressures of 380 psig or 630 psig at 70°F and shall meet the requirements of a nationally recognized testing laboratory. The containers shall also meet the U.S. Department of Transportation or the Canadian Board of Transport Commissioners\* requirements if used as shipping containers. If not a shipping container, it shall be constructed, tested, and marked in accordance with Section 8 of the ASME Unfired Pressure Vessels Code; independent inspection and certification is recommended.

1552. A reliable means of indication, other than weighing, shall be provided to determine the pressurization level of refillable containers.

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\* Sec. 78.36 and 78.37 of Title 49, Transportation, Code of Federal Regulations, Parts 71-78. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401. 601 pages. In Canada the corresponding information is set forth in the "Board of Transport Commissioners of Canada Regulations Governing the Transportation of Dangerous Articles by Rail" available from the Queen's Printer, Ottawa, Ontario, at a cost of \$6.00.

1553. Charged containers shall be tested for tightness before shipment in accordance with an approved procedure. Shipping containers in service shall be hydrostatically retested for continuing service at least every 12 years in accordance with the test procedure and apparatus set forth in the regulations of the U.S. Department of Transportation or Board of Transport Commissioners.

1554. When manifolded, containers shall be adequately mounted and suitably supported in a rack provided for the purpose of including facilities for convenient individual servicing or content weighings. Automatic means shall be provided to prevent the loss from the manifold if the system is operated when any containers are removed for maintenance.

1555. Each system shall have a permanent nameplate specifying the number, filling weight, and pressurization level of the containers.

1556. Only interchangeable containers of one selected size shall be manifolded within a system to provide the required total supply.

1557. Storage temperatures shall not exceed 150°F nor be less than -20°F unless the system is designed for proper operation with storage temperatures outside of this range (see 3421 for additional limitations on local application systems). External heating or cooling may be used to keep the temperature within this range. When special container charges are used, the containers shall be appropriately marked.

## 1600. Distribution Systems.

**1610. Piping.** Piping shall be noncombustible and shall withstand the expected temperatures without detrimental deformation. Iron or steel pipe and fittings preferably should be galvanized inside and out. Copper or brass pipe or tubing may be used without additional corrosion protection. Black steel or ductile iron pipe may be used in noncorrosive atmospheres. Special corrosion-resistant materials or coatings may be required in severely corrosive atmospheres.

1611. Ordinary cast iron pipe and fittings shall not be used.

1612. Welded joints, screwed or flanged fittings (malleable iron, steel, or ductile iron) should be used. Suitable flared or compression type fittings shall be used with copper or brass tubing.

**1620. Arrangement and Installation of Piping and Fittings.** Piping shall be installed in accordance with good commercial prac-

tices. Care shall be taken to avoid possible restrictions due to foreign matter or faulty fabrication or improper installation.

1621. The piping system shall be securely supported with due allowance for expansion and contraction and shall not be subject to mechanical, chemical, or other damage. Where explosions are possible, the piping system shall be hung from supports that are least likely to be displaced.

1622. Pipe shall be reamed and cleaned before assembly and after assembly the entire piping system shall be blown out before nozzles or discharge devices are installed.

1623. 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, means shall be provided to vent any container leakage from the manifold but which will prevent loss of the agent when the system operates.

1624. All pressure relief devices shall be of such design and so located that the discharge therefrom will not injure personnel or be otherwise objectionable.

**1630. Valves.** 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.

1631. Valves shall be protected against mechanical, chemical, or other damage.

1632. 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 include siphon tube, valve, discharge head and flexible connector.

**1640. Discharge Nozzles.** 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.

1641. Discharge orifices shall be of corrosion-resistant metal.

1642. Discharge nozzles used in local application systems should be so connected and supported that they may not readily be put out of alignment.

1643. Discharge nozzles shall be permanently marked to

Identify the nozzle and to show the equivalent single orifice diameter regardless of shape and number of orifices. This equivalent diameter shall refer to the orifice diameter of the "standard" single orifice type nozzle having the same flow rate as the nozzle in question. The marking shall be readily discernible after installation. The

**Table 1. Equivalent Orifice Sizes**

<u>Orifice Code No.</u>	<u>Equivalent Single Orifice Diameter—Inches</u>	<u>Equivalent Single Orifice Area—Sq. In.</u>
_____	.026	.00053
_____	1/16	.00307
_____	.070	.00385
_____	.076	.00454
_____	5/64	.0048
_____	.081	.00515
_____	.086	.00581
3	3/32	.0069
3+	7/64	.0094
4	1/8	.0123
4+	9/64	.0155
5	5/32	.0192
5+	11/64	.0232
6	3/16	.0276
6+	13/64	.0324
7	7/32	.0376
7+	15/64	.0431
8	1/4	.0491
8+	17/64	.0554
9	9/32	.0621
9+	19/64	.0692
10	5/16	.0767
11	11/32	.0928
12	3/8	.1105
13	13/32	.1296
14	7/16	.1503
15	15/32	.1725
16	1/2	.1964
18	9/16	.2485
20	5/8	.3068
22	11/16	.3712
24	3/4	.4418
32	1	.785
48	1 1/2	1.765
64	2	3.14

**NOTE:** The orifice code number indicates the equivalent single orifice diameter in 1/32 inch increments. A plus sign following this number indicates equivalent diameters 1/64 inch greater than that indicated by the numbering system (e. g., No. 4 indicates an equivalent orifice diameter of 4/32 of an inch; a No. 4+, 9/64 of an inch).

“standard” orifice is an orifice having a rounded entry with coefficient of discharge not less than 0.98 and flow characteristics as given in Table 2. For equivalent orifice diameters, the code given in Table 1 may be used.

1644. 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.

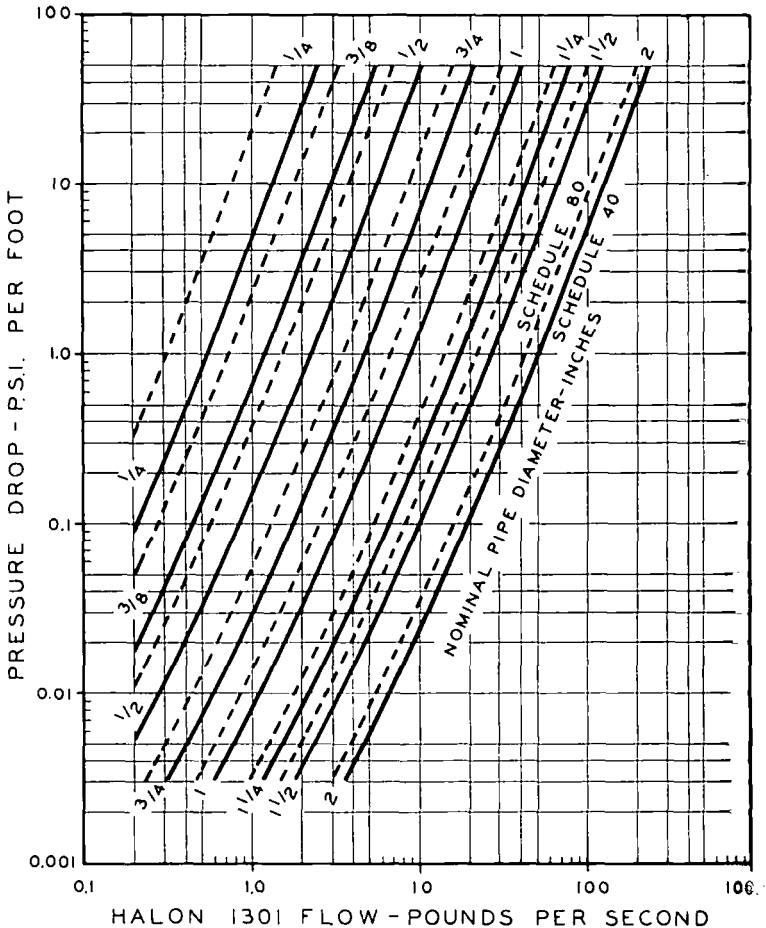


Fig. 1. Pressure drop vs. flow in steel pipe.

**\*1650. Pipe and Orifice Size Determination.** Pipe sizes and orifice areas shall be selected on the basis of calculations to deliver the required rate of flow at each nozzle.

1651. Figures 1 and 2 shall be used to determine the pressure drop in the pipe line: The system shall be designed based on a 70°F ambient temperature.

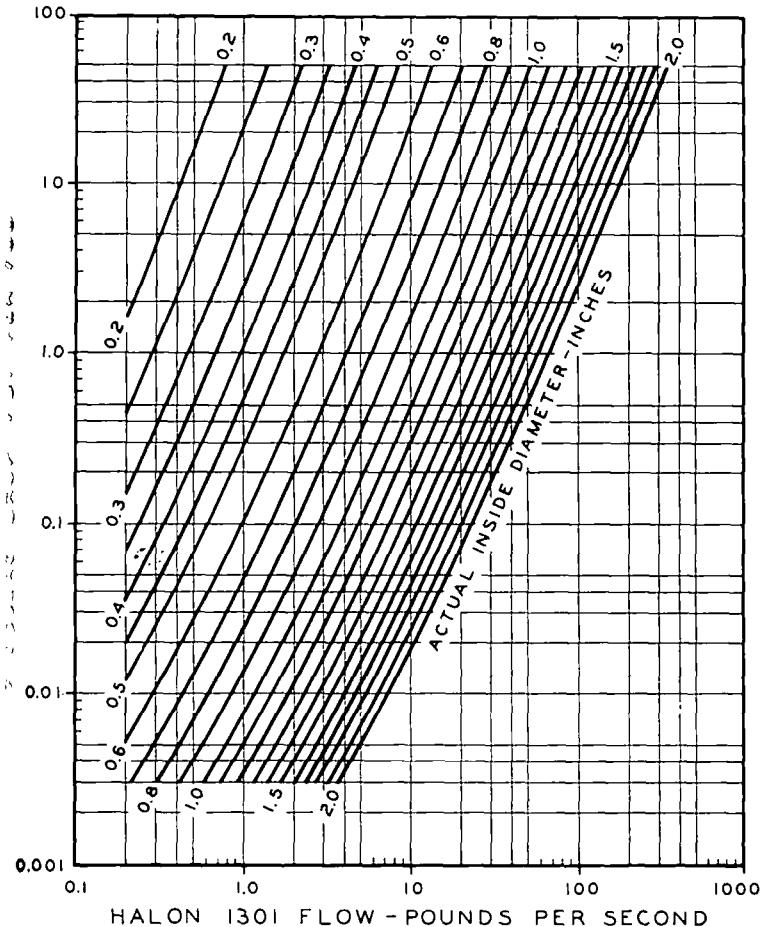


Fig. 2. Pressure drop vs. flow in copper tubing.



1652. Flow shall be calculated on the basis of an average storage pressure of 600 psig or 360 psig (as applicable) during discharge. The discharge rate for equivalent orifices shall be based on the values given in Table 2. Design nozzle pressures should not be less than 200 psig.

**Table 2. Halon 1301**  
**ORIFICE DISCHARGE RATES 70°F TEMPERATURE**

Pressure Above Orifice psig	Discharge Rate, Lb/sec-in <sup>2</sup>	
	At 600 psig Storage Pressure	At 360 psig Storage Pressure
200	14.3	20.8
210	15.5	23.4
220	17.0	26.0
230	18.1	28.7
240	19.6	31.7
250	21.2	34.8
260	22.6	38.2
270	24.2	41.5
280	25.7	45.0
290	27.2	49.1
300	28.7	53.3
310	30.6	57.1
320	32.1	61.6
330	33.6	66.5
340	35.5	71.5
350	37.0	76.6
360	38.9	81.7
370	40.8	
380	42.7	
390	44.6	
400	45.6	
410	48.4	
420	50.2	
430	52.1	
440	54.4	
450	56.3	
460	58.5	
470	60.9	
480	62.7	
490	65.0	
500	67.3	
510	69.5	
520	71.8	
530	74.0	
540	76.4	
550	79.0	
560	81.3	
570	83.5	
580	85.9	
590	88.4	
600	90.6	

**700. Inspection, Maintenance and Instructions.**

**1710. Inspection and Tests.** At least annually, all systems shall be thoroughly inspected and tested for proper operation by a competent inspector. Regular service contracts with the manufacturer or installing company are recommended.

1711. The goal of this inspection and testing shall be not only to ensure that the system is in full operating condition but shall indicate the probable continuance of that condition until the next inspection.

1712. Suitable discharge tests shall be made when inspection indicates their advisability.

1713. The inspection report with recommendations shall be filed with the owner.

1714. Between the regular service contract inspection or tests, the system shall be inspected visually or otherwise by competent personnel, following an approved schedule and procedure.

1715. At least semiannually, the weight and pressure of reliable containers shall be checked. If a container shows a loss in net weight of more than 5 percent or a loss in pressure (adjusted for temperature) of more than 10 percent, it shall be refilled or replaced.

1716. Factory charged nonrefillable containers which do not have a means of pressure indication shall be weighed at least semiannually. If a container shows a loss in net weight of more than 5 percent, it shall be replaced.

1717. The weight and pressure of the container shall be recorded on a tag attached to the container.

**1720. Maintenance.** These systems shall be maintained in full operating condition at all times. Use, impairment, and restoration of this protection should be reported promptly to the authority having jurisdiction.

1721. Any troubles or impairments shall be corrected at once by competent personnel.

**1730. 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

### \*2100. General Information.

**2110. Uses.** This type of system may be used where there is 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.

2111. Total flooding systems provide fire protection with rooms, vaults, enclosed machines, ovens, containers, storage tank and bins.

**2120. 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.

### 2200. Hazard Specifications.

**2210. Types of Fires.** Fires which can be extinguished by total flooding methods may be divided into three categories namely, (1) surface fires involving flammable liquids or solids; (2) gas fires; and (3) deep-seated fires such as can occur with Class A materials subject to spontaneous heating, smoldering and high heat retention.

2211. Surface fires and gas fires are subject to prompt extinguishment when Halon 1301 is quickly introduced into the enclosure in sufficient quantity to provide an extinguishing concentration for the particular materials involved. NFPA No. 69, Inerting for Fire and Explosion Prevention should be referred to when the possibility of flammable concentrations from gas leakage dictate explosion protection techniques.

2212. For deep-seated fires, the required extinguishing concentration shall be maintained for a sufficient period of time to allow the material to cool so that re-ignition will not occur when the inert atmosphere is dissipated. The hazard should be inspected as soon as possible thereafter to make certain that extinguishment is complete.

**2220. Enclosure.** In the design of total flooding systems, the characteristics of the enclosure must be considered as follows:

\*2221. For all three types of fires, the area of unclosable openings shall be kept to a minimum. These openings shall be compensated for by additional quantities of agent according to the design procedures outlined in the Appendix. The authority having

Jurisdiction may require tests to assure proper performance as defined by this standard.

2222. To prevent fire from spreading through openings to adjacent hazards or work areas and to make up for leakage of the agent, openings shall be compensated for with automatic closures, screening nozzles or additional agent, and shall be arranged to operate simultaneously with system discharge. The agent required by screening nozzles shall be in addition to the normal requirement for total flooding. Where reasonable confinement of agent is impracticable, protection shall be extended to include the adjacent hazards or work areas.

2223. For deep-seated fires only, where forced air ventilating systems are involved, they shall be preferably shut down and/or closed before or simultaneously with the start of agent discharge; or, additional compensating gas shall be provided. Refer to Appendix A-2220.

### \*2300. Halon 1301 Requirements for Surface Fires.

2310. **General.** The quantity of Halon 1301 for surface type fires involving flammable gases, liquids and solids is based upon

**Table No. 3**  
**Halon 1301 Design Concentrations**  
**for**  
**Flame Extinguishment**  
**IN AIR AT 1.0 Atm. and 70°F**

<u>Material</u>	<u>Minimum Design Concentration* % by Volume</u>
Commercial Denatured	
Alcohol	4.0
n-Butane	2.9
i-Butane	3.3
Carbon Disulfide	12.0
Carbon Monoxide	1.0
Ethane	3.3
Ethyl Alcohol	4.0
Ethylene	7.2
n-Heptane	3.7
Hydrogen	20.0
Methane	2.0
Propane	3.2
Kerosene	2.8
Petroleum Naphtha	6.6

\* Includes a safety factor of 10 percent minimum above experimental threshold values. For other temperatures or pressures, specific test data shall be obtained.

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

**2320. Flammable Materials.** In the determination of the design concentration of Halon 1301, proper consideration shall be given to the type and quantity of flammable material involved, the conditions under which it normally exists in the hazard, and any special conditions of the hazard itself. For a particular fuel, two minimum levels of Halon 1301 concentration may be used: either is permitted for situations where only flame extinguishment is required; the higher level of concentration shall be used where complete inerting is required to prevent a subsequent reflash or possible explosion.

Appendix A-2300 contains additional guidelines for determining the concentration level which should be selected for a particular hazard.

**2321. Flame Extinguishment Data.** Table No. 3 gives the minimum design concentration required to extinguish normal fires involving certain flammable gases and liquids at atmospheric pressure. These values are permitted if it can be shown that a probable explosive atmosphere cannot exist in the hazard as a result of the fire. An explosion potential is improbable when:

(a) 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 Appendix A-2200.

(b) 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.

**2322. Inerting Data.** Table No. 4 gives flammability peak data obtained with Halon 1301 for several materials. These values shall be used when the conditions of 2321 are not or cannot be met. The concentrations shown are greater than those given in Table No. 3, and are sufficient to "inert" the atmosphere against all proportions of fuel in air. Specifically, they should be used in the following situations:

(a) The quantity of fuel in the enclosure is greater than that permitted in 2321(a).

(b) The volatility of the fuel is greater than that permitted in 2321(b).

(c) 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.

**Table No. 4**  
**Halon 1301 Design Concentrations**  
**for**  
**Inerting**  
IN AIR AT 1.0 Atm. and 70°F

<u>Material</u>	<u>Minimum Design Concentration* % by Volume</u>
Acetone	5.3
Benzene	4.3
i-Butane	8.0
Carbon Disulfide	12.0
Diethyl Ether	6.3
Ethyl Alcohol	4.0
Ethyl acetate	4.6
Ethylene	11.0
Hydrogen	20.0
n-Heptane	8.0
JP-4	6.6
Methane	2.0
i-Pentane	6.3
Propane	6.5

\* For other temperatures or pressures, specific test data shall be obtained.

2323. For materials not given in the above tables, the Halon 1301 design concentration shall be obtained by test of flame extinguishing effectiveness plus a 10 percent minimum safety factor or by determination of the inerting concentration.

2324. For combinations of fuels the values for the fuel requiring the greatest concentration shall be used.

2325. Where gaseous or highly volatile or atomized fuels are expected, additional protective measures such as actuation by hazardous vapor detectors are recommended. NFPA Standard No. 69 covering explosion suppression techniques should also be consulted for such situations.

**2330. Flooding Factors.** Figure 3 gives mass and volume flooding factors for Halon 1301 required to achieve the design concentration within the enclosure. An allowance is included for normal leakage from a "tight" enclosure due to agent expansion. Additional quantities of agent shall be provided to compensate for unclosable openings or forced ventilation. Appendix A-2220 and A-2431 give further information.

**2340. Special Conditions.** Additional quantities of Halon 1301 shall be provided to compensate for any special conditions that adversely affect the extinguishing efficiency. 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.

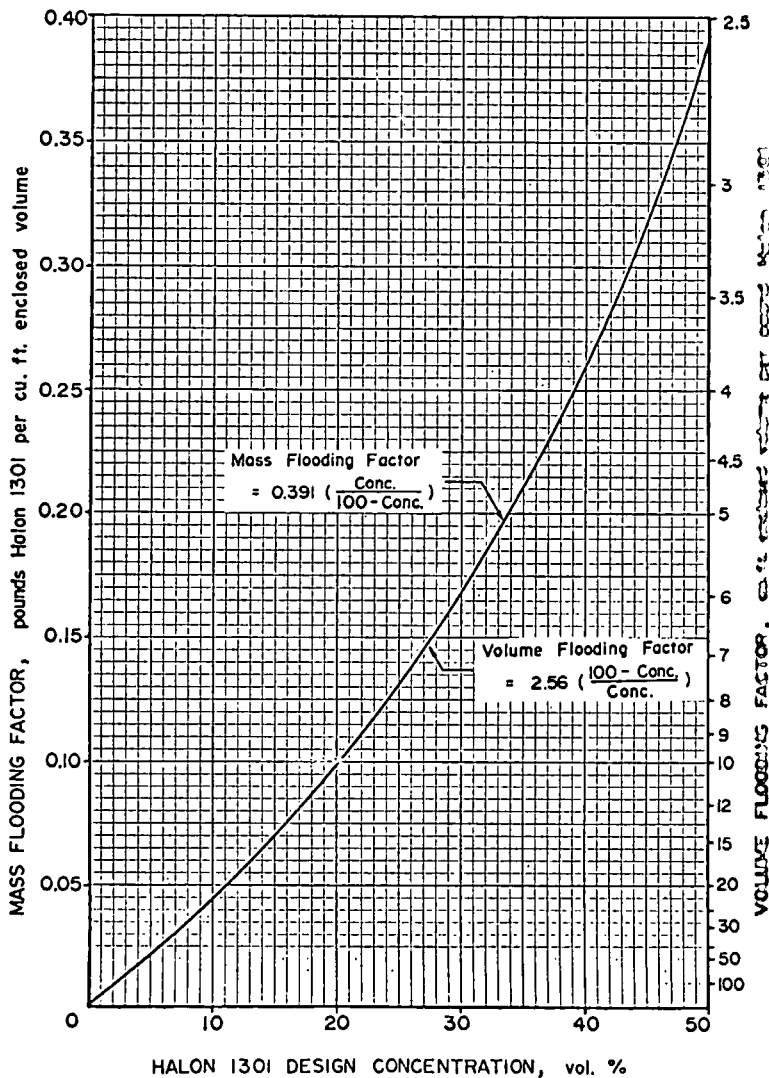


Fig. 3. Flooding factors vs. design concentration.

## 2400. Deep-Seated Fires.

**2410. General.** When Halon 1301 is used for control or extinguishment of deep-seated fires, Appendix A-2032 should be consulted before designing a total flooding system for this type of hazard.

**2420. Considerations.** Four factors shall be considered and their effects controlled for optimum extinguishment. These are: agent concentration, soaking time, fuel arrangement, and detection time.

**2421. Agent Concentration and Soaking Time.** The design concentration and the soaking time required at that concentration are given in Figure 4. These values provide a concentration of agent which will slow the combustion rate sufficiently so that the contained heat can be dissipated to the surroundings within the specified soaking time. To prevent possible re-ignition, the fire site should be inspected prior to reducing the agent concentration to assure that extinguishment is complete.

**\*2422. Fuel Arrangement.** The values in Figure 4 are valid only for a discontinuous fuel array. In situations in which the fuel arrangement would tend to prevent heat dissipation, the agent concentration and/or soaking time shall be increased.

**2423. Detection.** Many deep-seated fires can be reduced in severity by proper selection of a detection system. A system capable of detecting a fire in its earliest stages is strongly recommended.

## 2430. Special Conditions.

**\*2431.** Any openings which cannot be closed automatically shall require an initial excess or extended discharge in a quantity sufficient to maintain the agent concentration above the design level for the entire soaking period.

**2432.** The curve in Figure 4 shows that the effectiveness increases as the agent concentration is increased. Therefore, it is recommended that the highest agent concentration that can be tolerated from practical considerations be employed.

## 2500. Distribution System.

**2510. General.** The distribution system for applying Halon 1301 to enclosed hazards shall be designed with due consideration for the materials involved, the type of burning expected, and the nature of the enclosure. These factors all may affect the discharge times and rates of application.



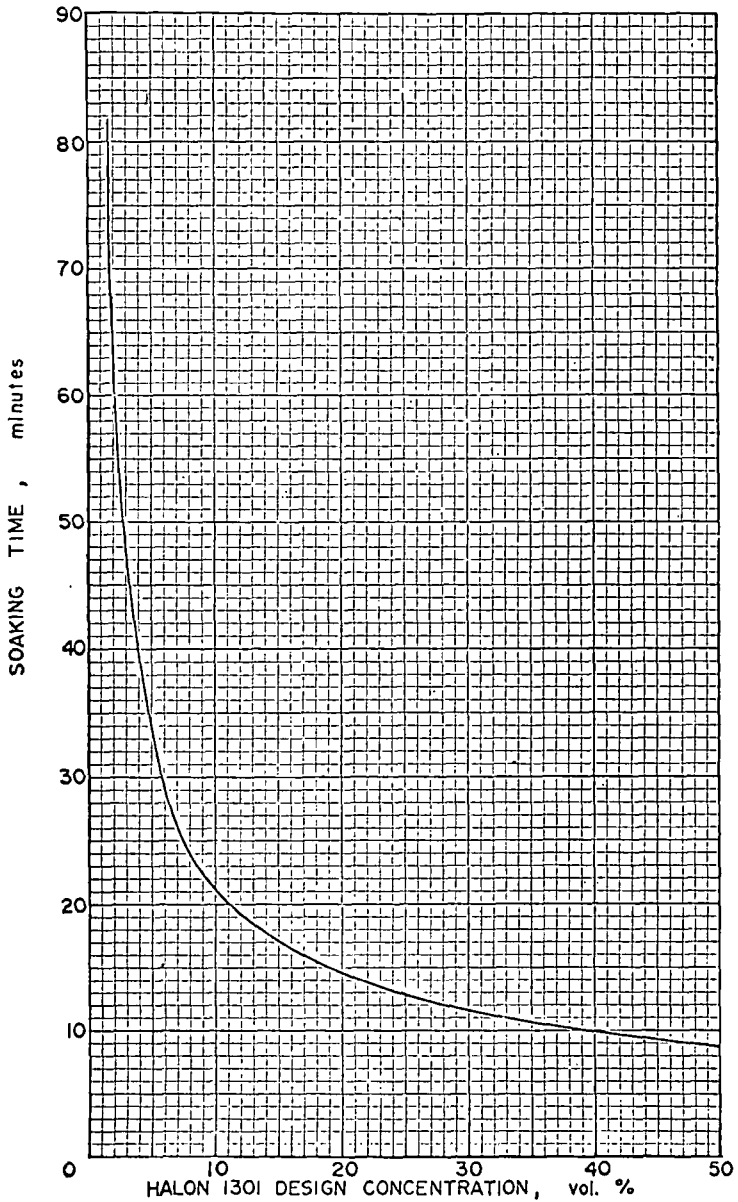


Fig. 4. Soaking time vs. design concentration for deep-seated fires.

**\*2520. Rate of Application.** 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.

2521. The design concentration shall be achieved in 30 seconds or a shorter period if practicable.

**2530. Extended Application Rate.** 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.

2531. This type of application is particularly suitable to enclosed rotating electrical apparatus, such as generators, motors and convertors, and also may be needed for total flooding protection of deep-seated fires.

2532. The design concentration shall be initially obtained within the time limits specified in 2520.

2533. The rate of extended discharge shall be sufficient to maintain the desired concentration for the duration of application.

**2540. 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.

**2550. Nozzle Choice and Location.** 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.

2551. 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.

## **2600. Venting Consideration.**

**2610. General.** Venting of an enclosure may be necessary to relieve pressure build-up due to the discharge of large quantities of Halon 1301. Appropriate pressure relief depends on the injection rate of the Halon 1301 and enclosure strength.

**2620. Pressure Relief Venting.** Porosity and leakages such as around doors, windows and dampers, though not readily apparent

or easily calculated, will usually provide sufficient relief for Halon 1301 flooding systems without need for additional venting. Record storage rooms, refrigerated spaces and duct work also generally need no additional venting.

2621. For very tight enclosures, the area necessary for free venting may be calculated from the following formula, taking the specific volume of Halon 1301 vapor at 70°F to be 2.56 cubic feet per pound:

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

x—Free venting area, sq. in.

Q—Halon 1301 injection rate, lb. per sec.

p—Allowable strength of enclosure, lb. sq. ft.

**Table No. 5**

**Strength and Allowable Pressures for Average Enclosures**

<u>Type Construction</u>	<u>Windage miles/hour</u>	<u>PRESSURE</u>		
		<u>lb/sq. ft.</u>	<u>In Water</u>	<u>psf</u>
Light Building	100	25*	5	.175
Normal Building	140	50†	10	.35
Vault Building	200	100	20	.70

\* Venting sash remains closed.

† Venting sash designed to open freely.

2622. 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.

2623. Table 5, based on general construction practices, provides a guide for considering the normal strength and allowable pressures of average enclosures.

## CHAPTER 3. LOCAL APPLICATION SYSTEMS.

### 3100. General Information.

**3110. Uses.** Local application systems may be used for the extinguishment of surface fires in flammable liquids, gases, and solids where the hazard is not enclosed or where the enclosure does not conform to the requirements for total flooding. Where deep-seated fires are expected, the requirements of Chapter 2 apply.

3111. 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, etc.

**3120. 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.

### 3200. Hazard Specifications.

**3210. Extent of Hazard.** 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.

3211. A series of interexposed hazards may be subdivided into smaller groups or sections with the approval of the authority having jurisdiction. Systems for such hazards shall be designed to give immediate independent protection to adjacent groups or sections as needed.

**3220. 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.

### 3300. Halon 1301 Requirements.

**3310. General.** 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 blanket the area or volume pro-

tected and the time that the discharge must be maintained to assure complete extinguishment.

3311. The computed quantity of agent shall be increased by 25 percent to determine nominal container storage capacity since only the liquid portion of the discharge is effective. This increase is not required for the total flooding portion of combined local application and total flooding systems.

3312. Where long pipelines are involved or where the piping may be exposed to higher than normal temperatures, the system shall be designed to compensate for liquid vaporized in the piping.

**3320. Rate of Discharge.** Nozzle discharge rates shall be determined as outlined below:

3321. If a part of the hazard is to be protected by total flooding, the discharge rate for the total flooding part shall be computed by multiplying the quantity required for total flooding by the factor 0.80 and dividing by the time of the local application discharge,

$$R_F = \frac{0.80Q_F}{T_0}$$

where  $R_F$  = rate of flow for the total flooding portion in pounds per second.

$Q_F$  = total quantity of Halon 1301 for the total flooding portion in pounds.

$T_0$  = liquid discharge time for the local application portion in seconds.

3322. The minimum design rate ( $R_o$ ) shall be two times the minimum rate for extinguishment ( $R_m$ ) independent of time, i.e.,

$$R_o = 2 R_m$$

The minimum design quantity ( $Q_o$ ) shall be two times the minimum quantity ( $Q_m$ ) required for extinguishment at any selected design rate. The minimum design time ( $T_o$ ) shall be determined by dividing the design quantity ( $Q_o$ ) by the design rate ( $R_o$ ) (see Figure 5).

3323. The basis for system design for overhead nozzles shall be a family of curves defining the extinguishing parameters of the nozzles at respective heights above the flammable liquid surface in the form shown by Figure 5.

3324. The basis for system design for tankside nozzles shall be a curve defining the extinguishing parameters of the nozzles in the form shown by Figure 5.

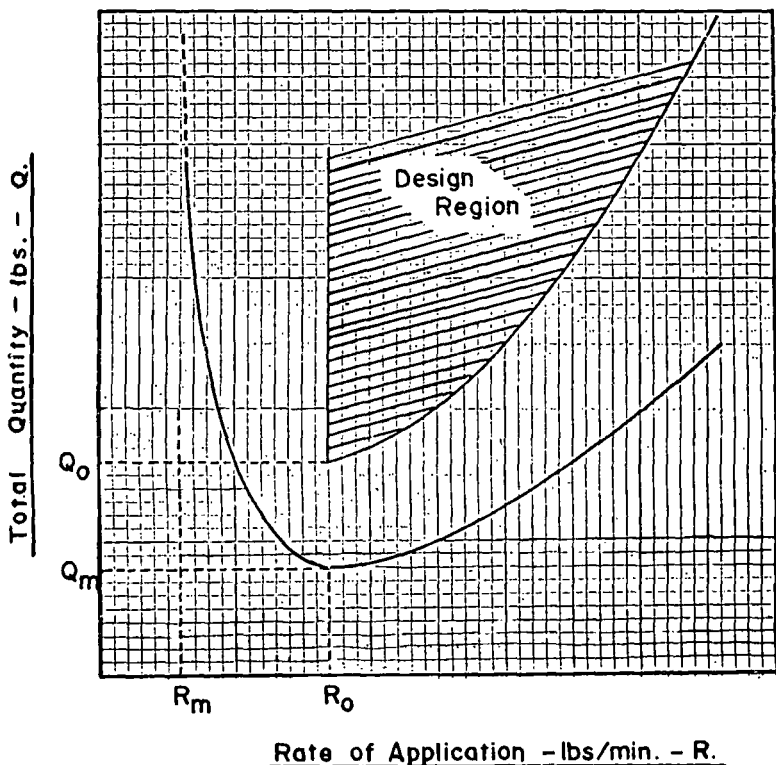


Fig. 5. Typical data presentation for local application nozzles.

3325. The curves described in 3331 and 3332 and related information on nozzle discharge pattern shall be determined by a nationally recognized testing laboratory.

3326. Where there is a possibility that metal or other material may become heated above the ignition temperature of the fuel, the effective discharge time shall be increased to allow adequate cooling time. This is especially important with paraffin wax and other materials having low auto-ignition temperatures.

3327. 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.

**3330. Area Per Nozzle.** The maximum area protected by each nozzle shall be determined on the basis of nozzle discharge pattern, distance from the flammable liquid surface, and the design discharge rate in accordance with listings of a nationally recognized testing laboratory.

3331. When coated rollers or other similar irregular shapes are to be protected, the projected wetted area may be used to determine nozzle coverage.

3332. When deep layer flammable liquid fires are to be protected, a minimum freeboard of 6 inches shall be provided unless otherwise noted in approvals or listings of nozzles.

**3340. Location and Number of Nozzles.** 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.

3341. Tankside or linear type nozzles shall be located in accordance with spacing and discharge rate limitations stated in nozzle listings.

3342. Overhead type nozzles shall be installed perpendicular to the hazard and centered over the area protected by the nozzle. They may also be installed at other angles to the surface in accordance with nozzle listings.

3343. Nozzles shall be located so as to be free of possible obstructions that could interfere with the proper projection of the discharged agent.

3344. Nozzles shall be located so as to develop an extinguishing concentration over coated stock or other hazard extending above a protected surface.

3345. 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.

#### **3400. Distribution System.**

**3410. General.** The system should be designed to provide an effective discharge of agent promptly before excessive amounts of heat can be absorbed by materials within the hazard.

3411. The agent supply should be located as near to the hazard as possible, and yet not exposed to the fire, and the pipelines should be as direct as possible so as to minimize the delay in the initial discharge of the agent.

**3420. Piping Systems.** Piping shall be designed in accordance with 1650 to deliver the required rate of application at each nozzle.

3421. Container storage temperatures shall be within a range from  $+32^{\circ}\text{F}$  to  $+150^{\circ}\text{F}$  unless special methods of compensating for changing flow rates are provided.

**3430. Discharge Nozzles.**

3431. The equivalent orifice size used in each nozzle shall be determined in accordance with 1650 to match the design discharge rate.

3432. Nozzles shall be accurately located and directed in accordance with the system design requirements as covered in 3300.



**APPENDIX**

THE FOLLOWING APPENDIX MATERIAL IS PROVIDED TO EXPLAIN THE BASIC PRINCIPLES, AGENT AND EQUIPMENT CHARACTERISTICS, AND MAINTENANCE AND INSTALLATION PRACTICES.

**A-1100. 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 ( $\text{CH}_4$ ) or ethane ( $\text{CH}_3\text{CH}_3$ ), are replaced with halogen atoms, the chemical and physical properties of the resulting compound are markedly changed. Methane, for example, is a light, flammable gas. Carbon tetrafluoride ( $\text{CF}_4$ ) is also a gas, is chemically inert, nonflammable and extremely low in toxicity. Carbon tetrachloride ( $\text{CCl}_4$ ) 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 ( $\text{CBr}_4$ ) and carbon tetraiodide ( $\text{CI}_4$ ) 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, increase the fire extinguishing effectiveness of the compound. Although a very large number of halogenated compounds exist, only the following five are used to a significant extent as fire extinguishing agents:

Halon 1011, bromochloromethane,  $\text{CH}_2\text{BrCl}$

Halon 1211, bromochlorodifluoromethane,  $\text{CBrClF}_2$

Halon 1202, dibromodifluoromethane,  $\text{CBr}_2\text{F}_2$

Halon 1301, bromotrifluoromethane,  $\text{CBrF}_3$

Halon 2402, dibromotetrafluoroethane,  $\text{CBrF}_2\text{CBrF}_2$

**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.) Examples of this numbering system are:

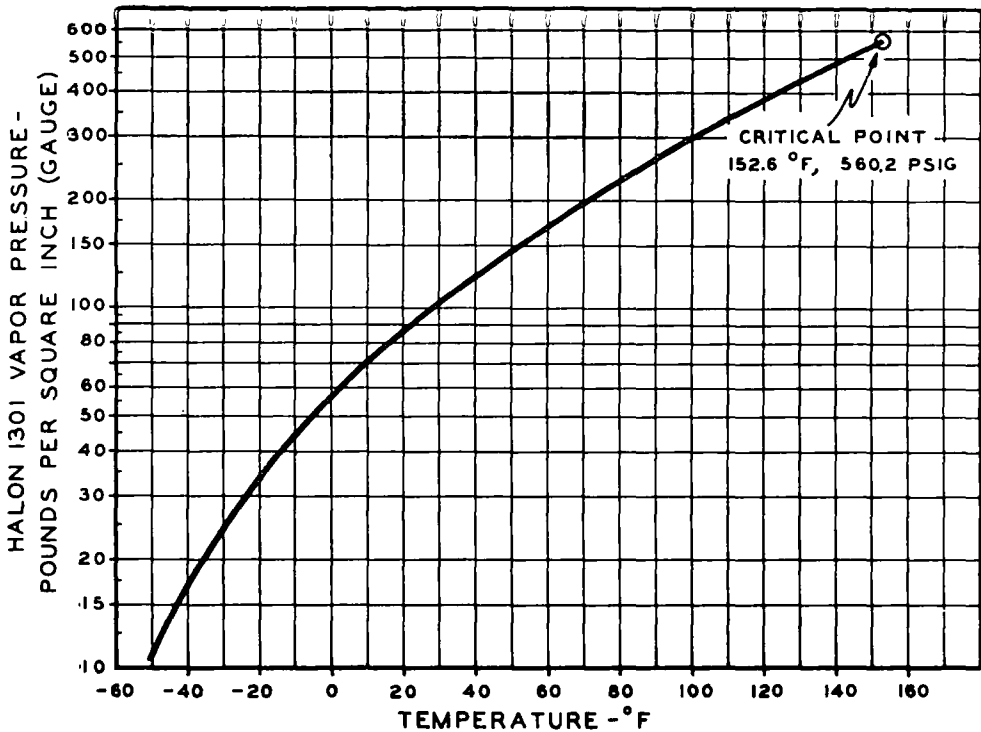


Fig. A-1. Vapor pressure of Halon 1301 vs. temperature.

<u>Chemical Name</u>	<u>Chemical Formula</u>	<u>Halon Number</u>
Methyl fluoride	CH <sub>3</sub> F	11
Methyl chloride	CH <sub>3</sub> Cl	101
Methyl bromide	CH <sub>3</sub> Br	1001
Methyl iodide	CH <sub>3</sub> I	10001
Dichlorodifluoromethane	CCl <sub>2</sub> F <sub>2</sub>	122
Chlorobromomethane	CH <sub>2</sub> ClBr	1011
Dibromodifluoromethane	CBr <sub>2</sub> F <sub>2</sub>	1202
Bromochlorodifluoromethane	CBrClF <sub>2</sub>	1211
Bromotrifluoromethane	CBrF <sub>3</sub>	1301
Dibromotetrafluoroethane	CBrF <sub>2</sub> CBrF <sub>2</sub>	2402

#### A-1120. Halon 1301.

Halon 1301 chemically is bromotrifluoromethane, CBrF<sub>3</sub>. Its cumbersome chemical name is often shortened to "bromotri" or even further to "BT." The compound is used as a low-temperature refrigerant and as a cryogenic fluid, as well as a fire extinguishing agent.

#### A-1121. Physical Properties.

A list of important physical properties of Halon 1301 is given in Table A-1. Under normal conditions, Halon 1301 is a colorless, odorless gas with a density approximately 5 times that of air. It can be liquefied upon compression for convenient shipping and storage. Unlike carbon dioxide, Halon 1301 cannot be solidified at temperatures above -270°F.

The variation of vapor pressure with temperature for Halon 1301 is shown in Figure A-1. As the temperature is increased, the vapor pressure and vapor density increase and the liquid density decreases, until the critical temperature of 152.6°F is reached. At this point the densities of the liquid and vapor phases become equal and the liquid phase ceases to exist. Above the critical temperature, the material behaves as a gas, but it can no longer be liquefied at any pressure.

#### A-1122. Fire Extinguishment Characteristics.

Halon 1301 is an effective fire extinguishing agent that can be used on many types of fires. It is effective in extinguishing surface fires, such as flammable liquids, and on most solid combusti-

**Table A-1**  
**Physical Properties of Halon 1301**

Molecular Weight	148.93
Boiling Point at 1 atm. °F	-71.95
°C	-57.75
Freezing Point, °F	-270.
°C	-168.
Critical Temperature, °F	152.6
°C	67.0
Critical Pressure, psia	575.
atm.	39.1
Critical Volume, cu. ft. per lb.	0.0215
Critical Density, lb. per cu. ft.	46.5
g/cc	0.745
Specific Heat, Liquid (Heat Capacity) at 77°F, Btu/lb.-°F	0.208
Specific Heat, Vapor, at constant pressure (1 atm) 77°F Btu/lb.-°F	0.112
Heat of Vaporization at Boiling Point, Btu/lb.	51.08
Thermal Conductivity of Liquid at 77°F, Btu/hr.-ft.-°F	0.025
Viscosity, Liquid at 77°F, centipoise	0.15
Viscosity, Vapor, at 77° F, centipoise	0.016
Surface Tension at 77°F, dynes/cm	4.
Refractive Index of Liquid at 77°F	1.238
Relative Dielectric Strength at 1 atm, 77°F (Nitrogen = 1)	1.83
Solubility of Halon 1301 in Water at 1 atm, 77°F, wt. %	0.03
Solubility of Water in Halon 1301 at 70°F, wt. %	0.0095

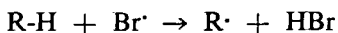
ble materials except for a few active metals and metal hydrides, and materials which contain their own oxidizer, such as cellulose nitrate, gunpowder, etc.

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

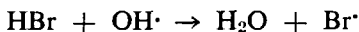


Two inhibiting mechanisms have been proposed, one which is based on a free radical process, and another based on ionic activation of oxygen during combustion.

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



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



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

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

#### A-1200. Hazards to Personnel.

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

**Natural or Undecomposed Halon 1301.** Undecomposed Halon 1301 has been determined to be safe to humans in concentration up to about 10 percent by volume in air for short exposures. Exposure of humans to higher concentrations has not been reported. Much greater exposure levels have been found nonlethal to animals, with an approximate lethal concentration (ALC) of 832,000 ppm (83.2%) by volume for a 15 minute exposure. Anesthetic effects have been reported in animals at concentrations above 30 percent, and a similar effect on humans has been found beginning at about 7½ percent. Underwriters' Laboratories, Inc., has classified Halon 1301 in Group 6, their least toxic classification, which requires that the compound not produce injury to test animals as a result of a 2-hour exposure to a concentration of 20% by volume pounds are given in Table A-2.

Halon 1301 is colorless and odorless. Discharge of the agent

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

Perhaps the greatest hazard to personnel from natural Halon 1301 is dilution of oxygen. Concentrations above 20 percent will reduce the oxygen concentration in air below the 16 percent level necessary to sustain life. The concentrations used for total flooding are usually well below this level. However, the high density of Halon 1301 vapor (5 times that of air) requires the use of discharge nozzles that will achieve a well-mixed atmosphere in order to avoid local pockets of higher concentration. It is also possible to develop local pockets of higher concentration in pits or low-lying areas adjacent to local application systems. Once mixed into the air, the agent will not settle out.

#### A-1202. Decomposition Products of Halon 1301.

Although the vapors of natural Halon 1301 are low in toxicity, the products of decomposition can present a hazard to personnel. At about 900°F, Halon 1301 becomes unstable and breaks down in the presence of moisture to give, predominantly, hydrogen fluoride (HF), free bromine (Br<sub>2</sub>), and carbonyl halides (C<sub>2</sub>O<sub>2</sub>F<sub>2</sub> and C<sub>2</sub>O<sub>2</sub>Br<sub>2</sub>). ALC values for 15 minute exposures to these compounds are given in Table A-2.

Table A-2

#### Approximate Lethal Concentrations for Predominate Halon 1301 Decomposition Products

<u>Compound</u>	<u>ALC for 15 Minute Exposure ppm by volume</u>
Hydrogen fluoride, HF	2500
Bromine, Br <sub>2</sub>	550
Carbonyl fluoride, C <sub>2</sub> O <sub>2</sub> F <sub>2</sub>	1500
Carbonyl bromide, C <sub>2</sub> O <sub>2</sub> Br <sub>2</sub>	100-150*

\* Value is for carbonyl chloride, C<sub>2</sub>O<sub>2</sub>Cl<sub>2</sub> (phosgene); value for carbonyl bromide is not available.

ALC values of 2500 ppm to 20,000 ppm have been reported for Halon 1301 decomposition products, based on the amount of agent decomposed.

The decomposition products of Halon 1301 have a characteristic sharp, acrid odor, even in minute concentrations of only a few parts per million. This characteristic provides a built-in warning system for the agent, but at the same time creates a noxious, irritating atmosphere for those who must enter the hazard following the fire.

The amount of Halon 1301 which can be expected to decompose in extinguishing a fire depends to a large extent upon the size of the fire, the size of the enclosure, and the rapidity with which the agent is discharged. For example, extinguishment of a 25 square foot heptane fire in a 10,000 cubic foot enclosure within 0.5 seconds produced only 12 ppm HF. A similar test having an extinguishment time of 10 seconds produced an average HF level of 250 ppm over a 9 minute period. Equivalent tests taking up to one minute for extinguishment would probably produce an atmosphere which would be quite hazardous to personnel. From this standpoint, it is advantageous to employ the most rapid detection system possible and to discharge the agent in the minimum possible time.

#### **A-1211. Safety Requirements.**

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

1. Provision of adequate aisleways and routes of exit and keeping them clear at all times.
2. Provision of the necessary additional and/or emergency lighting and directional signs to ensure quick, safe evacuation.
3. Provision of alarms with such areas that will operate immediately upon detection of the fire. For design concentrations of Halon 1301 above 20 percent by volume, the discharge of Halon 1301 and the activation of automatic door closures should be delayed for sufficient time to evacuate personnel from the area.
4. Provision of only outward swinging self-closing doors at exits from hazardous areas, and, where such doors are latched, provision of panic hardware.
5. Provision of continuous alarms at entrances to such areas until the atmosphere has been restored to normal.
6. Provision of warning and instruction signs at entrances to and inside such areas.
7. 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 men equipped with proper breathing equipment. Self-contained breathing equipment and personnel trained in its use, and in rescue practices, including artificial respiration, should be readily available.

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

9. Provision of means for prompt ventilation of such areas. Forced ventilation will often be necessary. Care should be taken to locally dissipate hazardous atmospheres and not merely move them to another location. Halon 1301 is heavier than air.

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

#### A-1220. Electrical Clearance.

The clearances in Table A-3 were obtained from the National Electrical Code and publications of the National Electrical Manufacturers Association (NEMA).

**Table A-3**  
**Minimum Clearance of System Components**  
**from**  
**Live Electrical Apparatus**

Line Voltage	Distance (in.)	Line Voltage	Distance (in.)
600 or less	1*	92,000	30
2,500	2*	115,000	37
5,000	3*	138,000	44
15,000	6	161,000	52
25,000	8	196,000	63
34,500	12	230,000	76
46,000	15	287,000	98
69,000	23	345,000	120

\* For interior dry locations.

NOTE: With the exception of those marked with an asterisk, the clearances given are for transformers operating at altitudes of 3,300 feet or less. For operation at altitudes in excess of 3,300 feet, the clearance shall be increased at the rate of 1 percent per 330 feet increase in altitude in excess of 3,300 feet.

#### A-1550. Storage Containers.

Storage containers for Halon 1301 must be capable of withstanding the total pressure exerted by the Halon 1301 vapor plus the nitrogen partial pressure, at the maximum temperature con-



templated in use. Generally, steel cylinders meeting the U.S. Department of Transportation requirements will be used to contain quantities up to about 100 pounds Halon 1301, 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 1301 at the required rate. Containers with top-mounted valves require an internal dip tube extending to the bottom of the cylinder to permit discharge of liquid phase Halon 1301.

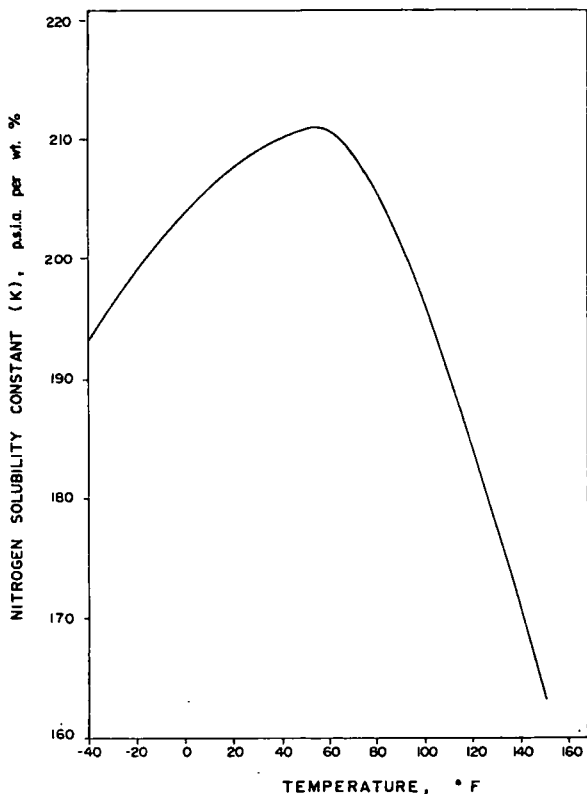


Fig. A-2. Nitrogen solubility constant in liquid Halon 1301.

**Nitrogen Superpressurization.** Although the 199 psig vapor pressure of Halon 1301 at 70°F is adequate to expel the contents of the storage containers, this pressure decreases rapidly with temperature. At 0°F, for example, the vapor pressure is 56.6 psig, and at -40°F it is only 17.2 psig. The addition of nitrogen to Halon 1301 storage containers to pressurize the agent above the vapor pressure, called "super-pressurizing," will prevent the container pressure from decreasing so drastically at low temperatures. In

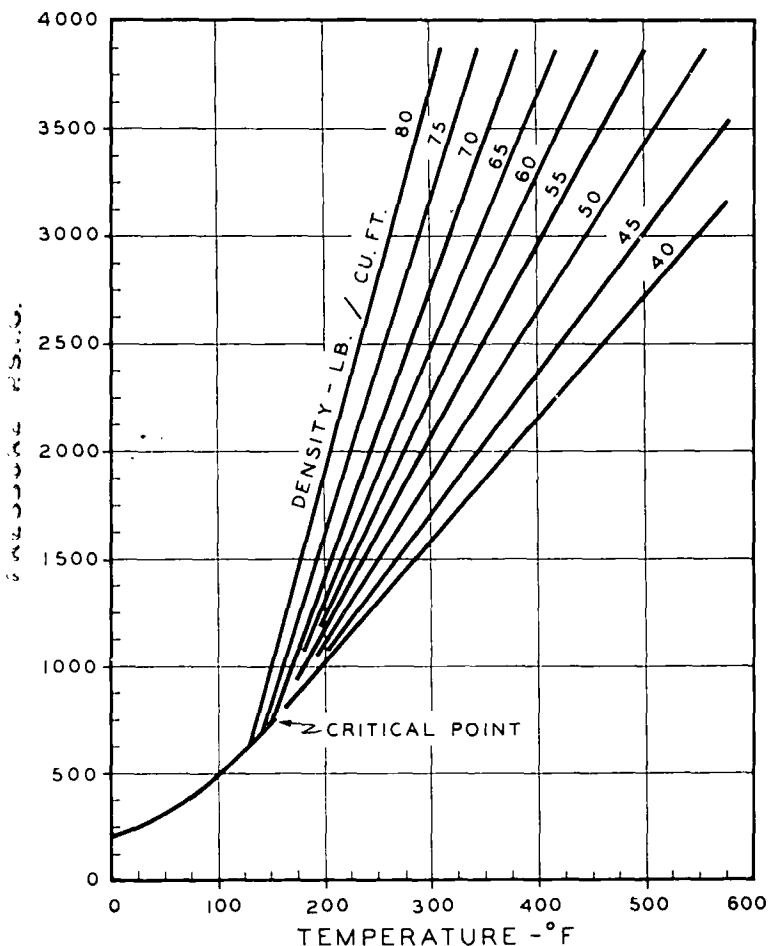


Fig. A-3. Isometric diagram. Halon 1301 pressurized to 360 psig at 70° F.

addition, it will maintain the agent in the liquid state during flow through pipelines, provided the pipeline pressure does not drop below the vapor pressure of the agent. This latter characteristic permits greatly simplified pressure drop-vs-flow calculations in the design of Halon 1301 discharge systems.

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

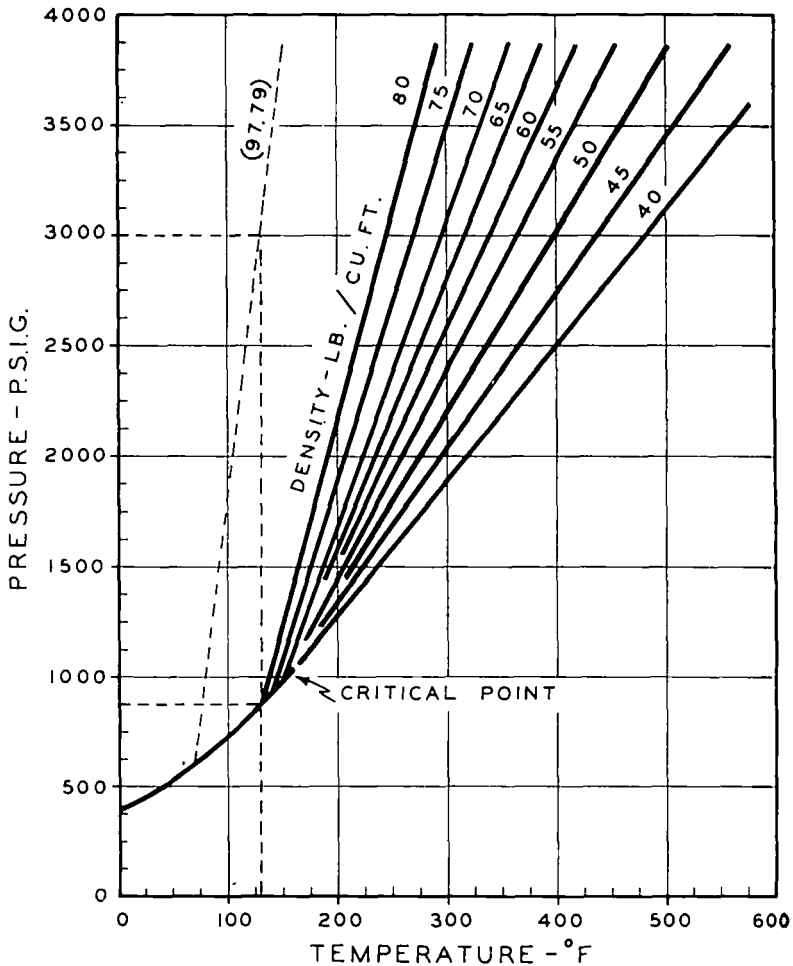


Fig. A-4. Isometric diagram. Halon 1301 pressurized to 600 psig at 70° F.

$$\text{Solubility (wt. \%)} = \frac{P_n}{K}$$

$P_n$  = nitrogen superpressure, psia

or,  $P_n$  = (total pressure, psia) - (Halon 1301 vapor pressure, psia)

$K$  = solubility constant, psia per wt. %

Figure A-2 shows the variation of the solubility constant,  $K$ , with temperature.

### Filling Density

The filling density of a container is defined as the number of pounds of Halon 1301 per cubic foot of contained volume. Iso-metric diagrams for Halon 1301 superpressurized with nitrogen—Figures A-3 (360 psig total pressure at 70°F) and A-4 (600 psig total pressure at 70°F)—show the relationship of storage container pressure vs. temperature with lines of constant fill density.

These curves demonstrate the danger in overfilling containers with Halon 1301. A container filled completely with liquid Halon 1301 at 70°F (97.79 lbs per cu. ft.) and subsequently superpressurized to 600 psig would develop a pressure of 3000 psig when heated to 130°F; if filled to 75 lb/cu. ft. or less as permitted in this standard, a pressure of only 875 psig would be developed. The same principles apply to liquid Halon 1301 that becomes trapped between two valves in pipelines. Adequate pressure relief should always be provided in such situations.

### A-1650. Piping Flow Characteristics.

Piping must be designed to handle the required flow of agent, utilizing the following maximum available pressure drops from storage container to nozzle:

360 psig Storage Pressure: 160 psi.

600 psig Storage Pressure: 400 psi.

Allowance must be made for the equivalent lengths of the container valve, dip tube, and flexible connectors, selector valves, time delays, and other installed equipment through which the agent must flow. Equivalent lengths for these components must be obtained from the approval laboratory listings for the individual components. Equivalent lengths of common pipe fittings and valves are given in Tables A-4 and A-5.

Changes in elevation are accounted for by subtracting 0.68 psi for each foot above the storage container (or by adding, if below) from the available pressure drop.

**Table A-4**  
**Equivalent Length in Feet of Threaded Pipe Fittings**  
**Schedule 40 Steel Pipe**

<b>Pipe Size, in.</b>	<b>Elbow Std. 45°</b>	<b>Elbow Std. 90°</b>	<b>Elbow 90° Long Rad. &amp; Tee Thru Flow</b>	<b>Tee Side</b>	<b>Union Coupling or Gate Valve</b>
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-5**  
**Equivalent Length in Feet of Welded Pipe Fittings**  
**Schedule 40 Steel Pipe**

<b>Pipe Size, in.</b>	<b>Elbow Std. 45°</b>	<b>Elbow Std. 90°</b>	<b>Elbow 90° Long Rad. &amp; Tee Thru Flow</b>	<b>Tee Side</b>	<b>Gate Valve</b>
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-1720. Maintenance.**

The entire fire extinguishing system should be completely inspected at least annually. More frequent general inspections 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 must be reset and reinstalled after testing.

**2. Agent Supply.**

- A. All containers shall be weighed to determine the contents of the container. Any container showing a loss of more than 5 percent of the marked net contents shall be refilled or replaced.
- B. Containers shall be examined for evidence of corrosion or mechanical damage.
- C. When required (see paragraph 1552) the pressure within the container shall be checked against the marked pressure. If the pressure (corrected for temperature) within

the container varies more than 10 percent from the marked pressure the container shall be refilled or replaced.

- D. Container bracketing, supports, etc., should be checked to determine that their condition is satisfactory.

### 3. Piping and Nozzles.

- A. Piping should be examined for any evidence of corrosion.
- B. Pipe hangers and/or straps should be examined to see that the piping is securely supported.
- C. Nozzles should be checked to determine that the orifices are clear and unobstructed.
- D. Where nozzle seals are provided, they should be checked for signs of deterioration, and replaced if necessary.
- E. Nozzles should be checked for proper position and alignment.

### 4. Auxiliary Equipment.

- A. All auxiliary and supplementary components such as switches, door and window releases, interconnected valves, damper releases, supplementary alarms, etc., should be manually operated (where possible) to ensure that they are in proper operating condition.
- B. All devices should be returned to normal "standby" condition after testing.

## A-2100. General Information on Total Flooding Systems.

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

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

The volume of Halon 1301 required to develop a given concentration will be greater than the final volume remaining in the enclosure. In most cases, Halon 1301 must be applied in a manner that promotes progressive mixing of the atmosphere. The displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents, as Halon 1301 is injected. Some Halon 1301 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 1301/air mixture lost in this manner contains the final design concentration of Halon 1301. This represents the worst case from a theoretical standpoint, and provides a built-in safety factor to compensate for non-ideal discharge arrangements.

The volume of Halon 1301 required to develop a given concentration in the enclosure is given by the following equation:

$$x = \frac{C}{100 - C}$$

where  $x$  = cu. ft. of Halon 1301 injected  
per cu. ft. enclosed volume

$C$  = concentration of Halon 1301, percent by vol.

The specific volume of Halon 1301 vapor at 70°F and 1.0 atm is 2.56 cu. ft. per pound. From the preceding equation, the mass and volume flooding factors may be calculated:

$$F_m = \frac{x}{v} = 0.391 \left( \frac{C}{100 - C} \right)$$

$$F_v = \frac{v}{x} = 2.56 \left( \frac{100 - C}{C} \right)$$

where  $v$  = specific volume of Halon 1301  
vapor, cu. ft. per pound

$F_m$  = mass flooding factor, pounds  
Halon 1301 injected per cu. ft.  
enclosed volume

$F_v$  = volume flooding factor, cu. ft.  
enclosed volume per pound Halon 1301

The curve of flooding factor vs. concentration given in Chapter 2, Fig. 3, is based on expansion of Halon 1301 at 70°F. For other design temperatures, the proper flooding factor may be calculated from the above equations, using the proper value of specific volume.

#### A-2221. Effects of Ventilation.

NOTE: See A-2431 for treatment of Halon 1301 leakage through enclosure openings.

Halon 1301 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 1301 discharge rate required to develop a given concentration of



agent at any given time after start of discharge is as follows:

$$R = \frac{0.00391 C E}{1 - e^{-\frac{E}{V}T}}$$

Where  $R$  = Halon 1301 discharge rate, lbs. per sec.

$C$  = Halon 1301 concentration, percent by volume

$E$  = Ventilation rate, cu. ft. per sec.

$V$  = Enclosure volume, cu. ft.

$T$  = time, sec.

$e$  = natural logarithm base, 2.71828

The Halon 1301 discharge rate necessary to maintain a given concentration of agent is given by the equation

$$R = 0.00391 E C$$

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

$$C = C_0 e^{-\frac{E}{V}T}$$

Where  $C_0$  = Agent concentration at end of discharge, percent by volume.

$T$  = time after stopping discharge, sec. Other variables as described above.

EXAMPLE 1: In a 10,000 cu. ft. enclosure which is ventilated with 2 air changes per minute, calculate the discharge rate and quantity of Halon 1301 required to develop a 5 percent concentration in 30 seconds.

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

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

$$C = 5\%$$

$$\begin{aligned} R &= \frac{0.00391 C E}{1 - e^{-\frac{E}{V}T}} \\ &= \frac{(0.00391) (5) (333)}{1 - e^{-\frac{(333)}{(10,000)}(30)}} \\ &= \frac{6.5}{(1 - .369)} \\ &= 10.3 \text{ lbs/sec.} \end{aligned}$$

$$Q = Rt = (10.3) (30) = 309 \text{ lbs.}$$

**EXAMPLE 2:** After achieving a 5 percent concentration of Halon 1301 in the above example, calculate the continuous discharge rate necessary to maintain the agent concentration at 5 percent:

$$\begin{aligned} R &= .00391 (333) (5) \\ &= 6.5 \text{ lb/sec} \end{aligned}$$

### A-2300. Halon 1301 Requirements for Surface Fires.

Two basic types of extinguishment data have been obtained for Halon 1301:

- (1) flame extinguishment data, which determine the agent concentration necessary to extinguish a flame of a particular fuel.
- (2) inerting data, which determine the minimum agent concentration to suppress propagation of a flame front at the "flammability peak," or stoichiometric fuel/air composition.

Flame extinguishment data generally relate closest to the concentration actually required in a fire extinguishing system. The measurements are often made with pan fires on a large scale, so that realistic conditions exist. The concentration requirements for large scale fires have been found to be the same as determined from small-scale pan fires in laboratory apparatus, provided the test conditions do not permit a significant amount of oxygen depletion before or during the extinguishment test. Agent concentrations obtained by this type of test are characteristically 20 to 50 percent lower than concentrations required for complete inerting.

In inerting measurements, a fuel/air/agent mixture is contained in a test chamber, such as an explosion burette, and an ignition source is activated. If the mixture cannot support a flame front, the mixture is considered to be nonflammable. The results may be plotted as shown in Figure A-5.

The normal flammability range which exists when no agent is present is shown at the left-hand side of the graph. As Halon 1301 is added to the system, the flammability range is reduced until it finally disappears entirely. The agent concentration at which this occurs is called the "flammability peak" concentration. All fuel-air mixtures containing concentrations of agent equal to or greater than the flammability peak value are nonflammable, hence the term "inert."

The choice between using the flame extinguishing concentration or the inerting concentration for a given fuel depends upon (1) the volatility characteristics of the fuel, (2) the quantity of fuel present, and (3) the conditions of use in the hazard. Applying Halon 1301 at the flame extinguishment concentration to actual fires will effectively extinguish the fire at no sacrifice in the reliability of the

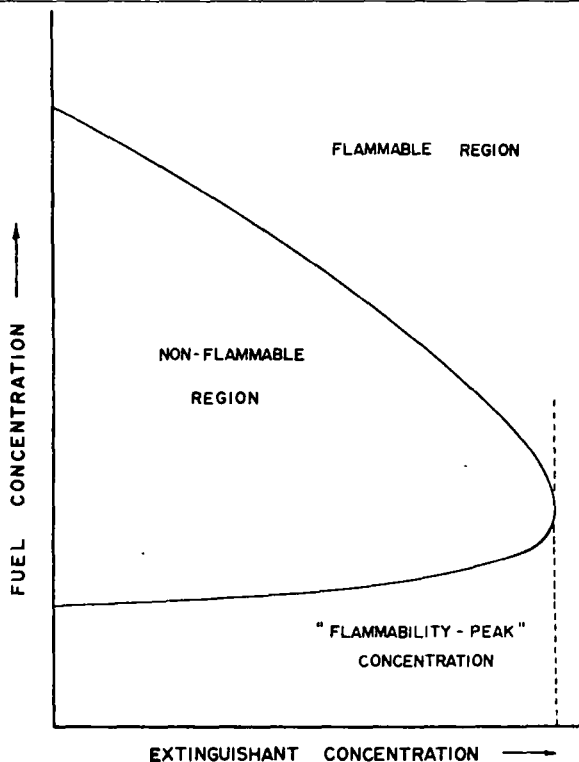


Fig. A-5. Typical flammability-peak presentation.

system. It is desirable to use this lower concentration when possible because of the following advantages:

- (1) The cost of the system will be correspondingly lower.
- (2) Reduced concentration to which personnel will be (advertently) exposed.
- (3) The level of decomposition products formed from breakdown in the fire will likely be lower.

The danger in supplying this lower concentration is that some time after extinguishment, a flammable concentration of fuel in 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 persistence of the fire, and other materials which may become heated or involved in the fire, must be taken into account. If the volume

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:

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

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

MW = molecular weight of fuel

T = temperature, °F

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-6 lists quantities for several fuels, to which an arbitrary safety factor of 3 has been applied. Greater safety factors may be required by individual situations.

Table A-6

Quantity of Fuel Required to Achieve 1/2 of Lower Explosive Limit in Air at 1.0 Atm. and 70°F

<u>Material</u>	<u>Fuel Quantity, lbs. per cu. ft. enclosed volume</u>
Commercial denatured alcohol	.0021
n-Butane	.0014
Isobutane	.0016
Carbon disulfide	.00099
Carbon monoxide	.0045
Ethane	.0012
Ethyl alcohol	.0018
Ethylene	.0020
n-Heptane	.0016
Hydrogen	.00011
Methane	.0011
Propane	.0013
Petroleum naphtha	.0016

**A-2400. Deep Seated Fires.**

No firm basis, either theoretical or empirical has as yet been determined to enable generalized prediction of the requirement for extinguishment of deep seated fires.

The soaking time required for extinguishment will be dependent on the concentration used and this relationship will in turn be dependent on the heat balance of the fuel array.

To form a basis for estimating requirements presupposes some knowledge of what the fire will be, for example, how deep seated is it. This can vary widely between fuel ignited on the surface and fuel which becomes ignited due to internal self-heating. The length of time that the material burns before suppression is initiated will also bear on the requirements for suppression. The fact that in many cases the fuel cannot be described as a fixed, nonchanging array further complicates the problem.

The questions in system design become: What is the desired end result? What is the required level of confidence and probability that the desired effect will be accomplished?

**A-2422. Fuel Arrangement.**

The rate at which heat may be dissipated from a deep-seated fire after the oxidation reaction of the fire has been stopped will depend largely upon the heat transfer characteristics from the fuel bed to the surroundings. Since radiation is an important heat transfer mechanism at temperatures encountered in a fire, the arrangement of the fuel is an important variable. Figure 4 in Chapter 2 is based on fuel arrays which are discontinuous, i.e., do not contain extensive plane surfaces in close proximity. For continuous arrays, the Halon 1301 concentration/soaking time requirements may be considerably greater than indicated.

**A-2431. Leakage of Halon 1301 Through Enclosure Openings.**

NOTE: See A-2220 for effects of forced ventilation.

Halon 1301 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

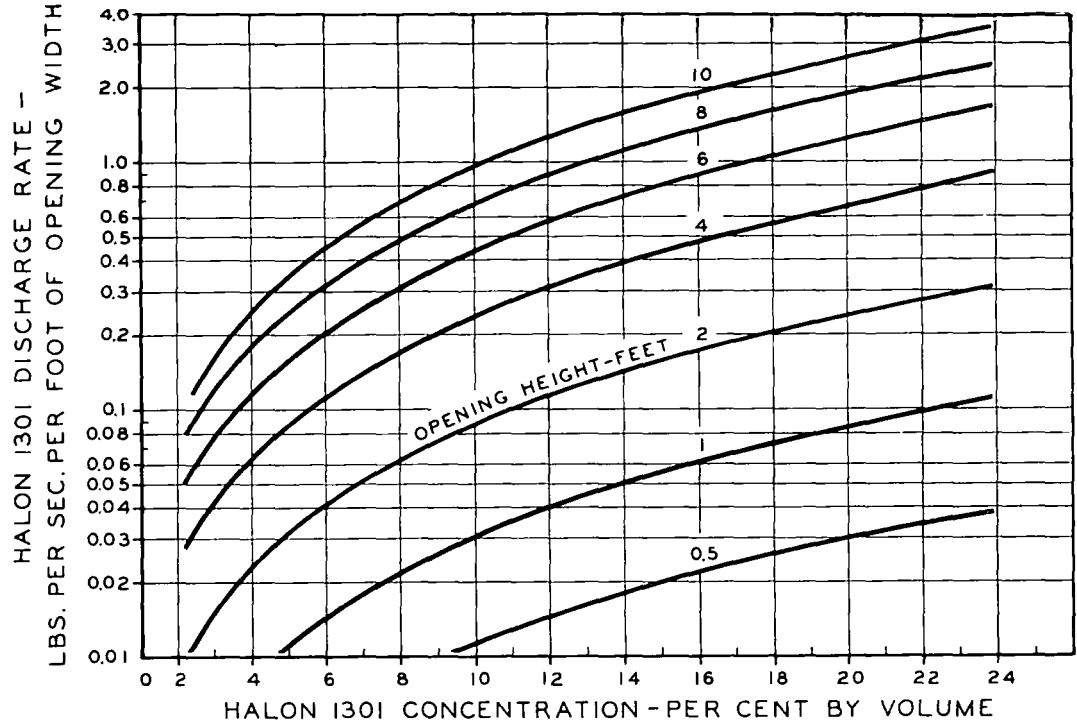


Fig. A-6. Extended discharge rate of Halon 1301 to maintain constant concentrations in enclosures with openings.

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 1301.

(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 1301 in enclosure at any given time, and by volume.

C<sub>0</sub> = Initial concentration of Halon in enclosure, percent by volume.

d = Overall height of the enclosure, ft.

g<sub>c</sub> = Gravitational acceleration = 32.2 ft/sec.<sup>2</sup>

H = Height of opening, ft.

K = Orifice discharge coefficient (Assumed equal to 0.66 for normal doors, windows, etc.)

R<sub>t</sub> = Halon 1301 discharge rate, lb/sec.

T = Period of extended protection (from end of initial discharge), sec.

V = Volume of enclosure, ft<sup>3</sup>.

W = Width of opening, ft.

G = A geometric constant, equal to  $\frac{KW}{3V} \sqrt{2g_c H^3}$

**Extended Agent Discharge.** Halon 1301 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-6 gives the Halon 1301 makeup rate per unit open-

ing width required to maintain a specified concentration in the enclosure, for various values of opening height.

(EXAMPLE: Calculate the Halon 1301 makeup rate required to maintain a concentration of 5 percent by vol. in an enclosure, one wall of which has an opening 4 ft. wide by 6 ft. high:

From Figure A-6,  $R/W = 0.16$  lb/sec.-ft.

$$R = (0.16) (4) = 0.64 \text{ lb/sec.}$$

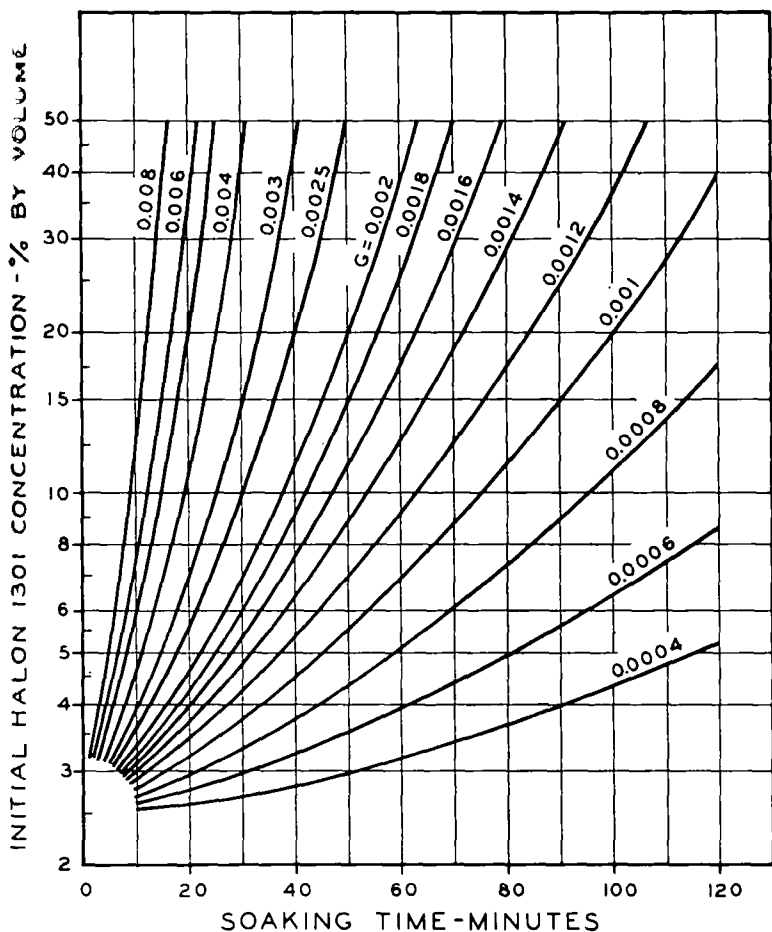


Fig. A-7. Initial amounts of Halon 1301 to produce a 2.5% residual concentration in enclosures equipped for mechanical mixing.



**Enclosure with Mechanical Mixing:** An adequate overdose of Halon 1301 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-7, A-8, and A-9 relate the initial agent concentration

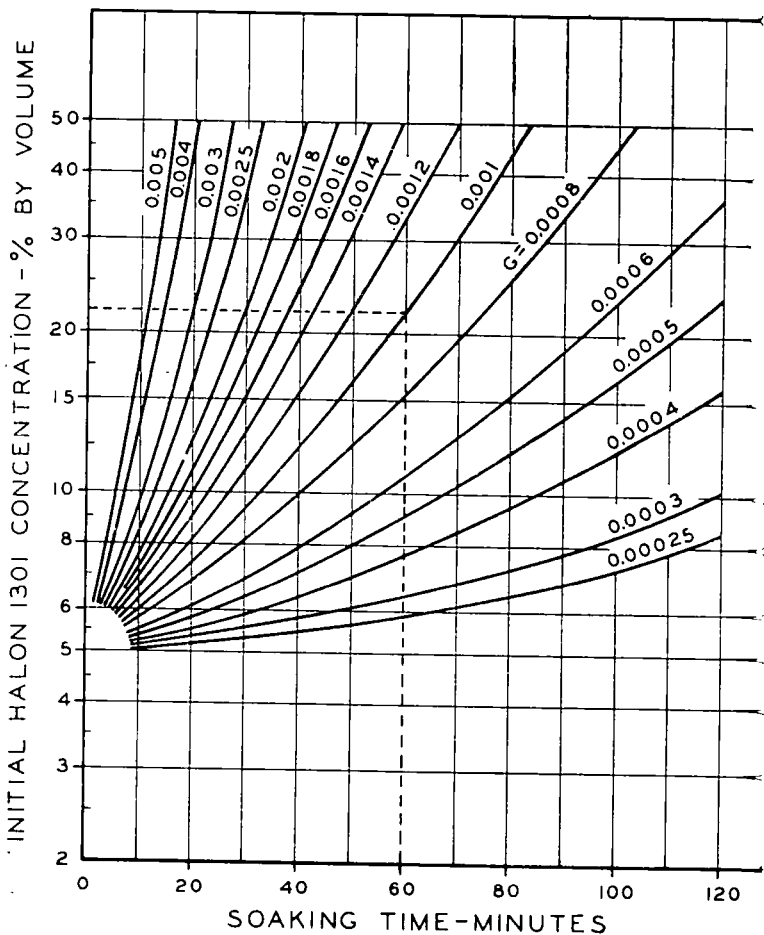


Fig. A-8. Initial amounts of Halon 1301 to produce a 5% residual concentration in enclosures equipped for mechanical mixing.

tion required to the soaking time for variables of G, a function of enclosure and opening dimensions.

$$G = \frac{KW}{3V} \sqrt{2g.H^3}$$

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

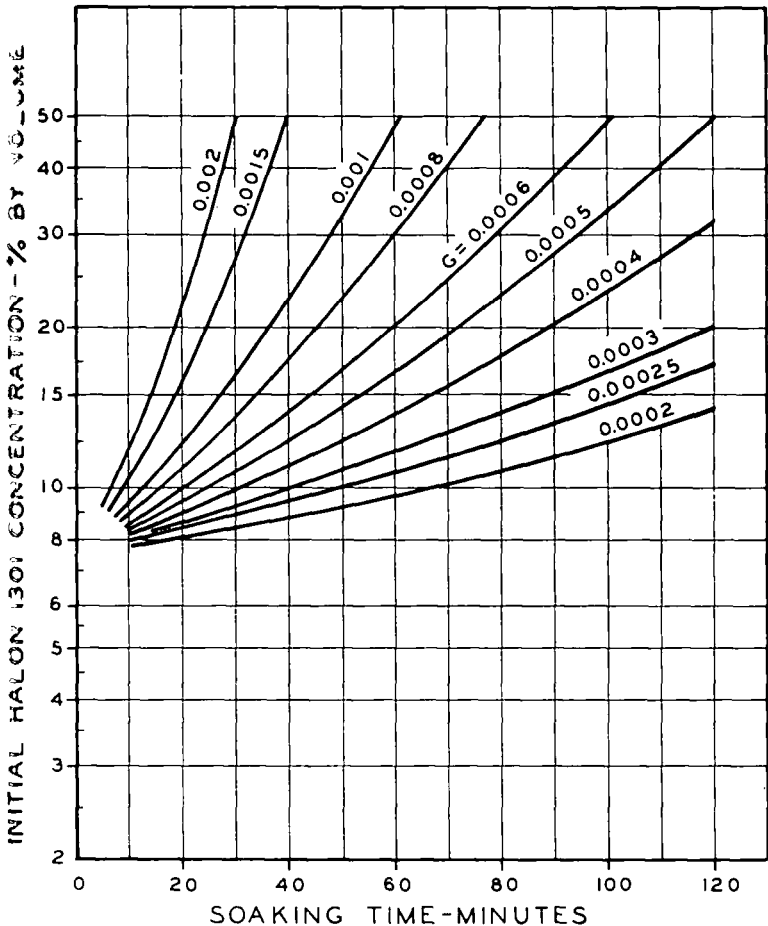


Fig. A-9. Initial amounts of Halon 1301 to produce a 7.5% residual concentration in enclosures equipped for mechanical mixing.

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

$$V = 100,000 \text{ cu. ft.}$$

$$W = 4 \text{ ft.}$$

$$H = 6 \text{ ft.}$$

$$C_t = 5. \%$$

$$T = 1 \text{ hr.} = 60 \text{ min.}$$

$$\begin{aligned} \text{Calculate } G &= \frac{KW}{3V} \sqrt{2g_c H^3} \\ &= \frac{(0.66)(4)}{(3)(10,000)} \sqrt{(2)(32.2)(6)^3} \\ &= .001 \end{aligned}$$

From Figure A-8,  $C_o = 22 \%$

**Descending Interface:** The design concentration of Halon 1301 is established in the enclosure initially. The time required for the interface to reach half-way down the enclosure height is shown in Figure A-10 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 1301/air mixture to reach the center of a 100,000 cu. ft. enclosure which has an opening 4 ft. wide  $\times$  6 ft. high along one wall:

$$\begin{aligned} \text{Calculate } G &= \frac{KW}{3V} \sqrt{2g_c H^3} \\ &= \frac{(0.66)(4)}{(3)(100,000)} \sqrt{(2)(32.2)(6)^3} \\ &= .001 \end{aligned}$$

From Figure A-10,  $T = 27 \text{ min.}$

### A-2520. Rate of Application.

The minimum rates established are considered adequate respectively for the usual surface or deep-seated fire. However, where the spread of fire may be faster than normal for the type of fire, or where high values or vital machinery or equipment are involved, rates higher than the minimums may, and, in many cases, should be used. Where a hazard contains material that will produce both

surface and deep-seated fires, the rate of application should be at least the minimum required for surface fires. Having selected a rate suitable to the hazard, the tables and information that follow in the Standard shall be used, or such special engineering as is required shall be carried out, to obtain the proper combination of container releases, supply piping, and orifice sizes that will produce this desired rate.

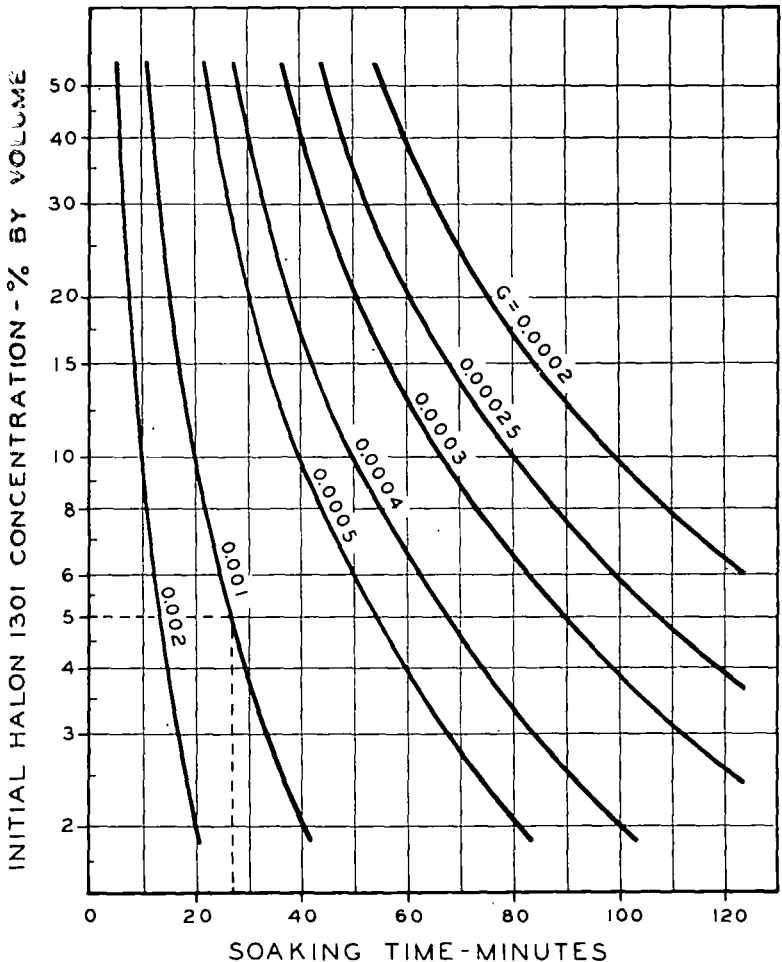


Fig. A-10. Time required for interface between effluxing Halon 1301/air mixtures and inflowing air to descend to center of enclosures not equipped for mixing.