BRITISH STANDARD

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Code of practice for

Fire extinguishing installations and equipment on premises —

Part 5: Halon systems
Section 5.2 Halon 1211 total flooding systems

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Committees responsible for this British Standard

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British Fire Services' Association
British Gas Corporation
Chief and Assistant Chief Fire Officers' Association
Confederation of British Industry
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Department of the Environment (Property Services Agency)
Department of Health and Social Security
Department of Transport (Marine Directorate)
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Foreword

This Section of this British Standard has been prepared under the direction of the Fire Standards Committee.

This British Standard constitutes Part 5-5.2 of the BS 5306 series, the main title of which is:

BS 5306, *Code of practice for fire extinguishing installations and equipment on premises*.

The other Parts of BS 5306 are or will be:

— *Part 1: Hydrant systems, hose reels and foam inlets (formerly CP 402.101)*;

— *Part 2: Sprinkler systems (formerly CP 402.201)*;

— *Part 3: Portable fire extinguishers for buildings and plant (formerly CP 402-3)*;

— *Part 4: Carbon dioxide systems*;

— *Part 5: Halon systems;*

— *Section 5.1: Halon 1301 total flooding systems*;

— *Section 5.3: Halon 1211 local application systems*[1)];

— *Part 6: Foam systems*[1)];

— *Part 7: Extinguishing powder systems*[1)].

Halon 1211 total flooding systems, with which this Section of the standard is concerned, are designed to provide a piped or otherwise connected supply of Halon 1211 for the extinction of fire by achieving a given extinguishing concentration throughout the protected volume.

There is a need for dissemination of information on established system design and this code of practice has been prepared to meet this need. Its recommendations are made in the light of the best technical data known to the committee at the time of writing, but since a wide field is covered it has been impracticable to consider every possible factor or circumstance that might affect implementation of these recommendations. Accordingly, while the aim has been to give as full and helpful an account as possible of the background knowledge available within the stated scope of the document, the recommendations should be applied in practical situations with discretion and due regard to local circumstances.

This British Standard calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to the technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1)] In course of preparation.

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0 Introduction

It is important that the fire protection of a building or plant should be considered as a whole.
Halon 1211 total flooding systems form only a part, though an important part, of the available facilities, but it should not be assumed that their adoption necessarily removes the need to consider supplementary measures, such as the provision of portable fire extinguishers or other mobile appliances for first aid or emergency use, or to deal with special hazards.

Halon 1211 has for many years been a recognized effective medium for the extinction of flammable liquid fires and fires in the presence of electrical risks, but it should not be forgotten, in the planning of the comprehensive schemes, that there may be hazards for which this medium is not suitable, or that in certain circumstances or situations there may be dangers in its use, requiring special precautions.

Advice on these matters can be obtained from the appropriate fire authority, the Health and Safety Executive or other enforcing authority under the Health and Safety at Work etc. Act 1974, and the insurers. In addition, reference should be made as necessary to other Parts of this code.

It is essential that fire extinguishing equipment should be carefully maintained to ensure instant readiness when required. This routine is liable to be overlooked or given insufficient attention by supervisors. It is, however, neglected at peril to the lives of occupants of the premises and at the risk of crippling financial loss. The importance of maintenance cannot be too highly emphasized.

1 Scope

This Section of this code gives recommendations for the design, installation, maintenance and safety of Halon 1211 total flooding fire extinguishing systems in buildings or plant.

Such a system consists of an installation designed to convey Halon 1211 from storage containers for the protection of particular plant or parts of the premises against possible fire risk. Such systems may be piped or otherwise connected.

This code provides factual data on the characteristics of Halon 1211 and the types of fire for which it is a suitable extinguishant.

The code does not cover the design of explosion suppression systems.

Two methods of operation, viz. manual and automatic, are described

Advice is given on the selection of a system and on the operational method; also included are detailed recommendations on the design, maintenance and efficient operation of installations. Reference is also made to the part which Halon 1211 systems should play in general schemes of fire protection of premises, having regard to safety as well as efficiency.

NOTE 1 Unless otherwise stated, all pressures are gauge pressures (in bar). 1 bar = 10^5 N/m^2 = 10^5 Pa.
NOTE 2 The titles of the publications referred to in this code are listed on the inside back cover.

2 Definitions

For the purposes of this Section of this code, the definitions given in BS 4422-4 apply, together with the following.

2.1
authority

an organization, office or individual responsible for approving equipment, installations or procedures

2.2
automatic system

a fire extinguishing system that, under specified conditions, functions without intervention by a human operator

2.3
filling density

the mass of Halon charge in a container per unit nett container volume

2.4
manual system

a fire extinguishing system that, under specified conditions, functions by means of the intervention of a human operator

2.5
normally occupied area

an area that is occupied by people during working hours

2.6
normally unoccupied area

an area that is not occupied by people during working hours but that may be entered into occasionally for brief periods

2.7
total flooding system

an automatic or manual Halon 1211 fire extinguishing system consisting of a supply of Halon 1211 arranged to discharge and fill an enclosed space to the proper concentration

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3 Characteristics of Halon 1211

3.1 General. The chemical name of Halon 1211 is bromochlorodifluoromethane (CF_2 ClBr), which is sometimes abbreviated to BCF.

Under normal conditions Halon 1211 is a colourless, odourless, electrically non-conductive gas with a density approximately five times that of air.

A list of important physical properties of Halon 1211 is given in Table 1.

According to present knowledge Halon 1211 extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. The extinguishing effect due to cooling, dilution of oxygen or fuel vapour is minor.

3.2 Quality. Halon 1211 should be in accordance with Table 2.

NOTE A British Standard specifying requirements for Halon media is in course of preparation.

3.3 Halon numbering system. This four-digit number is a convenient method of identifying halogenated hydrocarbon compounds such as Halon 1211, Halon 1301, etc. Reading from left to right, each digit represents the number of particular atoms in the compound molecule, thus:

number of carbon atoms

number of fluorine atoms

number of chlorine atoms

number of bromine atoms

For example, bromochlorodifluoromethane (CF_2 ClBr) is referred to as Halon 1211 because the chemical formula shows:

one carbon atom;

two fluorine atoms;

one chlorine atom;

one bromine atom.

NOTE If the fourth digit is zero, then this is omitted from the Halon number.

3.4 Use of Halon 1211. Halon 1211 total flooding systems may be used to fight fires of classes A, B or C as defined in BS 4547. In the case of class C fires, the risk of explosion after extinction of the fire due to the continued presence of flammable gases should be carefully considered.

Flammable liquid and gas fires are promptly extinguished when Halon 1211 is injected quickly into the enclosure in sufficient quantities to provide an extinguishing concentration for the materials involved.

Surface fires and embers associated with the burning of solid materials are also quickly extinguished with Halon 1211, provided the fire is detected quickly and the Halon 1211 is injected promptly, and that the concentration is maintained for an adequate period of time.

Halon 1211 should *not* be used to fight fires involving the following:

a) chemicals containing their own supply of oxygen, such as cellulose nitrate or mixtures containing oxidizing agents, such as sodium chlorate or sodium nitrate;

b) reactive metals, such as sodium, potassium, magnesium, titanium and zirconium;

c) metal hydrides or metal amides;

d) chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides;

e) solid materials in which fires quickly become deep-seated (see Appendix A).

Halon 1211 is suitable for use on fires involving live electrical apparatus.

3.5 Hazard to personnel

3.5.1 The discharge of Halon 1211 from a total flooding system to extinguish a fire may create a hazard to personnel both from the Halon 1211 itself and from the products of decomposition that result from exposure of the Halon vapour to the fire or other hot surfaces. Exposure of personnel to high concentrations of Halon 1211 (see **3.5.2**) used in total flooding systems should be avoided as should unnecessary exposure to the decomposition products. Once discharged into an enclosure, it is difficult to detect its presence through normal human senses; in concentrations above about 3 % *(V/V)*, voice characteristics are changed owing to the increased density of the Halon vapour/air mixture.

Other potential hazards to be considered for individual systems are the following.

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

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

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c) *Low temperature*. Direct contact with the vaporizing liquid being discharged from a Halon 1211 system will have a strong chilling effect on objects. The liquid phase vaporizes rapidly when mixed with air and thus limits the effect to the immediate vicinity of the discharge point.

d) *Visibility*. Discharge of Halon 1211 may create a light mist 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.

e) *Uneven distribution*. In total flooding systems, the high density of Halon 1211 vapour requires the use of discharge nozzles that will achieve a well-mixed atmosphere in order to avoid local pockets of higher concentration. Halon 1211 and Halon 1211/air mixtures are also more dense than air and will drift and accumulate in low spaces such as cellars, pits and floor voids and may be difficult to ventilate effectively.

3.5.2 The effects of Halon 1211 (complying with Table 2) on humans have been studied extensively. The principal observed effect arising from acute exposure is that of anaesthesia which could lead to unconsciousness and possible death. The degree of potential risk is related to the duration and degree of exposure. For example, minimal, if any, effects on the central nervous system have been found following test exposure to concentrations of 4 % to 5 % (*V/V)* for 1 min.

In the case of human exposure an equilibrium concentration is quickly reached in the body. Exposure to fresh air causes this concentration to reduce quickly to zero and Halon 1211 is not retained in the body. Recovery from any dizziness or lightheadedness is usually rapid and complete.

Should anyone suffer as a result of exposure to Halon 1211 they should immediately be removed to fresh air and medical assistance should be sought. Use of epinephrine (adrenalin) and similar drugs should be avoided as they may produce cardiac arrhythmias, including ventricular fibrillation.

In general the concentrations used in total flooding systems exceed 5 % (*V/V)*, i.e. above the maximum safe concentration. For this reason suitable precautions should be taken to ensure that personnel are not present in a protected enclosure when a system starts to discharge (see clause **7**).

3.5.3 Although Halon 1211 vapour has a low toxicity, its decomposition products can be hazardous. The most widely accepted theory is that the vapour decomposes before Halon 1211 can inhibit the combustion reactions. The decomposition takes place on exposure to a flame, or to a hot surface at a temperature above 450 °C. In the presence of available hydrogen (from water vapour or the combustion process itself) the main decomposition products are the halogen acids (HF, HBr, HCl).

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

The amount of Halon 1211 that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the concentration and the length of time of contact of the Halon vapour with flame or heated surfaces above 450 °C. If there is a very rapid build-up of concentration to the design value, the fire will be extinguished quickly, and the decomposition minimized. The actual concentration of the decomposition products will then depend on the volume of the room in which the fire was burning, and on the degree of mixing and ventilation.

Longer exposure of the vapour to temperatures in excess of 450 °C would produce greater concentrations of these gases. The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the vapours to the elevated temperature if the concentration of breakdown products is to be minimized.

4 Planning

4.1 Where a fixed Halon 1211 extinguishing system (whether automatic or manual) or a combined automatic/manual system is being considered for new or existing buildings it is important that the following be consulted at an early stage to ensure compliance with all statutory or other requirements and local bye-laws:

a) the Fire Authority;

b) the insurers;

c) the appropriate public authorities.

The requirements of the authorities should be coordinated in the planning stages of the contract.

4.2 When considering fire protection in premises it is of the utmost importance that protection of all the premises be considered as this constitutes good fire engineering practice. Buildings and rooms that communicate with premises protected by a Halon 1211 system may well require protection by automatic fire detection and alarm, water sprinklers, and portable fire extinguishers. Consideration should also be given to buildings and other risks that are detached from the protected premises but that constitute a fire hazard.

5 Contract arrangements

5.1 Buying specification. The buying specification should require the installation and the principal components to comply with the recommendations of this code and meet the approval of the relevant authority. It should include fully dimensioned drawings that clearly indicate the areas to be protected and give details of the risk, together with the proposed location of the Halon 1211 containers. Plans are not normally required to be supplied by the manufacturer at the enquiry stage, but the specification should require the manufacturer to supply a list of major items of approved equipment[2)].

5.2 Contract drawings

5.2.1 Prior to installation, drawings related to the contract should be prepared and submitted to the relevant authority for approval. These should be to scale or be fully dimensioned with sufficient detail to define clearly both the risk and the proposed system. Details of the risks should be included to show the materials involved, the location and/or limits of the risk and any other materials that are likely to become exposed to the risk in the event of a fire.

5.2.2 The location and sizes of piping and nozzles should be clearly indicated together with the location of the Halon 1211 supply, fire detection devices, manual controls and all auxiliary equipment. Features such as dampers, conveyors, and doors related to the operation of the system should also be shown, together with details of all calculations used in assessing the required quantity of Halon 1211. Further information should be given separately, if required, indicating the equivalent lengths of pipe and fittings, flow rates and pressure drops throughout the system.

5.3 Test and acceptance

5.3.1 The manufacturer of the equipment or his agent should be required to make tests of the completed installation to the satisfaction of the relevant authority within the recommendations of this code.

5.3.2 The tests should include the following.

a) A check that all components of the system have been installed in accordance with the approved contract drawings.

b) A check that all nuts, bolts and fittings have been correctly tightened.

c) A check that all electrical connections are safe and in working order.

d) Tests to check the gas tightness of closed sections of pipework. Separate gas discharges should be made into each space to ensure that the piping is continuous and that the nozzles have not become blocked. The test gases may be air, carbon dioxide, nitrogen, Halon 122 or Halon 1211. Care should be taken to avoid hazard to personnel conducting these tests.

CAUTION. The test gas should not be discharged into flammable or explosive atmospheres because of the danger of the generation of static electricity (see also **6.2.3**).

e) In case it cannot be proved that a uniform concentration and an adequate soaking time will be reached, a full discharge test should be done with Halon 1211.

5.3.3 The manufacturer should provide a comprehensive check list to enable the authority to witness that the tests are being carried out in a satisfactory manner.

5.3.4 When the installation has been completed and tested, the purchaser should be provided with a completion certification (together with one copy for the authority) and a set of operating instructions.

6 System design

6.1 General. The design of the total flooding system should be such as to ensure that a uniform concentration of Halon 1211 is achieved throughout the volume to be protected within 1 min of the commencement of the discharge.

Care should be taken to ensure that the required concentration of Halon 1211 can be maintained for a sufficient period of time to both extinguish and prevent reignition in the enclosed volume.

[2)] Further information on bodies issuing approvals for equipment may be obtained by applying to Enquiry Section (London), British Standards Institution, enclosing a stamped addressed envelope for reply.

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The quantity of Halon 1211 required in a given system will vary according to the type of risk, the combustible material involved, the construction of the enclosure, particularly with regard to leakage, and to the environmental conditions.

6.2 Concentration

6.2.1 *Flammable liquids and gases.* For class B and C fires the design concentration for a Halon 1211 system should be selected from either flame extinguishment or inerting data.

a) The flame extinguishment concentration is the concentration of Halon 1211 necessary to extinguish a flame of a particular fuel. Typical experimental values are given in Table 3 which also gives design concentrations obtained by adding a 20 % safety factor to the experimental values subject to a minimum concentration of 5.0 % (*V*/*V*).

b) The inerting concentration is the minimum concentration of Halon 1211 required to suppress the propagation of a flame front through a mixture of fuel vapour and air at all concentrations. Typical experimental values are given in Table 4 which also gives design concentrations obtained by adding a 20 % safety factor to the experimental values.

If the design concentration from Table 3 is used, flames will be rapidly extinguished. However, with gaseous fuels and volatile liquids a potentially explosive fuel vapour/air/Halon 1211 vapour mixture could subsequently be produced. It is therefore recommended that the design concentrations given in Table 3 should only be used for fuels whose flash point is above ambient temperature unless it can be proved that other precautions (e.g. shutting off a gas leak) will make the production of an explosive atmosphere unlikely. Otherwise the figures in Table 4 should be used.

For materials not listed in Table 3 or Table 4 and for other temperatures and pressures, specific test data should be obtained but no design concentration should be less than 5 % (*V*/*V*) (including the 20 % safety factor).

6.2.2 *Flammable solids.* For class A fires a minimum design concentration of 5 % (*V*/*V*) should be used, but for deep-seated fires attention is drawn to Appendix A.

6.2.3 *Inerting.* Owing to the possible generation of static electricity during the discharge of a Halon 1211 total flooding system, it is not normally recommended for inerting a potentially explosive atmosphere. An explosion could occur if a spark ignited the fuel/air mixture before the system had completely discharged, i.e. before the Halon 1211 concentration had reached the inerting value. The exception is as discussed in **6.2.1** where Halon 1211 would only be discharged in the presence of a fire and where a spark due to static electricity would not increase the hazard.

6.3 Quantity of Halon 1211

6.3.1 *General.* The quantity of Halon 1211 required to achieve the required design concentration (see Table 3 and Table 4) should be determined by using the flooding quantity given in Table 5. The flooding quantity will vary according to the minimum ambient temperature that may be expected in the enclosure.

In addition to the quantities derived from Table 5, further quantities of Halon 1211 may be required to compensate for the final residue of Halon 1211 in the container and pipes at the end of the discharge and for openings which cannot be closed, forced ventilation, or other special conditions that might affect the efficiency of the extinguishing system.

Where Halon 1211 may flow freely between two or more interconnected volumes the quantity of Halon 1211 should be the sum of the quantities calculated for each volume.

If one volume requires a higher concentration than the other then the higher concentration should be used throughout.

The volume of the enclosure to be used for calculations should be the gross volume. The volume may only be reduced to account for permanent impermeable building elements within the enclosure.

6.3.2 ***Compensation for leakage***

6.3.2.1 *Openings.* Where openings can be closed these should be arranged to close automatically before the commencement of the discharge.

The area of openings that cannot be closed should be kept to a minimum. These openings should be compensated for by additional quantities of Halon 1211 calculated in accordance with the procedures described in **6.3.2.2**.

6.3.2.2 *Natural ventilation.* Halon 1211 discharged into an enclosure for total flooding will result in an air/Halon vapour mixture that has a higher relative density than the air surrounding the enclosure. Therefore, any opening in the walls, especially when located in the lower parts of the enclosure, will allow the heavier air/vapour mixture to flow out of the enclosure and to be replaced with lighter outside air flowing into the enclosure through the same opening. The rate at which Halon 1211 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 Halon 1211 in the enclosure.

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Fresh air entering the enclosure may collect towards the top, forming an interface between the air/Halon vapour mixture and fresh air. As leakage proceeds, the interface will move towards the bottom of the opening. The space below the interface will contain essentially the original extinguishing concentration of Halon 1211, whereas the upper space will be completely unprotected. The rate at which the interface moves downwards increases with increasing concentrations of Halon 1211, so that simply injecting an overdose of Halon 1211 initially may not provide protection for a longer period. Where extended protection in the upper portions of an enclosure is necessary, either extended discharge of Halon 1211 throughout the entire protection time, or continuous mechanical mixing of the contents of the enclosure (e.g. with a fan) following an initial overdose of Halon 1211 is recommended. Methods for calculating the appropriate concentrations for the following are described in Appendix B.

a) *Extended agent discharge.* Halon 1211 should be continually added at a rate that will just compensate for leakage out of the enclosure. This make-up rate will be dependent upon the concentration of Halon 1211 and the height and width of the opening. Halon 1211 should be discharged in such a way that uniform mixing of vapour and air is obtained. (See **B.2**.)

b) *Enclosure with mechanical mixing.* Additional protection time can be obtained by applying an overdose of Halon 1211 initially to an enclosure provided with mechanical mixing. An adequate overdose of Halon 1211 should be provided initially, so that at the end of the desired protection period, a pre-established minimum concentration of Halon 1211 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. (See **B.3**.)

c) *Descending interface.* The design concentration of Halon 1211 should be established initially in the enclosure. The time required for the interface to reach half-way down the height of the enclosure is a function of concentration of Halon 1211 and geometrical constant *Y*. (Defined in **B.3**. See **B.4**.)

6.3.2.3 *Forced ventilation.* Where forced ventilation systems are involved, they should be shut down and/or closed before or simultaneously with the start of the discharge of Halon 1211, or additional Halon 1211 should be provided to compensate adequately for the losses.

Halon 1211 discharged into a ventilated enclosure for total flooding is subject to loss in the effluent ventilating air. A greater amount of Halon 1211 may be required to develop a given concentration, and continuous discharge is required to maintain the concentration at a given constant level. Examples of calculating the quantity of Halon 1211 where there is forced ventilation are given in Appendix C.

6.4 Discharge time. The discharge of Halon 1211 required to achieve design concentration should be substantially completed in a nominal 10 s or a shorter time if practicable and be calculated with the Halon 1211 container(s) at its ambient storage temperature. A longer discharge time should be permitted only if required by the relevant authority.

The discharge duration is the interval between the first appearance of liquid at the discharge nozzle and the time when the discharge becomes predominantly gaseous, recognized by a marked change in the appearance and sound of the discharge.

For the protection of enclosed rotating electric apparatus, such as generators, motors and converters, an additional discharge for an extended duration may be applied at a reduced rate. The rate of extended discharge should be sufficient to maintain the desired concentration for the duration of application. The initial discharge should be completed within 10 s.

7 System operation

7.1 General. Systems should be designed for either manual or automatic operation. The choice of the means of operation will depend upon the nature of the risk to be protected, and will be subject to the requirements of the relevant authority.

IMPORTANT NOTE. In order to guard against accidental release of gas from the storage containers, the supply of Halon 1211 should, when practicable, be isolated by means of an automatic monitored normally closed valve in the feed line, which will open only on a signal from the detection system or the manual release system (see clause **12**).

7.2 Manual systems. Manual systems will normally be used in conjunction with automatic fire detection equipment, but will require a person to initiate system operation manually. The manual control for the operation of the system should be easily accessible at all times, including the time a fire occurs. The manual system control point should be clearly identified, so that it cannot be confused with a fire alarm point. (See **12.8**.)

Where the controls for more than one system are located in the same place, then each manual system control should be properly labelled, identifying the risk that is protected by the system control.

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Manual controls should not require a pull of more than 150 N force or a movement of more than 350 mm to achieve system operation.

7.3 Automatic systems

7.3.1 *Automatic control.* The system should only be placed under automatic control whilst the protected area is unoccupied (see **3.5.2** and clause **12**). When the area is occupied the system should be placed under manual control. In both cases the operation of the fire detection system should sound the fire alarm.

7.3.2 *Fire detection.* Automatic systems should be controlled by an appropriate automatic fire detection system, selected according to the particular risk, and should comply with the recommendations of BS 5839-1. In any automatic fire detection system the detector has to discriminate between a fire and the normal environment existing within the hazardous area. The system chosen should have detectors that are suited to the conditions and that provide the earliest reliable warning of fire.

The power supply for electrical detection, alarm and release devices should be independent of the supply for the hazardous area. Where this is not practicable, fluidic or mechanical devices should be used, or the system should be provided with emergency secondary power supplies with automatic changeover, if the primary supply fails. Where rapid-response fire detectors, such as those detecting smoke or flame are used, the extinguishing system should be designed to operate only after two separate fire signals have been initiated. The use of "coincidence" detector operation, i.e. the need for corroboration of a fire from two separate detectors before release of Halon 1211 is initiated, is a recommended technique.

Automatic systems should be continuously monitored where the possible consequences due to any delay in actuation may be serious and/or the detection and control systems are so extensive and complex that they cannot be readily checked by a visual or other inspection. Where monitoring is provided it should be so arranged that there will be an immediate indication of any system fault.

7.3.3 *Manual control.* Automatic systems should be provided with an independent manual override control(s) which should be located outside the protected area and be conveniently and easily accessible at all times including the time a fire occurs. The control(s) should cause the complete system to operate in its normal fashion. The manual control point(s) should be clearly identified so that it cannot be confused with a fire alarm point. The control(s) should be sited as required by the relevant authority.

8 Enclosure characteristics

8.1 Fire resistance. A well enclosed space is required to maintain the designed extinguishing concentration.The walls and doors of the enclosure should have a fire resistance of not less than 30 min in accordance with BS 476-8.

8.2 Pressure relief ventilation. Venting of an enclosure may be necessary to relieve pressure build-up due to the discharge of Halon 1211. Appropriate pressure relief depends on the injection rate of Halon 1211 and the maximum pressure the enclosure is capable of withstanding.

Porosity and leakage around openings, e.g. doors, windows and dampers, though not readily apparent or easily calculated, will usually provide sufficient relief for Halon 1211 flooding systems without need for additional venting. Record storage rooms, refrigerated spaces and duct work also generally need no additional venting. For very tight enclosures the area necessary for free venting, X (in m^2), may be calculated from the expression:

$$X = \frac{2.42 \times 10^{-4}}{\sqrt{P}} Q$$

where

Q is the Halon 1211 mass flow rate (in kg/s);

P is the maximum allowable absolute pressure in enclosure (in bar).

In many instances, particularly where hazardous materials are involved, relief openings should already have been provided for explosion venting. These and other available openings often provide adequate venting.

NOTE Portions of structural members of buildings constructed in accordance with The Building Regulations 1976, The Building Standards (Scotland) Regulations 1981 and The Building Regulations (Northern Ireland) 1977 are required to sustain without failure in addition to combined dead load, imposed load and wind load, a load of 34 kN/m^2 applied to that portion from any direction [34 kN/m^2 = 0.34 bar].

There are no other known strength requirements for buildings not constructed to the above regulations. Guidance however is given in Table 2 — **7.2.4** of National Fire Protection Association Standard (NFPA) 12B[3)] for various types of construction.

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8.3 Services. All services in the enclosure, e.g. fuel supplies, heating appliances, paint spraying, that are likely to impair the efficiency of the extinguishing system should be shut down prior to or simultaneously with the discharge of Halon 1211.

9 System components

9.1 General. Various operating devices are necessary to control the flow of the Halon 1211 and to operate the associated equipment. These include storage containers, valves, distribution valves, automatic and manual controls, pressure trips and switches, and discharge nozzles.

All devices should be designed for the service they will encounter and should not be readily rendered inoperative or susceptible to accidental operation. Devices should be normally designed to function properly in the temperature range – 30 °C to + 55 °C or be marked to indicate their temperature limitations.

All devices, especially those having external moving parts, should be located, installed or suitably protected, so that they are not subject to mechanical, chemical or other damage that would render them inoperative.

9.2 Storage containers

9.2.1 *Arrangement and location.* Storage containers and accessories should be so located and arranged that inspection, testing, recharging and other maintenance is facilitated and interruption to protection is held to a minimum.

Storage containers should be located as near as possible to the risk or risks they protect, but should not be exposed to a fire in a manner that is likely to impair system performance.

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

9.2.2 *Design.* The Halon 1211 supply should be stored in containers designed to hold Halon 1211 in liquefied form at ambient temperatures. Containers should not be charged to a filling density greater than 1.472 kg/L. Isometric diagrams for Halon 1211 superpressurized with dry nitrogen (see Figure 1 and Figure 2) show the relationship of the storage container pressure against temperature with lines of constant filling density. Containers should be clean and dry internally before filling to prevent corrosion.

Superpressurization (the addition of nitrogen to Halon 1211 storage containers to pressurize the Halon 1211 above its vapour pressure) will prevent the container pressure from decreasing drastically at low temperatures. Superpressurization causes some of the nitrogen to dissolve in the liquid portion of the Halon 1211. This solubility is related both to the degree of superpressurization and to the temperature. Containers holding Halon 1211 should be superpressurized with dry nitrogen in accordance with the requirements of BS 4366 to pressures of 10.5 bar ± 5 % or 25 bar ± 5 % at 21 °C. Containers should be marked distinctively and permanently with the type and quantity of Halon contained therein, together with the degree of superpressurization.

Halon 1211 should be stored in containers designed, constructed and tested and marked in accordance with the relevant part of BS 5045.

A reliable means of indication of the pressure in the containers should be provided. A means should also be provided to indicate the variation of container pressure with temperature.

Storage temperatures should not exceed 55 °C nor be less than – 30 °C for total flooding systems unless the system is designed for proper operation with storage temperatures outside this range. External heating or cooling may be used to keep the temperature within the desired range. When special container charges are used, the containers should be appropriately marked.

All containers on any one battery should be of the same size, mass and pressurization level.

Halon 1211 containers for fire-fighting purposes should be painted signal red in accordance with the requirements of BS 381C or Red 04E53 in accordance with the requirements of BS 5252.

When manifolded, containers should be adequately mounted and suitably supported in a rack that provides for convenient individual servicing or content weighing. Automatic means should be provided to prevent loss of Halon 1211 from the manifold if the system is operated when any containers are removed for maintenance.

9.2.3 ***Container valve***

9.2.3.1 *General.* Each container should be equipped with a discharge valve capable of discharging liquid Halon 1211 at the required rate. Containers with top-mounted valves should be provided with an internal dip tube to ensure discharge of liquid Halon 1211. Container valves should be protected by a suitable means during transportation.

[3] Available from National Fire Prevention Association, Boston, Mass., USA.

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9.2.3.2 *Pressure*

a) *Static pressure.* The valve body should withstand a pressure of not less than 42 bar (for 10.5 bar systems) or 90 bar (for 25 bar systems) without failure.

b) *Operating pressure.* The valve body should operate satisfactorily and should not produce leakage upon being subjected to a pressure of not less than 21 bar (for 10.5 bar systems) or 45 bar (for 25 bar systems).

9.3 Pipework

9.3.1 *General.* Piping should be non-combustible in accordance with BS 476-4, and should be able to withstand the expected pressures and temperatures without damage.

Threaded steel pipework and fittings should be galvanized inside and out. Copper, brass or stainless steel tube may be used without additional corrosion protection.

Pipe and fittings should be free of burrs, spelter and rust. Steel pipe and fittings should comply with the recommendations given in **9.3.3**, **9.3.4** and **9.3.5**. Manifolds should be tested at the manufacturer's works to a minimum pressure of 28 bar for 10.5 bar systems or 56 bar for 25 bar systems. A test certificate should be provided on request.

All pipework intended to carry Halon 1211 should be painted signal red in accordance with requirements of BS 381C or Red 04E53 in accordance with the requirement of BS 5252.

9.3.2 *Earthing of pipework.* To minimize the risks from electrostatic discharge, induced electrical charge and earth leakage currents, all Halon 1211 pipework should be adequately earthed.

NOTE CP 1013 gives guidance on earthing.

9.3.3 *Pipes.* Open and closed sections[4)] of pipe for 10.5 bar and 25 bar systems should be of the types given in Table 6.

9.3.4 *Fittings.* Fittings should be selected according to the wall thickness or schedule number of the pipe to which they are intended to be fitted. In addition, screwed fittings should be selected to be compatible with pipe screw threads.

a) *Open sections of pipe for* 10.5 bar *and* 25 bar *systems*

1) *Fittings:*

All sizes

Forged steel screwed or socket-welded fittings complying with the requirements of BS 3799; or butt-welding fittings complying with the requirements of BS 1640-3; or class 300 of ANSI B 16.9.

Up to and including 100 mm
Screwed fittings complying with the requirements of
BS 1740-1.

Up to and including 80 mm
Screwed fittings complying with the requirements of BS 1256; or class 150 or class 300 of ANSI B 16.3.

2) *Flanges:*

All sizes

Forged carbon steel, raised face complying with the requirements of class 300 of Table PE 1 of BS 1560-2 or class 300 of ANSI B 16.5.

3) *Gaskets for flanged joints*

The recommendations of the manufacturer should be followed selecting the grade, specification and thickness to be used.

b) *Closed sections of pipe for* 10.5 bar *and* 25 bar *systems*

1) *Fittings:*

All sizes

Forged steel screwed or welded fittings complying with the requirements of BS 3799; or butt-welding fittings complying with the requirements of BS 1640-3; or class 300 of ANSI B 16.9.

Up to and including 80 mm

Screwed fittings complying with the requirements of class 300 of ANSI B 16.3.

2) *Flanges:*

All sizes

Forged carbon steel, raised face complying with the requirements of class 300 of Table PE 1 of BS 1560-2; or class 300 of ANSI B 16.5.

3) *Gaskets for flanged joints*

The recommendations of the manufacturer should be followed selecting the grade, specification and thickness to be used.

NOTE With regard to the pressure ratings, stainless steel, copper and copper alloy fittings complying with the requirements of BS 4368 and BS 2051-1 may be used where tubes complying with the requirements of BS 3605 and BS 2871-2 have been given.

[4)] An open section of pipe is the section between a valve (including a relief valve) and open nozzles that cannot be under a continuous pressure. A closed section of pipe is the section between two valves that may be intentionally or unintentionally closed, or between valves and Halon 1211 storage containers including filling and gas balance lines.

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9.3.5 *Screw threads.* Screw threads should comply with the dimensions specified in BS 21 or API Std 5B. These threads are not compatible and threads of only one type should be used on any particular system.

9.3.6 *Flexible hose connections.* Flexible hoses should be selected, inspected and tested only by engineers or specialists trained in this field and should be suitable for service at the pressures and temperatures involved.

9.3.7 ***Installation of pipework***

9.3.7.1 *General.* Pipework should be installed in accordance with the requirements of BS 3351:1971 with particular reference to sections 5, 6 and 7 and the tables and diagrams referred to therein, except where modified by this standard.

It is important to ensure that pipework is securely supported, making due allowance for expansion and contraction.

Before final assembly, tube and fittings should be inspected visually to ensure that no foreign matter is inside and the full bore is clean. After assembly the system should be thoroughly blown through with carbon dioxide or air.

Where Halon-carrying pipes and associated fittings are to be concealed, provision should be made for access to them at all times.

9.3.7.2 *Protective finish.* Galvanizing of prefabricated pipe sections is recommended wherever possible. It is not suitable, however, in certain atmospheres where chemical fumes, dust or moisture may attack the coating. Where corrosion-resistant materials are not used for pipes, fittings or support brackets and steelwork, adequate external protection should be given against normal corrosion due to atmospheric or local chemical conditions that are likely to affect the materials used.

Before any protective coating is applied, it is important to prepare metal surfaces to remove all rust, scale, dirt and grease. Surfaces should be free from moisture immediately before the application of the protective medium.

Painted finishes should normally be selected from lead-based, zinc-enriched (cold galvanizing) or special paints. Whichever type is selected, the manufacturer's recommendations for the particular application should be strictly adhered to (see also **9.3.1**).

9.3.7.3 *Pipework supports.* The recommended maximum span between supports to take into account the total mass of pipe and Halon 1211 should be as given in Table 7.

Additional supports should be provided where there are extra loads, such as valves. If the pipework is located in an area with a potential explosion hazard, the piping system should be hung from supports that are least likely to be displaced.

9.3.7.4 *Pipe anchors.* Anchors should be designed for the working temperature and be able to withstand the dynamic and static forces involved. Care should be taken to ensure that the anchor bolts, and the supporting structures to which the anchor points are fixed, are adequate to take the proposed load.

9.3.7.5 *Welding of pipework and precautions.* Welding should comply with the requirements of BS 2633 or BS 4677 for metal arc welding or, as appropriate, with the requirements of BS 1821 for oxy-acetylene welding except as modified by **12.11**.

Where welding is carried out in the vicinity of valves fitted with seats and seals that can be damaged by heat from the weld, the seats and seals should be removed during the welding operation.

9.3.7.6 *Pressure relief devices.* Where there is a possibility of liquid Halon 1211 entrapment in pipework (as, for example, between valves) a suitable excess pressure relief device should be fitted. For 10.5 bar systems the device should be designed to operate at 18 bar ± 10 %. For 25 bar systems the device should be designed to operate at 37 bar ± 10 %.

Safety relief devices should be so fitted that the discharge, in the event of operation, will not injure or endanger personnel and, if necessary, the discharge should be piped to an area where it will not become a hazard to personnel (see **3.5.1**).

9.3.7.7 *Drain traps.* Drain traps protected against interference by unqualified personnel should be fitted in the lowest point in a pipework system if there is any possibility of accumulation of condensed water.

9.4 Distribution valves. If several risks are protected separately but connected to one Halon 1211 supply source, a distribution valve should be provided for each risk. Distribution valves should be capable of being opened when subjected to the maximum Halon 1211 pressure. Valves should be equipped so that they can be opened manually.

All valves should be suitable for the intended use, particularly in respect to flow capacity and operation. Valves should be rated for equivalent length in terms of the pipe or tubing sizes with which they will be used, and should be used only under temperatures and other conditions for which they are approved. Distribution valves should be designed for the maximum working pressure of the system plus a 50 % safety factor.

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9.5 Discharge nozzles. The discharge nozzle normally consists of the selected orifice and any associated shield or baffle.

The flow of nitrogen-saturated Halon 1211 through a nozzle depends not only on the nozzle geometry and nozzle pressure but also on the initial container pressure. This determines the quantity of nitrogen in solution.

Discharge characteristics should be determined experimentally, measuring the flow per unit area of the nozzle at various nozzle pressures with the Halon 1211 first saturated with nitrogen to the selected initial container pressure (see **10.6**).

Discharge nozzles should be manufactured in corrosion-resistant material and should be of adequate strength to withstand expected working temperatures and pressures.

Discharge nozzles should be permanently marked with a suitable reference for identification purposes. The markings should be readily discernible after installation.

Discharge nozzles should be provided with frangible discs or blow-out caps where clogging by foreign materials is likely. These devices should provide an unobstructed opening upon system operation.

Nozzles used with total flooding systems should be suitable for the intended purpose, and should be located with the geometry of the risk and enclosure taken into consideration.

The type of nozzles selected, their number, and their placement should be such that the design concentration will be established in all parts of the 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 should be selected on the basis of their adequacy for the use intended.

10 System design procedure

10.1 Symbols. Symbols used in this clause are as follows.

Symbol	Quantity	Unit
C_d	discharge coefficient	—
D	inside diameter of pipe	mm
G	Halon 1211 mass flow rate per unit area of nozzle cross section	kg/(s mm^2)
g_n	acceleration due to gravity	9.81 m/s^2
L	length of pipe	m
P_n	nozzle pressure	bar
P_r	initial container pressure	bar
ΔP	pressure drop (or gain)	bar
Q	Halon 1211 mass flow rate	kg/s
f	filling density	kg/L
ρ	liquid density	kg/m^3

10.2 Basic principles. The following steps are recommended for designing a Halon 1211 total flooding system.

a) Decide on the design concentration based on the flammable material with the highest flame extinguishing concentration or inerting concentration as appropriate (see **6.2**).

b) Calculate the quantity of agent required considering:

1) the total volume of the enclosure, allowing for any permanent building features (see **6.3**);

2) unclosable openings and ventilation (see **6.3** and Appendix B and Appendix C).

c) Decide on the number and type of nozzles to ensure adequate distribution and discharge time. The number and size of nozzles should be sufficient to ensure that the gas is evenly distributed and that the discharge is substantially complete in a nominal 10 s or less (see **6.4**).

d) Decide on the pipe layout. In general, a balanced system will be easier to design but Halon 1211 can be used with any type of pipe arrangement.

e) Select pipe sizes. Experience will often indicate approximate sizes for the preliminary calculations. However as a guide, pipes should be sized to give a pressure drop of approximately 0.07 bar/m at the average system discharge rate, i.e. the mass of agent required, divided by the total required discharge time.

f) Filling density. The ratio of liquid Halon 1211 volume to container volume should not exceed 0.8. The actual value will depend upon a number of factors, but has to be such to ensure that at the end of the discharge there is sufficient pressure to:

1) provide an absolute pressure of at least 3.1 bar at the nozzle to ensure that the Halon 1211 remains liquid;

2) overcome the pressure change due to any vertical pipework;

3) overcome pipe friction losses.

It will be found for most systems that the residual absolute pressure will be approximately 4.5 bar and so the maximum filling density f (in kg/L) is given by:

$$f = 1.78\ (1 - 4.5/P_r) = 1.78 - 8.01/P_r$$

where

P_r is the initial container absolute pressure (in bar).

This gives $f = 1.08$ for a 10.5 bar (11.5 bar, absolute pressure) system or 1.472 for a 25 bar (26 bar, absolute pressure) system, but a more precise method for calculating the filling density is given in Appendix D and Appendix E.

g) Nozzle size. The nozzle sizes should be chosen to give the required discharge time. A preliminary estimate of the nozzle size should be obtained by taking the mean discharge rate and the pressure when the container is half empty. This value should be then refined by calculation as shown in Appendix D and Appendix E.

10.3 Pressure drop through pipes. The pressure drop for Halon 1211 from a container pressurized with nitrogen has been determined experimentally and the results for galvanized steel pipe for a range of diameters are given in Figure 3. The information in Figure 3 corresponds to the following formula:

$$\frac{\Delta p}{L} = \left\{ 12.0 + 0.82D + 37.7 \left(\frac{D}{Q}\right)^{0.25} \right\} \frac{Q^2}{D^5} \times 10^3$$

10.4 Pipe fittings. Friction losses occur as liquid Halon 1211 flows through the pipeline to the discharge orifice. Allowance should be made for the equivalent lengths of the container valve, dip tube and flexible connectors, selector valves and other installed equipment through which Halon 1211 flows. Equivalent lengths for these components should be obtained from the lists supplied by the approval body (see **5.1**) for the individual components. Equivalent lengths of common pipe fittings and valves are given in Table 8 and Table 9.

10.5 Changes in elevation. Changes in static pressure due to changes in elevation should be accounted for by subtracting 0.18 bar/m above the storage container (or by adding if below) from the total pressure.

10.6 Nozzles. The mass flow rate per unit area of nozzle cross section G of Halon 1211 through a nozzle could be predicted from:

$$G = C_d \sqrt{(2 g_n \rho P_n)}$$

However, due to nitrogen coming out of solution and boiling of Halon 1211 in the nozzle under conditions of high pressure drop and turbulence, the discharge coefficient (C_d) is in practice a function of the nozzle pressure (P_n) and the initial container pressure (P_r). It is necessary therefore to determine the parameters for a given nozzle experimentally (see **9.5**).

Figure 4 and Figure 5 show the relationship between G and P_n and P_r for the two nozzles shown in Figure 6 and Figure 7.

10.7 Container pressure. As liquid is discharged from the container the volume of gas above it will increase and hence the gas pressure will fall. Experimental measurements made on the discharge of liquid Halon 1211 from nitrogen-pressurized containers indicate that:

a) the relationship between pressure P and gas volume V can be represented by PV = constant;

b) the nitrogen dissolved in the liquid Halon 1211 in the container remains in solution as the pressure falls.

10.8 Balanced systems. A balanced system is one in which:

a) the actual pipe length from container to each nozzle is equal to or greater than 90 % of the longest pipe length; *and*

b) the equivalent pipe length (see Table 8 and Table 9) from container to each nozzle is equal to or greater than 90 % of the longest equivalent pipe length; *and*

c) the design flow rate at each nozzle is equal.

An example of a calculation for a balanced system is shown in Appendix D.

10.9 Unbalanced systems. An unbalanced system is one in which one or more of the three criteria for balanced systems described in **10.8** a), b) and c) are not met.

An example of a calculation for an unbalanced system is shown in Appendix E.

11 Maintenance

11.1 The user of the installation, i.e. the person(s) responsible for or having effective control over the fire safety provisions adopted in or appropriate to the premises or the building, should ensure that the system is in good working order at all times.

The installation should be inspected at least twice a year by a competent engineer, and an inspection report made. This could be achieved by entering into an "inspection and service" contact whereby the manufacturer, his agent or an accredited servicing organization will carry out this inspection.

11.2 The user of the equipment should carry out a weekly visual examination of the fire protection equipment. This should include an examination of all pressure gauges, and a general check that all operating controls are both properly set and accessible, and that indicators are functioning. It is important to inspect pipework and nozzles visually to ensure that they are not physically damaged and remain in the designed position.

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During all inspections it should be determined that the fire risk and enclosure have not changed.

11.3 During the twice-yearly inspection, all pressure containers should be weighed or checked with a liquid level detector. Any container that shows a loss in net content of more than 5 % or a loss in pressure of more than 10 % (adjusted for temperature) should be refilled or replaced. Tests should be made of the principal components, including pressure-operated devices, to ensure that they function correctly. The object of the inspection should be to ensure that the system is fully operational and that it will remain so until the next inspection. The use, impairment and restoration of this protection should be reported promptly to the relevant authority. Any impairments should be corrected by experienced personnel.

11.4 Any extension or alteration to the installation should be carried out by the manufacturer or his agent, and the relevant authority should be notified promptly.

11.5 Storage containers should be sited where they will be readily accessible for inspection, testing, recharging or maintenance with the minimum of interruption of protection. Halon 1211 containers should be maintained, inspected and tested in accordance with the relevant Part of BS 5430.

12 Safety

NOTE See also the additional safety recommendations in clause **7**.

12.1 General. Suitable safeguards should be provided to protect persons in areas where the atmosphere may be made hazardous by the discharge, either planned or accidental, of Halon 1211 from a fire extinguishing system.

12.2 Safety lock-off to storage containers. To enable system inspection and maintenance to be carried out in safety, a means should be provided to prevent the discharge of Halon 1211 from the storage container(s) (see **7.1**).

12.3 Normally occupied areas. Entry into a protected area should only be made when the total flooding system has been placed under manual control.

The automatic discharge of the Halon 1211 total flooding system should be prevented by means of a lock-off control when persons are present within the protected area.

The system should be returned to automatic control as soon as all persons have left the area.

Manual controls should be protected against inadvertent operation.

12.4 Normally unoccupied areas. During periods of entry the automatic release of Halon 1211 should be prevented by means of a lock-off control which renders the system capable only of manual operation. The system should be returned to automatic control as soon as all persons have left the area.

Manual controls should be protected against inadvertent operation.

12.5 Pressure relief device alarm. A pressure relief device should be fitted in closed sections of pipe to give an alarm to indicate that Halon 1211 is present in a closed section (see also **9.3.7.6**).

12.6 Manually operated vent valve. A manually operated vent valve may be fitted to the manifold or any section of pipework where Halon 1211 could be trapped so that the Halon can be safety vented to atmosphere. The vent valve should normally be kept in a locked shut position.

12.7 Audible and visual alarms. Alarms should be provided within the protected area to indicate, where applicable:

a) operation of the fire detection system: audible and visual alarm;

b) commencement of agent discharge: visual.

Evacuation alarms should be easily distinguishable from normal fire alarms. Visual indication of system operation should be provided outside the protected area at all entrances, and the indicator should be identified with the wording “SYSTEM OPERATED”. Consideration should be given to providing such alarms in adjacent areas where hazardous atmospheres may result from the discharge of large quantities of Halon 1211 in the protected areas.

12.8 Warning signs. Warning signs, as illustrated in Figure 12 or Figure 13, should be prominently displayed at all control points and at all the entrances to the area protected by the Halon 1211 system.

12.9 Area ventilation. A means of ventilating protected areas after a discharge of Halon 1211 should be provided. Care should be taken to ensure that the post-fire atmosphere is not ventilated into other parts of the building. Provision should also be made for the prompt discovery and rescue of persons rendered unconscious.

12.10 Exits. There should be provision of adequate escape routes and exits, clearly identified and kept clear at all times; outward-opening self-closing doors should also be provided at exits from hazardous areas. Where such doors are latched, panic hardware should be provided, and it is essential that doors should be openable from the inside even when locked from the outside.

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12.11 Electrical hazards. Where Halon 1211 systems are to be installed in substations or switch stations the site electrical safety rules should be followed to ensure that operation and maintenance of the system can be carried out with safety.

Where Halon 1211 systems are installed in locations containing exposed electrical conductors, clearances not less than those given in Table 10, which is taken from BS 162, should be provided if practicable, between the electrical conductors and any point where the person may be required to stand when working on the system. BS 162:1961 should also be consulted.

Where these clearance distances cannot be achieved, warning notices should be provided and a safe system of maintenance work should be adopted.

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Appendix A Deep-seated fires

Most class A fires burn initially at the surface and such fires will be rapidly and efficiently extinguished by Halon 1211 with minimum amounts of breakdown products. However, many class A materials, after a preburn time which varies with the material, produce significant amounts of glowing embers and may not be totally extinguished by Halon 1211 at the concentration normally employed. Such fires are said to be deep-seated, and whilst Halon 1211 will extinguish the flames, smouldering may continue with the production of considerable quantities of breakdown products and tar which can cause corrosion damage. Halon 1211 in total flooding systems is therefore not suitable for this type of fire.

Since the time for a class A fire to become deep-seated varies with the material and its degree of comminution, it is difficult to give any definite rules concerning materials to avoid. However, fires involving the following materials can become deep-seated rapidly and care should be taken to ensure that these materials do not accumulate in significant quantities:

crumpled (e.g. scrap) and shredded paper;

cardboard;

cloth, rags, etc.

Materials in which fires can start spontaneously from inside a bulk, e.g. baled cotton, are similarly deep-seated and Halon 1211 is not suitable.

Appendix B Examples of calculation of Halon 1211 quantity where there is natural ventilation

B.1 Symbols

Symbols used in this appendix are as follows:

Symbol	Quantity	Unit
C	concentration of Halon 1211 in the enclosure at any given time	% (V/V)
C_o	initial concentration of Halon 1211 in the enclosure	% (V/V)
g_n	acceleration due to gravity	9.81 m/s^2
H	height of opening	m
K	orifice discharge coefficient (assumed equal to 0.66 for normal doors, windows etc.)	—
Q	Halon 1211 mass flow rate	kg/s
T	period of extended protection (from end of initial discharge)	min
V	volume of enclosed space	m^3
W	width of opening	m

Y is a geometric constant equal to $\frac{KW}{3V}\sqrt{(2g_nH^3)}$

B.2 Extended agent discharge

Halon 1211 should be continually added at a rate that will just compensate for leakage out of the enclosure. The make-up rate will be dependent upon the concentration of Halon 1211 and the height and width of the opening. Halon 1211 should be discharged in such a way that uniform mixing of vapour and air is obtained.

Figure 14 gives the Halon 1211 make-up rate per unit opening width required to maintain a specified concentration in the enclosure, for various values of opening height.

Example. Calculate the Halon 1211 make-up rate required to maintain a concentration of 5 % (V/V) in an enclosure, one wall of which has an opening 1 m wide by 1.8 m high.

From Figure 14, Q/W = 0.38 kg/s per metre width of opening.

Therefore the make-up rate = 0.38 kg/s.

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B.3 Enclosure with mechanical mixing

An adequate overdose of Halon 1211 should be provided initially, so that at the end of the desired protection period, a pre-established minimum concentration 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.

Figure 15, Figure 16 and Figure 17 show the relationship for different values of the final minimum permitted concentration between the initial agent concentration required for the holding period and Y, a function of enclosure and opening dimensions and which is given by the expression:

$$Y = \frac{KW}{3V}\sqrt{(2g_nH^3)}$$

Example. Calculate the initial concentration of Halon 1211 required for a final residual concentration of 5 % (V/V) after 15 min in a 1 000 m^3 enclosure having an opening 1 m wide by 1.8 m high along one wall.

V = 1 000 m^3

W = 1 m

H = 1.8 m

C = 5 %

T = 15 min

Using the expression for Y:

$$Y = \frac{KW}{3V}\sqrt{(2g_nH^3)}$$

$$= \frac{0.66 \times 1}{3 \times 1000}\sqrt{(2 \times 9.81 \times 1.8^3)}$$

$$= 0.002353$$

From Figure 16, C_o equals approximately 13 %.

B.4 Descending interface

The design concentration of Halon 1211 is established initially in the enclosure. The time required for the interface to reach half-way down the height of the enclosure is shown in Figure 18 as a function of concentration of Halon 1211 and geometrical constant Y.

Example. Calculate the time required for the interface of a 5 % (V/V) Halon 1211/air mixture to reach the centre of a 3 000 m^3 enclosure that has an opening 1 m wide to 1.8 m high along one wall.

Using the expression for Y:

$$Y = \frac{KW}{3V}\sqrt{(2g_nH^3)}$$

$$= \frac{0.66 \times 1}{3 \times 3000}\sqrt{(2 \times 9.81 \times 1.8^3)}$$

$$= 0.00078$$

From Figure 18, T = approximately 25 min.

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Appendix C Examples of calculation of Halon 1211 quantity where there is forced ventilation

Symbols used in this appendix are as follows:

Symbol	Quantity	Unit
C	Halon 1211 concentration	% (V/V)
C_f	Halon 1211 concentration at end of discharge	% (V/V)
E	ventilation rate	m^3/s
e	natural logarithm base (2.71828)	—
Q	Halon 1211 mass flow rate	kg/s
t	time from end of discharge to compensate for losses (see clause **6**)	s
V	volume of enclosure	m^3
v	specific volume of Halon 1211 vapour at the design temperature	m^3/kg

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

$$Q = \frac{CE}{v(100 - C)\ (1 - e^{-Et/V})}$$

NOTE If the volumetric discharge rate Q_v of Halon 1211 is greater than the ventilation rate, E, the effects of ventilation should be ignored and the quantity of Halon 1211 required should be based solely on an unventilated enclosure. However, ventilation effects should still be considered if the concentration is to be maintained for any significant time.

The Halon 1211 mass flow rate necessary to maintain a given concentration is given by the expression:

$$Q = \frac{CE}{v(100 - C)}$$

After discharge of Halon 1211 is stopped, the concentration versus the time relationship is given by the expression:

$$C = C_f\, e^{-Et/V}$$

Example. Calculate the mass flow rate and total quantity of Halon 1211 required to develop a 5 % (V/V) concentration in 10 s, at a temperature of 20 °C, for an enclosure of volume 360 m^3, with a ventilation rate of two air changes per minute.

C = 5 % (V/V)

$$E = \frac{360 \times 2}{60} = 12\ m^3/s$$

v = 0.14 (at 20 °C, from Table 5)

t = 10 s

V = 360 m^3

Using the expression for the mass flow rate, Q:

$$Q = \frac{CE}{v(100 - C)\ (1 - e^{-Et/V})}$$

$$= \frac{5 \times 12}{0.14(100 - 5)\left(1 - e^{-(12 \times 10)/360}\right)}$$

$$= \frac{60}{3.77}$$

= 16 kg/s (approximately)

The quantity required is therefore

16 × 10 = 160 kg.

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Appendix D Example of design calculation for balanced system

D.1 A building is used to store a variety of solvents for which the highest Halon 1211 concentration is 9.0 % (*V*/*V*). It is proposed to provide fire protection by means of a Halon 1211 total flooding system. The building has the following dimensions:

5.0 m × 8.0 m × 3.0 m high

D.2 The following assumptions are made:

a) The pipework and nozzles are arranged as shown in Figure 8.

b) Pipes are made of galvanized steel (i.e. Figure 3 may be used).

c) The nozzles are of the type shown in Figure 6 so that mass flow rate through the nozzles can be obtained using Figure 4.

d) When the Halon 1211 liquid level reaches the bottom of the dip tube it is assumed that continuous expansion of the gas will blow the pipes clear of liquid up to nozzles B and B′. At this point it is assumed that the gas will escape rapidly such that any liquid remaining in the pipes will emerge slowly.

e) The ambient temperature is 20 °C.

D.3 The volume of the building is 5.0 × 8.0 × 3.0 = 120 m^3. The quantity of Halon 1211 required to produce 9.0 % (*V*/*V*) in the room is 0.7078 kg/m^3 (Table 5), i.e. 120 × 0.7078 = 85 kg.

NOTE The pressures stated in the following example are absolute pressures (in bar).

The required discharge time is 10 s. Hence the average mass flow rate = 8.5 kg/s. To achieve a pressure drop of approximately 0.07 bar/m from Figure 3 the diameter of CD should be 40 mm.

CB (which has only half the flow) should be 30 mm.

AB (which has only quarter the flow) should be 25 mm.

The approximate nozzle sizes should be obtained from a midpoint flow rate of 8.5 = 2.1 kg/s per nozzle. If the ratio of liquid Halon 1211 volume to container volume is 0.60, then the initial vapour volume is 0.40. At the midpoint of the discharge, this vapour volume will increase to 0.70. Thus if the initial container absolute pressure is 11.5 bar, then the midpoint container pressure will be (4/7) × 11.5 = 6.57 bar.

The nozzle pressure will be less than this due to the vertical lift of 2.75 m (0.5 bar) and 11.25 m of pipe to the furthest nozzle at an approximate average pressure loss of 0.07 bar/m (0.79 bar).

The pressure drop across the valve should also be included. If this is a globe valve, from Table 8, this is equivalent to $\frac{300 \times 40}{1000}$ = 12 m of pipe giving 0.84 bar.

The nozzle pressure will be approximately:

6.57 – 0.50 – 0.79 – 0.84 = 4.44 bar

Assuming a nozzle of type A (Figure 6) then at a nozzle pressure of 4.44 bar, the nozzle will pass 0.016 kg/s·mm^2 (Figure 4).

To deliver 2.1 kg/s the nozzle area should be $\frac{2.1}{0.016}$ = 131.25 mm^2

therefore

Nozzle diameter = $2\sqrt{\left(\frac{131.25}{\pi}\right)}$ = 13 mm

It is now necessary to check the discharge time for the system so far planned and to adjust the nozzle size if this proves incorrect. To do this first calculate the container pressure corresponding to various mass flow rates.

It will be necessary to take a range of nozzle pressures likely to be encountered during the discharge and calculate back from the furthest nozzle to the container to arrive at the total mass flow rate and the corresponding container pressure.

The nozzle pressure should not be lower than 3.1 bar so the calculation is started at a figure slightly higher than this (3.2 bar) and is tabulated below.

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Let the nozzle pressure at A =	3.2 bar	4.0 bar	6.0 bar
From Figure 4, G =	0.01 kg/(s·mm^2)	0.014 kg/(s·mm^2)	0.0245 kg/(s·mm^2)
therefore			
mass flow rate through nozzle A = nozzle area × G =	131.25 × 0.01 = 1.31 kg/s	131.25 × 0.014 = 1.84 kg/s	131.25 × 0.0245 = 3.22 kg/s
From Figure 3 for 25 mm pipe, the pressure drop along AB (4 m long) at this mass flow rate =	4 × 0.019 = 0.076 bar	4 × 0.036 = 0.14 bar	4 × 0.1 = 0.4 bar
Nozzle pressure at B =	3.2 + 0.076 = 3.28 bar	4.0 + 0.14 = 4.14 bar	6.0 + 0.4 = 6.4 bar
From Figure 4, G =	0.0105 kg/(s·mm^2)	0.0145 kg/(s·mm^2)	0.0265 kg/(s·mm^2)
therefore mass flow rate through nozzle B =	131.25 × 0.0105 = 1.38 kg/s	131.25 × 0.0145 = 1.90 kg/s	131.25 × 0.0265 = 3.48 kg/s
therefore mass flow rate along BC = mass flow rate through nozzles A and B =	1.31 + 1.38 = 2.69kg/s	1.84 + 1.90 = 3.74kg/s	3.22 + 3.48 = 6.70kg/s
From Figure 3 for 30 mm pipe, the pressure drop along BC at this mass flow rate = (Length of BC + equivalent length of elbow) × pressure drop/m			
$= \left(4.5 + \frac{20 \times 30}{1\,000}\right) \times$ pressure drop/m =	5.1 × 0.03 = 0.153 bar	5.1 × 0.58 = 0.30 bar	5.1 × 0.17 = 0.87 bar
(From Table 8 this includes 20 equivalent pipe diameters for the elbow)			
Pressure at the tee C =	3.28 + 0.153 = 3.43 bar	4.14 + 0.30 = 4.44 bar	6.4 + 0.87 = 7.27 bar
The mass flow rate along CD is equivalent to the combined mass flow rates from A′C and AC =	2 × 2.69 = 5.38 kg/s	2 × 3.74 = 7.48 kg/s	2 × 6.70 = 13.40 kg/s
From Figure 3 for 40 mm pipe, the pressure drop along CD at this flow rate = (Length of CD + equivalent length of valve and tee) × pressure drop/m			
$= \left(2.75 + \frac{300 \times 40}{1\,000} + \frac{60 \times 40}{1\,000}\right) \times$ pressure drop/m =	17.15 × 0.03 = 0.51 bar	17.15 × 0.056 = 0.96 bar	17.15 × 0.17 = 2.92 bar
(From Table 8 this includes 300 equivalent pipe diameters for the valve and 60 for the tee)			
Container pressure =	3.43 + 0.51 = 3.94 bar	4.44 + 0.96 = 5.40 bar	7.27 + 2.92 = 10.19 bar

These three results are summarized in the table below from which Figure 9 has been plotted.

Container pressure	Total flow rate
bar	kg/s
3.94	5.38
5.40	7.48
10.19	13.40

Before calculating the discharge time from Figure 9 the total Halon 1211 charge should be calculated. In addition to the 85.0 kg of Halon 1211 required to flood the room, additional material is needed:

a) for the Halon 1211 left in the container below the level of the dip tube; assume that this is 1.0 kg;

b) for the Halon 1211 left in the pipes AB and A′B′ (Figure 8) since it has been assumed that when the nitrogen gas has reached nozzles B and B′ no further liquid discharge will occur.

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The volume of AB + A′B′ is that of 8 m of 25 mm pipe

$$= 8 \times \pi \times \frac{(0.025)^2}{4} = 0.00393 \text{ m}^3$$

Density of Halon 1211 = 1.83 kg/L

therefore

mass of Halon 1211 = $0.00393 \times 1.83 \times 10^3 = 7.2$ kg

therefore

total Halon 1211 charge = 85.0 + 1.0 + 7.2 = 93.2 kg

Volume of 93.2 kg of Halon 1211 = 0.0509 m^3

When the nozzle pressure falls to 3.2 bar it has been shown that the container will be at 3.94 bar which in turn represents the minimum permissible container pressure.

If the container has a volume V and the initial pressure is 11.5 bar then:

$$\frac{\text{Initial pressure}}{\text{Final pressure}} = \frac{V}{V - \text{Volume of Halon 1211}}$$

$$\frac{11.5}{3.94} = \frac{V}{V - 0.0509}$$

$V = 0.07742 \text{ m}^3$

This corresponds to a maximum permissible filling density for this system derived from:

$$\frac{\text{Density of Halon 1211 at 20 °C} \times \text{volume of Halon 1211}}{\text{Volume of container}}$$

$$= \frac{0.0932}{0.07742} = 1.204 \text{ kg/L}$$

To ensure an adequate pressure, a filling density of 1.10 kg/L is used, therefore

$$\text{Container volume} = \frac{\text{Volume of Halon 1211} \times 1.83}{\text{Filling density}} =$$

$$\frac{0.0932}{1.1} = 0.0848 \text{ m}^3$$

When the system is operated the pipes first have to become filled with liquid.

Volume of CD	(2.75 m of 40 mm pipe)	= 0.00346 m^3
Volume of BC + B′C	(9.0 m of 30 mm pipe)	= 0.00636 m^3
Volume of AB + A′B′	(8.0 m of 25 mm pipe)	= 0.00393 m^3
	Pipe volume	= 0.01375 m^3

Therefore when the system starts to discharge the volume of Halon 1211 remaining in the container is now 0.0509 – 0.0137 = 0.0372 m^3.

therefore

Free volume is 0.0848 – 0.0372 = 0.0476 m^3

Initial free volume is 0.0848 – 0.0509 = 0.0339 m^3

therefore

Pressure at the start of discharge is $\frac{0.0339}{0.0476} \times 11.5 = 8.19$ bar

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Starting from this pressure of 8.19 bar, Figure 9 shows that the Halon 1211 mass flow rate is 10.9 kg/s. This rate will, of course, fall with time as the container empties and the pressure falls. However if it is assumed that this rate can be treated as constant for the first second of discharge then $\frac{10.9}{1830} = 0.00596\ m^3$ of Halon 1211 is lost from the container. The container pressure will therefore fall to 7.27 bar, as the vapour volume increases by the same amount. Thus again from Figure 3 a new mass flow rate of 9.7 kg/s is obtained which enables the calculation to proceed.

The stepwise calculation is continued until the vapour volume increases to the point where the container and the pipework up to nozzles B and B′ become full of vapour.

This volume = Volume of container + volume of CD + volume of BC + volume of B′C

= 0.0848 + 0.00346 + 0.00636

= 0.0946 m^3

The results of the stepwise calculation are shown in the table below:

Time	Vapour volume	Container pressure	Halon 1211 mass flow rate	Halon 1211 volume flow rate
s	m^3	bar	kg/s	m^3/s
0	0.0476	8.19	10.9	0.00596
1	0.0536	7.27	9.7	0.00530
2	0.0589	6.62	8.9	0.00486
3	0.0638	6.11	8.25	0.00451
4	0.0683	5.71	7.75	0.00423
5	0.0725	5.38	7.30	0.00399
6	0.0765	5.10	7.00	0.00383
7	0.0803	4.86	6.65	0.00363
8	0.0839	4.65	6.4	0.00350
9	0.0874	4.46	6.15	0.00336
10	0.0908	4.29	5.95	0.00325
11	0.0940	4.14		

This shows that the vapour volume of 0.0946 m^3 will be reached in about 11 s and incidentally that the container pressure of 4.14 bar is in excess of the minimum 3.94 bar calculated previously, i.e. the nozzle pressures will remain in excess of 3.1 bar.

The discharge time of 11 s is sufficiently close to 10 s to allow the system to be used as designed.

Alternatively increasing the nozzle orifice diameter to 14 mm and repeating the calculation will reduce the time to 10 s.

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Appendix E Example of design calculation for unbalanced system

E.1 The procedure for an unbalanced system is similar to that for a balanced system. Assume the same conditions as in Appendix D but with a pipe layout as shown in Figure 10.

NOTE The pressures stated in the following example are absolute pressures (in bar).

E.2 Taking nozzle A as 13 mm as in Appendix D calculate a discharge rate v pressure relationship as before.

Let the nozzle pressure at A =	3.2 bar	4.0 bar	6.0 bar
From Figure 4, G =	0.01 kg/(s mm^2)	0.014 kg/(s mm^2)	0.0245 kg/(s mm^2)
therefore			
mass flow rate through nozzle A = nozzle area × G =	131.25 × 0.01 = 1.31 kg/s	131.25 × 0.014 = 1.84 kg/s	131.25 × 0.0245 = 3.22 kg/s
From Figure 3 for 25 mm pipe, the pressure drop along AB at this mass flow rate = (Length of AB + equivalent length of elbow) × pressure drop/m			
$= \left(2.5 + 3.0 + \frac{20 \times 25}{1000}\right) \times$ pressure drop/m =	6 × 0.019 = 0.114 bar	6 × 0.037 = 0.222 bar	6 × 0.10 = 0.60 bar
Nozzle pressure at B =	3.2 + 0.114 = 3.31 bar	4.0 + 0.222 = 4.22 bar	6.0 + 0.60 = 6.60 bar
From Figure 4, G =	0.0105 kg/(s mm^2)	0.015 kg/(s mm^2)	0.028 kg/(s mm^2)
therefore			
mass flow rate through nozzle B =	131.25 × 0.0105 = 1.38 kg/s	131.25 × 0.015 = 1.97 kg/s	131.25 × 0.028 = 3.68 kg/s
therefore			
mass flow rate along BC = mass flow rate through nozzles A and B =	1.31 + 1.38 = 2.69 kg/s	1.84 + 1.97 = 3.81 kg/s	3.22 + 3.68 = 6.90 kg/s
From Figure 3 for 30 mm pipe, the pressure drop along BC at this mass flow rate = (Length of BC + equivalent length of elbow) × pressure drop/m			
$= \left(2.5 + 3.0 + \frac{20 \times 30}{1000}\right) \times$ pressure drop/m =	6.1 × 0.03 = 0.183 bar	6.1 × 0.058 = 0.354 bar	6.1 × 0.180 = 1.098 bar
Pressure at nozzle C =	3.31 + 0.183 = 3.49 bar	4.22 + 0.354 = 4.57 bar	6.60 + 1.098 = 7.70 bar
From Figure 4, G =	0.0115 kg/(s mm^2)	0.017 kg/(s mm^2)	0.0335 kg/(s mm^2)
therefore			
mass flow rate through nozzle C =	131.25 × 0.0115 =1.51 kg/s	131.25 × 0.017 = 2.23 kg/s	131.25 × 0.0335 = 4.40 kg/s
These are sufficiently higher than mass flow rates through nozzles A and B so the nozzle size is reduced from 12 mm to 13 mm which has an area of 113.10 mm^2 and gives a mass flow rate of:	113.10 × 0.0115 = 1.30 kg/s	113.10 × 0.017 = 1.92 kg/s	113.10 × 0.0335 = 3.73 kg/s
therefore			
mass flow rate along EC = mass flow rate through nozzles A + B + C =	2.69 + 1.30 = 3.99 kg/s	3.81 + 1.92 = 5.73 kg/s	6.90 + 3.73 = 10.62 kg/s
From Figure 3 for 40 mm pipe, the pressure drop along EC (2.5 m long) at this mass flow rate =	2.5 × 0.017 = 0.04 bar	2.5 × 0.033 = 0.0825 bar	2.5 × 0.105 = 0.26 bar
Pressure at E =	3.49 + 0.04 = 3.53 bar	4.57 + 0.0825 = 4.65 bar	7.70 + 0.26 = 7.96 bar

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Assume the mass flow rate along ED (25 mm pipe) is:	1.3 to 1.4 kg/s	2 kg/s	3.4 kg/s
From Figure 3, the pressure drop along DE (3 m long) should be approximately 3 × pressure drop/m =	3 × 0.02 = 0.06 bar	3 × 0.042 = 0.126 bar	3 × 0.11 = 0.33 bar
Nozzle pressure at D =	3.53 – 0.06 = 3.47 bar	4.66 – 0.126 = 4.53 bar	7.96 – 0.33 = 7.63 bar
From Figure 4, G =	0.0115 kg/(s·mm^2)	0.017 kg/(s·mm^2)	0.033 kg/(s·mm^2)
Calculating the nozzle diameter for D from nozzle area = mass flow rate/G gives 12 mm as a more suitable size than 13 mm			
therefore mass flow rate through nozzle D =	113.10 × 0.0115 = 1.30 kg/s	113.10 × 0.017 = 1.92 kg/s	113.10 × 0.033 = 3.73 kg/s
therefore mass flow rate along EF =	3.99 + 1.30 = 5.29 kg/s	5.73 + 1.92 = 7.65 kg/s	10.62 + 3.73 = 14.35 kg/s
From Figure 3 for 40 mm pipe, the pressure drop along EF at this mass flow rate = (Length of EF + equivalent length of elbow and valve) ×pressure drop/m			
$= \left(2.75 + \frac{300 \times 40}{1000} + \frac{90 \times 40}{1000}\right) \times$ pressure drop/m =	18.35 × 0.029 = 0.532 bar	18.35 × 0.058 = 1.06 bar	18.35 × 0.19 = 3.48 bar
(From Table 8 this includes 300 equivalent pipe diameters for the valve and 90 for the elbow)			
Container pressure =	3.53 + 0.53 = 4.06 bar	4.66 + 1.06 = 5.72 bar	7.96 + 3.48 = 11.44 bar

The results are summarized in the table below from which Figure 11 has been plotted.

Container pressure	Total mass flow rate
bar	kg/s
4.06	5.29
5.72	7.65
10.64	13.58

As in Appendix D the Halon 1211 charge is increased by:

a) the Halon 1211 below the dip tube in the reservoir (1 kg);

b) the Halon 1211 remaining in the pipes after discharge which is taken as the volume in pipe AC (calculated as 12.04 kg).

Total Halon 1211 charge = 85.0 + 1.0 + 12.04 = 97.04 kg

Volume of 97.04 kg of Halon 1211 = 0.0538 m^3

Again as in Appendix D taking a starting pressure of 11.5 bar and a minimum final pressure of 4.06 bar (corresponding to a nozzle pressure of 3.2 bar) the maximum container volume is calculated as 0.0832 m^3 at a filling density of about 1.19 kg/L.

To ensure an adequate pressure, a filling density of 1.10 kg/L will be used, therefore

$$\text{Container volume} = \frac{\text{Volume of Halon 1211} \times 1.83}{\text{Filling density}}$$

$$= \frac{0.0985}{1.1}$$

$$= 0.0895 \text{ m}^3$$

The initial vapour volume is thus 0.0895 – 0.0538 = 0.0357 at 11.5 bar

At the start of the discharge, i.e. when all the pipes are filled with liquid this increases to 0.0488 m^3, therefore

Pressure at the start of discharge = 8.46 bar

Final vapour volume at the end of the discharge (i.e. container volume + volume of pipes up to nozzles C and D) is 0.0929 m^3.

As in Appendix D the stepwise calculation is shown in the table below:

Time	Vapour volume	Container pressure	Halon 1211 mass flow rate	Halon 1211 volume flow rate
s	m^3	bar	kg/s	m^3/s
0	0.0488	8.46	11.2	0.00612
1	0.0549	7.52	10.0	0.00546
2	0.0604	6.84	9.15	0.00500
3	0.0654	6.32	8.4	0.00459
4	0.0700	5.90	7.9	0.00432
5	0.0743	5.56	7.35	0.00402
6	0.0783	5.31	7.0	0.00383
7	0.0821	5.06	6.7	0.00366
8	0.0858	4.84	6.4	0.00350
9	0.0893	4.65	6.1	0.00333
10	0.0926	4.48		

Thus the system will have discharged in 10 s and the residual container pressure of 4.48 bar is above that required to give a nozzle pressure in excess of 3.1 bar.

Table 1 — Physical properties of Halon 1211

Property	Value
Relative molecular mass	165.38
Boiling point at 1.013 bar (absolute)	– 4 °C
Freezing point	– 160.5 °C
Critical temperature	153.8 °C
Critical pressure (gauge)	42.06 bar
Critical volume	0.00141 m^3/kg
Critical density	713 kg/m^3
Liquid density at 20 °C	1 830 kg/m^3
Vapour pressure (gauge) at 20 °C	1.36 bar
Vapour pressure (gauge) at 60 °C	6.2 bar
Saturated vapour density at 20 °C	17.4 kg/m^3
Specific volume of superheated vapour at 1.013 bar (absolute) and 20 °C	0.145 m^3/kg

Table 2 — Quality of Halon 1211

Property	Value
Purity	99.0 % (*m*/*m)* min.
Acidity	3.0×10^{-4} % *(m*/*m*) max. (3 p.p.m. max.)
water content	2×10^{-3}(*m*/*m*) max. (20 p.p.m. max.)
High boiling impurities	0.01 % (*m*/*m*) max.
Suspended matter or sediment	None visible

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Table 3 — Halon 1211 flame extinguishment concentrations

In air at 1.0 atm[a] and 25 °C

Fuel	Measured extinguishing concentration at 25 °C	Minimum recommended design extinguishment concentration
	% (*V*/*V*)	% (*V*/*V*)
Methane	2.8	5.0
Ethane	5.0	6.0
Propane	4.5	5.4
Butane	4.0	5.0
Isobutane	3.8	5.0
Ethylene	6.8	8.2
Propene	5.2	6.2
Methanol	8.2	9.8
Ethanol	4.5	5.4
Propan-1-ol	4.3	5.2
Propan-2-ol	3.8	5.0
Butan-1-ol	4.4	5.3
2-methylpropan-1-ol	4.3	5.2
Butan-2-ol	3.8	5.0
Pentan-1-ol	4.2	5.0
Hexan-1-ol	4.5	5.4
Ethanediol	3.0	5.0
Pentane	3.7	5.0
Heptane	3.8	5.0
Hexane	3.7	5.0
2,2,5-trimethylhexane	3.3	5.0
Acetone	3.8	5.0
Pentane-2,4 -dione	4.1	5.0
Butanone	3.9	5.0
Ethyl acetate	3.3	5.0
Ethyl acetoacetate	3.6	5.0
Methyl acetate	3.3	5.0
Diethyl ether	4.4	5.3
Benzene	2.9	5.0
Toluene	2.2	5.0
Ethylbenzene	3.1	5.0
Mixed xylenes	2.5	5.0
Chlorobenzene	0.9	5.0
Benzyl alcohol	2.9	5.0

[a] 1 atm = 101 325 Pa.

Table 3 — Halon 1211 flame extinguishment concentrations

In air at 1.0 atm[a] and 25 °C

Fuel	Measured extinguishing concentration at 25 °C	Minimum recommended design extinguishment concentration
	% (*V*/*V*)	% (*V*/*V*)
Acetonitrile	3.0	5.0
Acrylonitrile	4.7	5.6
1-chloro-2,3-Epoxypropane	5.5	6.6
Nitromethane	4.9	5.9
N,N-dimethyl-Formamide	3.6	5.0
Carbon disulphide	1.6	5.0
Methylated spirit	4.2	5.0
White spirit	3.6	5.0
Avtag	4.0	5.0
Avgas	3.5	5.0
Avtur	3.7	5.0
Avcat	3.5	5.0
Petroleum ether	3.7	5.0
Gasoline (98 octane petrol)	3.9	5.0
Cyclohexane	3.9	5.0
Decahydronaphthalene	2.9	5.0
Isopropyl nitrate	7.5	9.0

[a] 1 atm = 101 325 Pa.

Table 4 — Halon 1211 inerting concentrations

In air at 1.0 atm and 25 °C

Fuel	Measured inerting concentration at 25 °C	Minimum recommended design inerting concentration (including 20 % safety factor)
	%(*V*/*V*)	%(*V*/*V*)
Methane	6.1	7.3
Propane	8.4	10.1
Hydrogen	37.0	44.4
Hexane	7.4	8.9
Ethylene	11.6	13.9
Acetone	6.9	8.3

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Table 5 — Halon 1211 total flooding quantity

Design temperature in hazardous area, θ	Specific volume of halon 1211 vapour, V[a]	Quantity[b] of Halon 1211 in kg per m^3 of protected volume required for a concentration in air C, of:							
		3 % (V/V)	4 % (V/V)	5 % (V/V)	6 % (V/V)	7 % (V/V)	8 % (V/V)	9 % (V/V)	10 % (V/V)
°C	m^3/kg	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3
0	0.129	0.2403	0.3237	0.4089	0.4959	0.5848	0.6756	0.7684	0.8632
5	0.131	0.2353	0.3169	0.4003	0.4855	0.5725	0.6614	0.7523	0.8452
10	0.134	0.2304	0.3104	0.3921	0.4756	0.5608	0.6479	0.7369	0.8278
15	0.137	0.2258	0.3042	0.3842	0.4660	0.5495	0.6348	0.7200	0.8112
20	0.140	0.2213	0.2982	0.3767	0.4568	0.5387	0.6223	0.7078	0.7952
25	0.142	0.2171	0.2924	0.3694	0.4480	0.5283	0.6103	0.6941	0.7798
30	0.145	0.2130	0.2869	0.3624	0.4395	0.5183	0.5987	0.6810	0.7651
35	0.148	0.2090	0.2816	0.3557	0.4313	0.5086	0.5876	0.6683	0.7508
40	0.151	0.2052	0.2764	0.3492	0.4234	0.4993	0.5769	0.6561	0.7371
45	0.153	0.2015	0.2715	0.3429	0.4159	0.4904	0.5665	0.6443	0.7239
50	1.156	0.1979	0.2667	0.3369	0.4085	0.4817	0.5565	0.6330	0.7111
55	0.159	0.1945	0.2621	0.3310	0.4015	0.4734	0.5469	0.6220	0.6988
60	0.162	0.1912	0.2576	0.3254	0.3946	0.4653	0.5376	0.6114	0.6869
65	0.165	0.1880	0.2533	0.3199	0.3880	0.4576	0.5286	0.6012	0.6754
70	0.167	0.1849	0.2491	0.3147	0.3816	0.4500	0.5199	0.5913	0.6643
75	0.170	0.1819	0.2451	0.3096	0.3754	0.4427	0.5115	0.5817	0.6536
80	0.173	0.1790	0.2412	0.3046	0.3695	0.4357	0.5033	0.5725	0.6431
85	0.176	0.1762	0.2374	0.2999	0.3637	0.4288	0.4954	0.5635	0.6331
90	0.178	0.1735	0.2337	0.2952	0.3581	0.4222	0.4878	0.5548	0.6233
95	0.181	0.1709	0.2302	0.2907	0.3526	0.4158	0.4804	0.5463	0.6138

[a] The specific volume of superheated Halon 1211 vapour, v, may be approximated by the expression: $v = 0.1287 + 0.000551\theta$

[b] The quantity of Halon 1211, in kg per m^3 of protected volume, is given by the expression

$$\frac{C}{v\ (100 - C)}$$

where

C is the indicated concentration in air at the specified temperature [in % (V/V)];

v is the specific volume of superheated vapour at the specified temperature (in m^3/kg).

Table 6 — Pipes

Nominal pipe size	Standard[a]	Type of pipe[b]	Grade of steel	Nominal wall thickness[bc]
All sizes	BS 3602-1 BS 3601	HFS or CFS S	360[d] or 410[e] 410	Sch 40 Sch 80
6 mm to 50 mm only	BS 1387	BW	—	Heavy
6 mm to 100 mm only	BS 3601	S	410	Sch 40

[a] Stainless steel, copper and copper alloy pipes complying with the requirements of BS 3605 or BS 2871-2 may be used but the grade should be chosen in consulation with the pipe manufacturer with regard to the duty to be performed.

[b] Abbreviations are as follows:

HFS	Hot finished seamless
CFS	Cold finished seamless
S	Seamless
BW	Butt welded
Sch	Schedule

[c] Schedule numbers determine the minimum wall thickness in accordance with BS 1600-2. Where the specified pipe is not obtainable in these dimensions, the next larger thickness should be specified.

[d] Alternatively ASTM A 106, grade A, hot finished or cold drawn Schedule 40 may be used.

[e] Alternatively 1) ASTM A 106, grade B, hot finished or cold drawn, Schedule 40 may be used.
2) API 5 L grade B seamless for sizes above 50 mm may be used.

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Table 7 — Maximum pipework spans

Pipe size	Maximum pipework span
mm	m
15	1.5
20	1.8
25	2.1
32	2.4
40	2.7
50	3.4
80	3.7
100	4.3
150	5.2
200	5.8

Table 8 — Friction loss in screwed pipe fittings and valves

Pipe fittings and valves	Equivalent length in pipe diameters
45° elbow	15
90° elbow, standard radius	32
90° elbow, medium radius	26
90° elbow, long sweep	20
90° square elbow	60
Tee, used as elbow, entering run	60
Tee, used as elbow, entering branch	90
Globe valve (open)	300
180° close return bend	75
180° medium radius return bend	50

Table 9 — Friction loss in welded pipe elbows

Pipe elbows	Equivalent length in pipe diameters
45° long-radius	5.8
45° short-radius	8.0
90° long-radius	9.0
90° short-radius	12.5
180° long-radius	12.1
180° short-radius	16.8

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Table 10 — Safety clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out

(IMPORTANT. See qualifying notes of clause **34** and definitions **30** and **31** of BS 162:1961 from which this table is taken.)

Maximum rated voltage	Minimum clearance from any point on or about the permanent equipment where a man may be required to stand (measured from position of the feet)	
	To the nearest unscreened live conductor in air (section clearance)	To the nearest part not at earth potential of an insulator[a] supporting a live conductor (ground clearance)
kV	m	m
11	2.59	2.44
15		
22	2.74	
33		
44	2.89	
66	3.05	
88	3.20	
110	3.35	
132	3.50	
165	3.81	
220	4.27	
275	4.57	

[a] The term insulator includes all forms of insulating supports, such as pedestal and suspension insulators, bushings, cable sealing ends, the insulating supports of certain types of circuit breaker, etc.

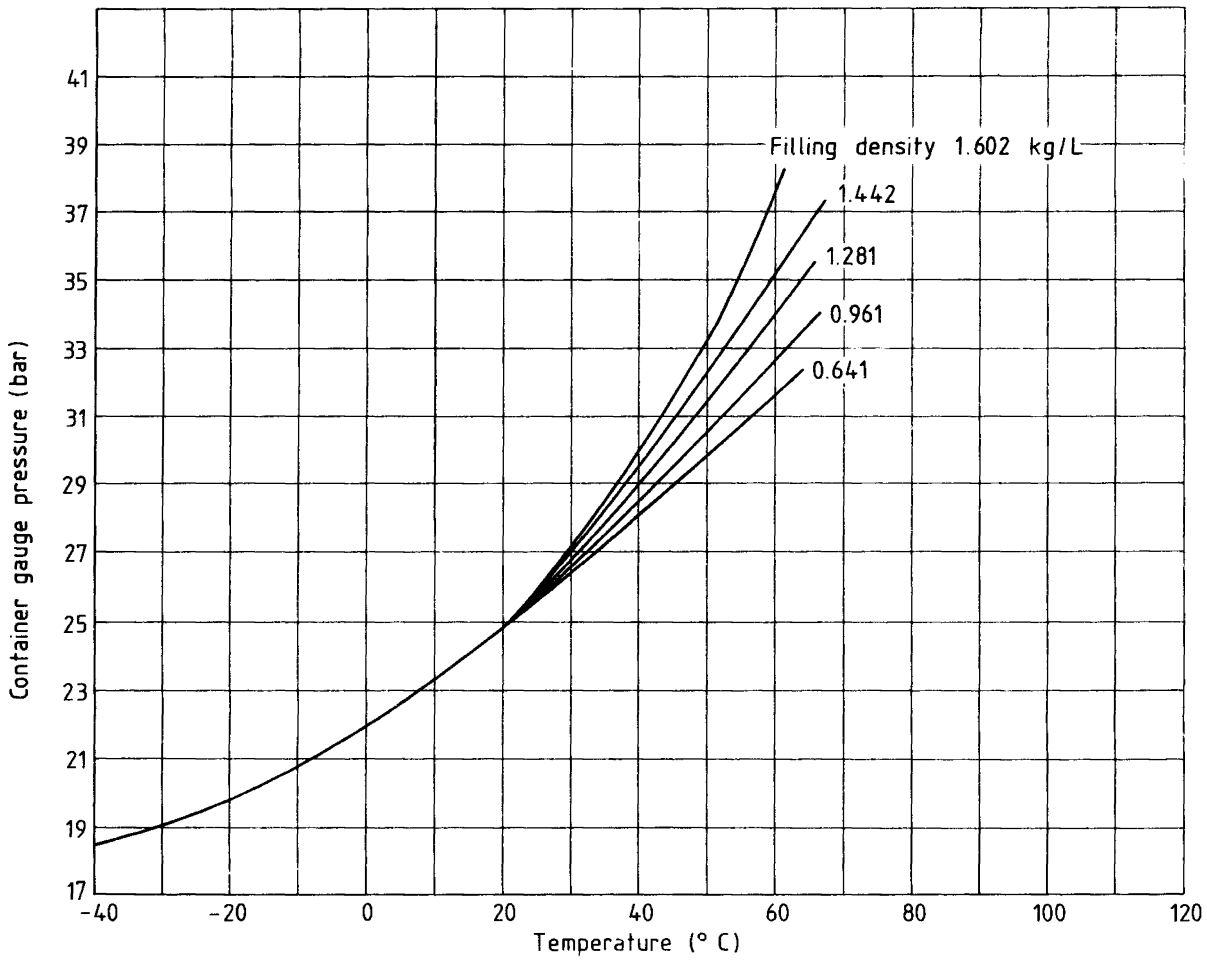

Figure 1 — Isometric diagram of Halon 1211 pressurized to 25 bar at 21 °C

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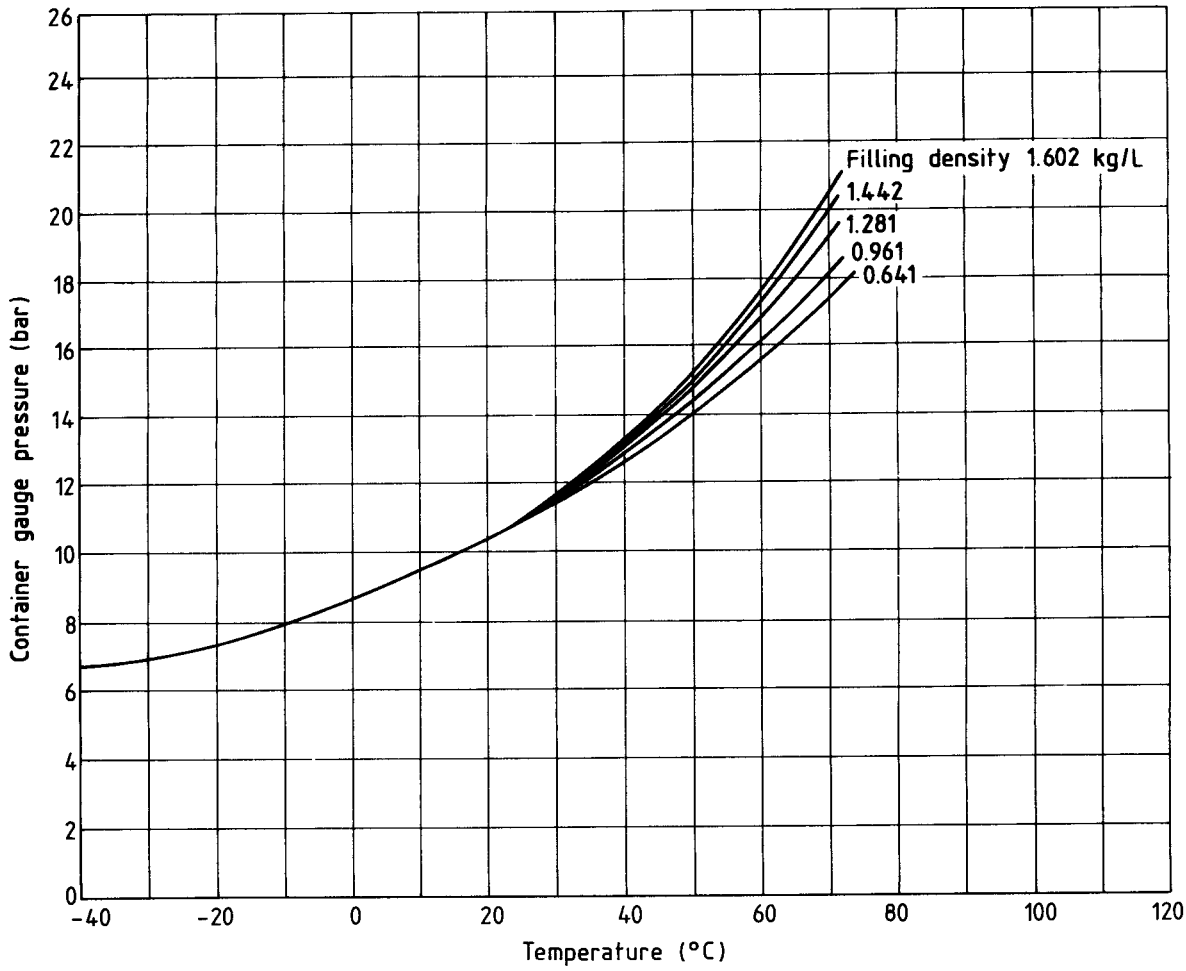
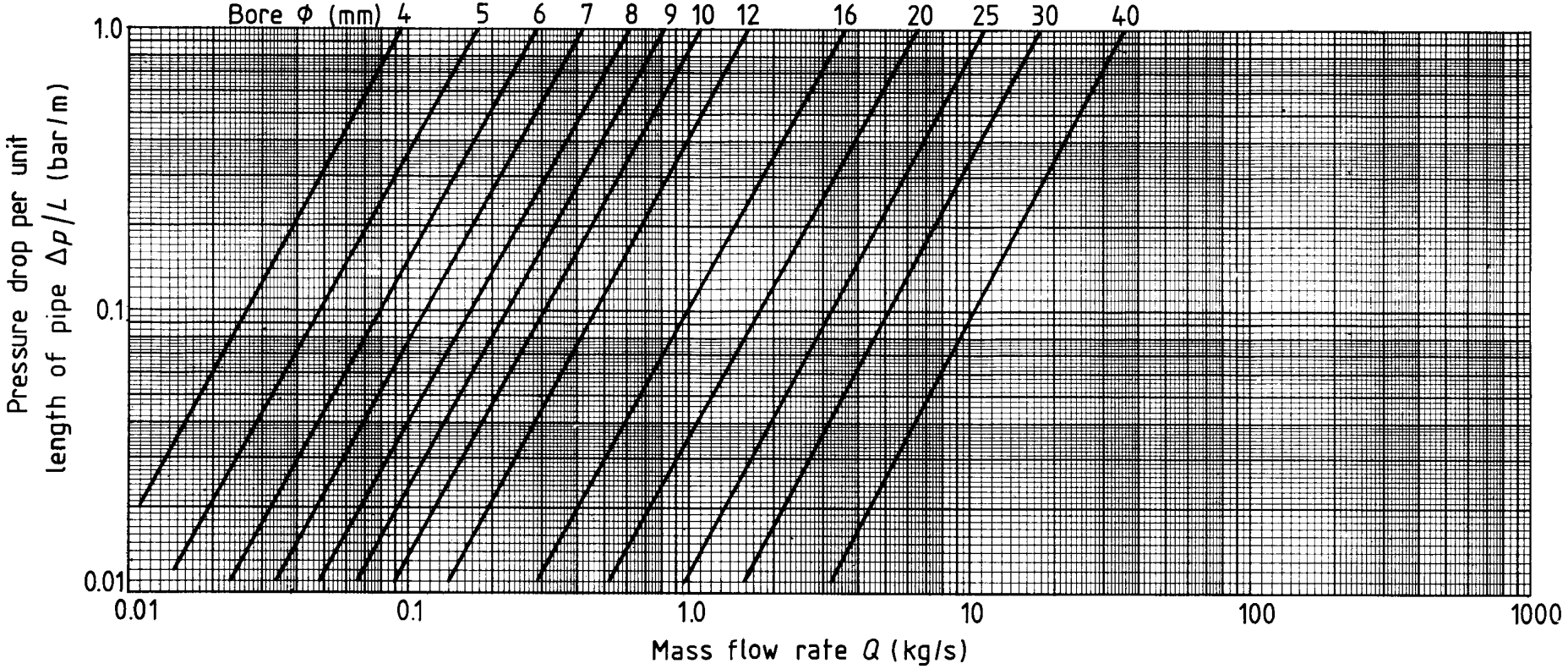


Figure 2 — Isometric diagram of Halon 1211 pressurized to 10.5 bar at 21 °C



$$\frac{\Delta p}{L} = \left\{ 12.0 + 0.82D + 37.7\,(D/Q)^{0,25} \right\} \frac{Q^2}{D^5} \times 10^3$$

Figure 3 — Pressure drop against mass flow rate for Halon 1211 in galvanized steel pipes

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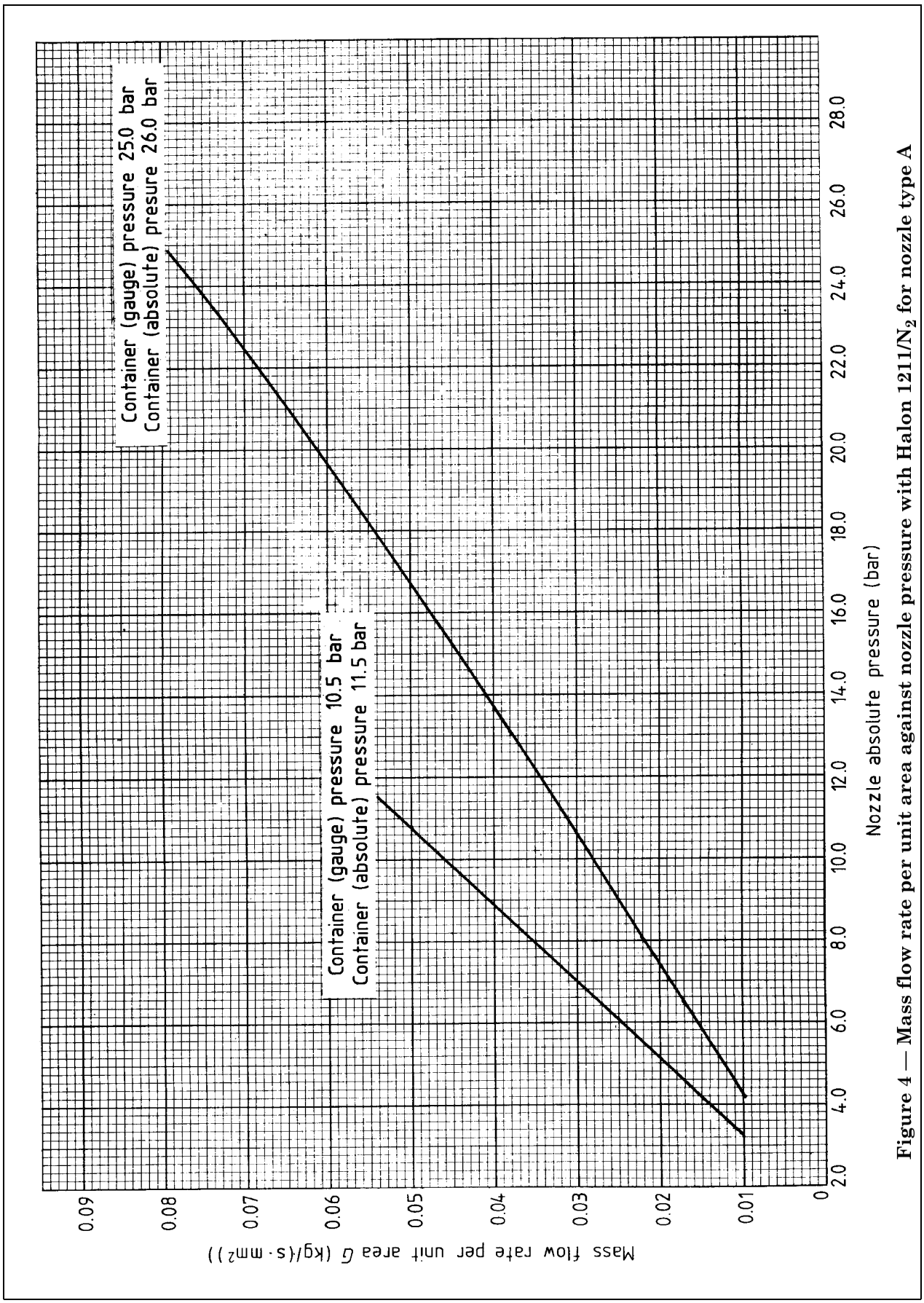

Figure 4 — Mass flow rate per unit area against nozzle pressure with Halon 1211/N_2 for nozzle type A

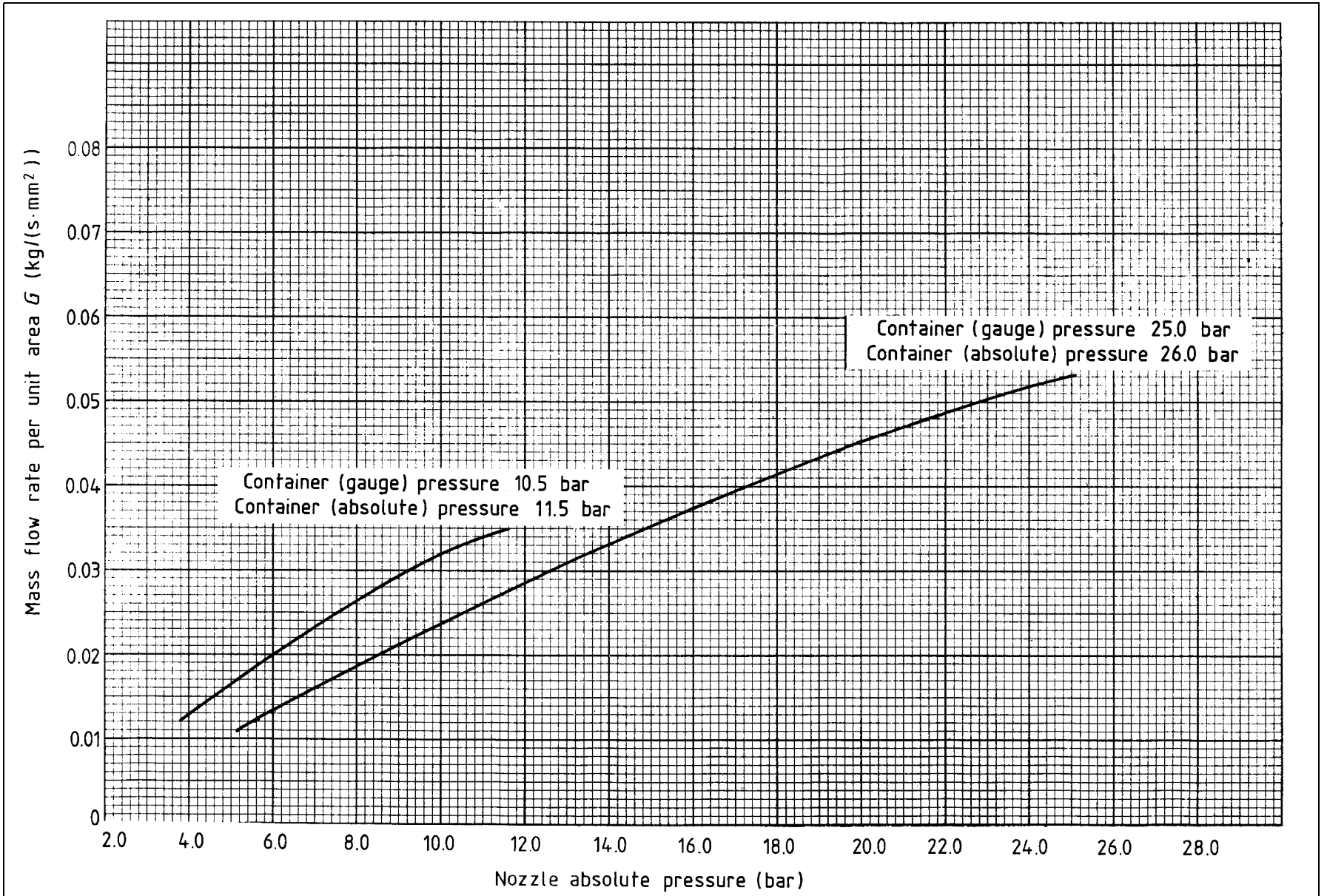

Figure 5 — Mass flow rate per unit area against nozzle pressure with Halon 1211/N_2 for nozzle type B

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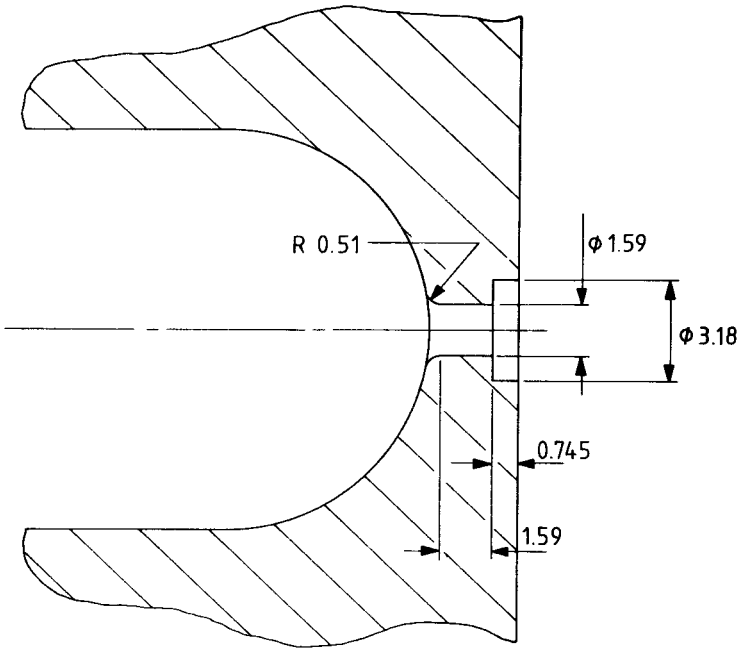
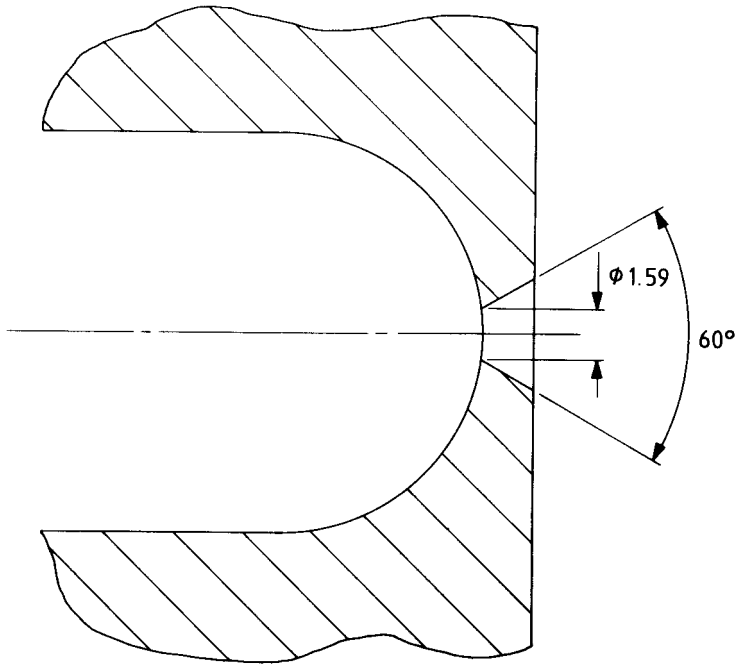


All dimensions are in millimetres.

Figure 6 — Type A nozzle



Linear dimension is in millimetres.

Figure 7 — Type B nozzle

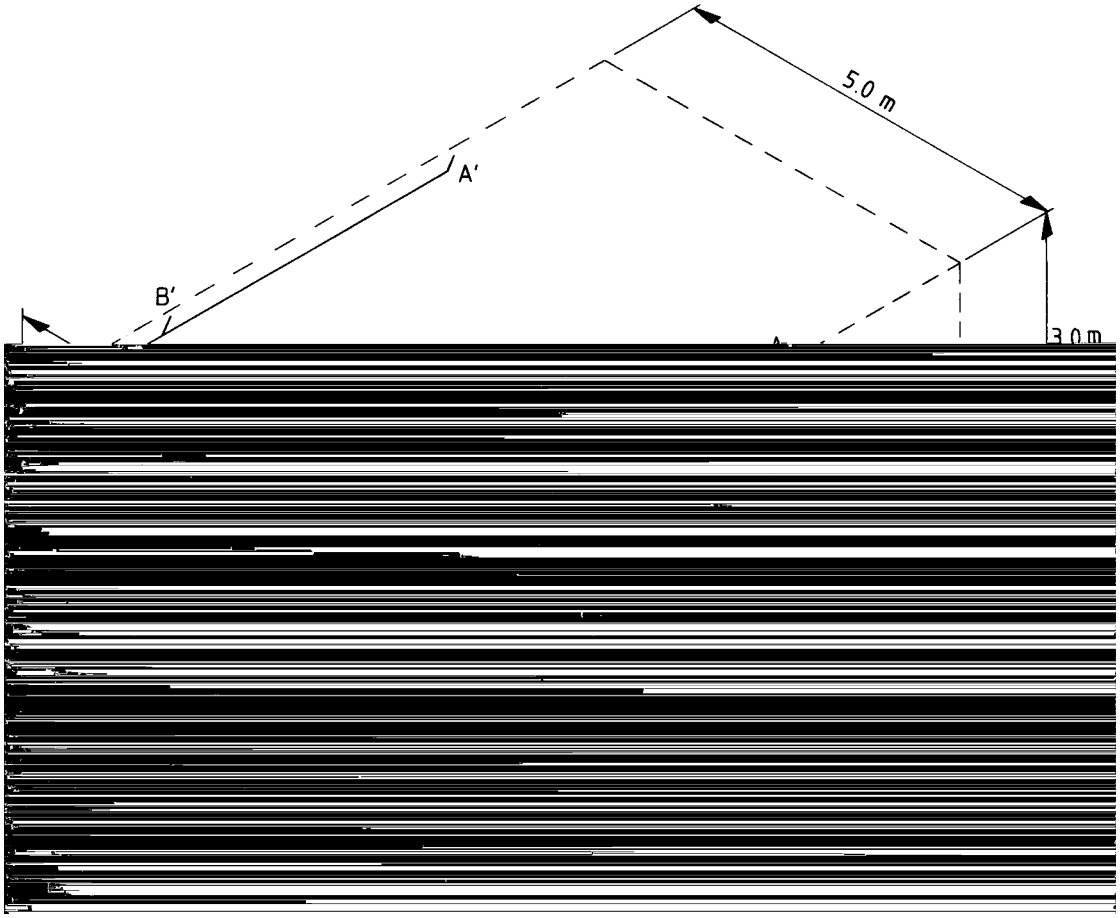


Figure 8 — Example of balanced system

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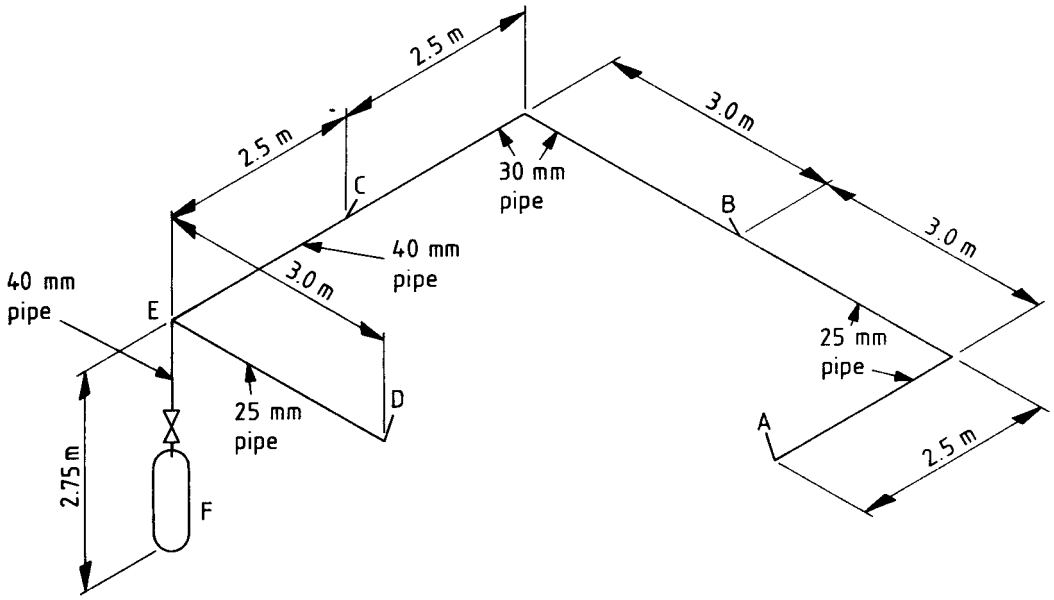

Figure 10 — Example of unbalanced system

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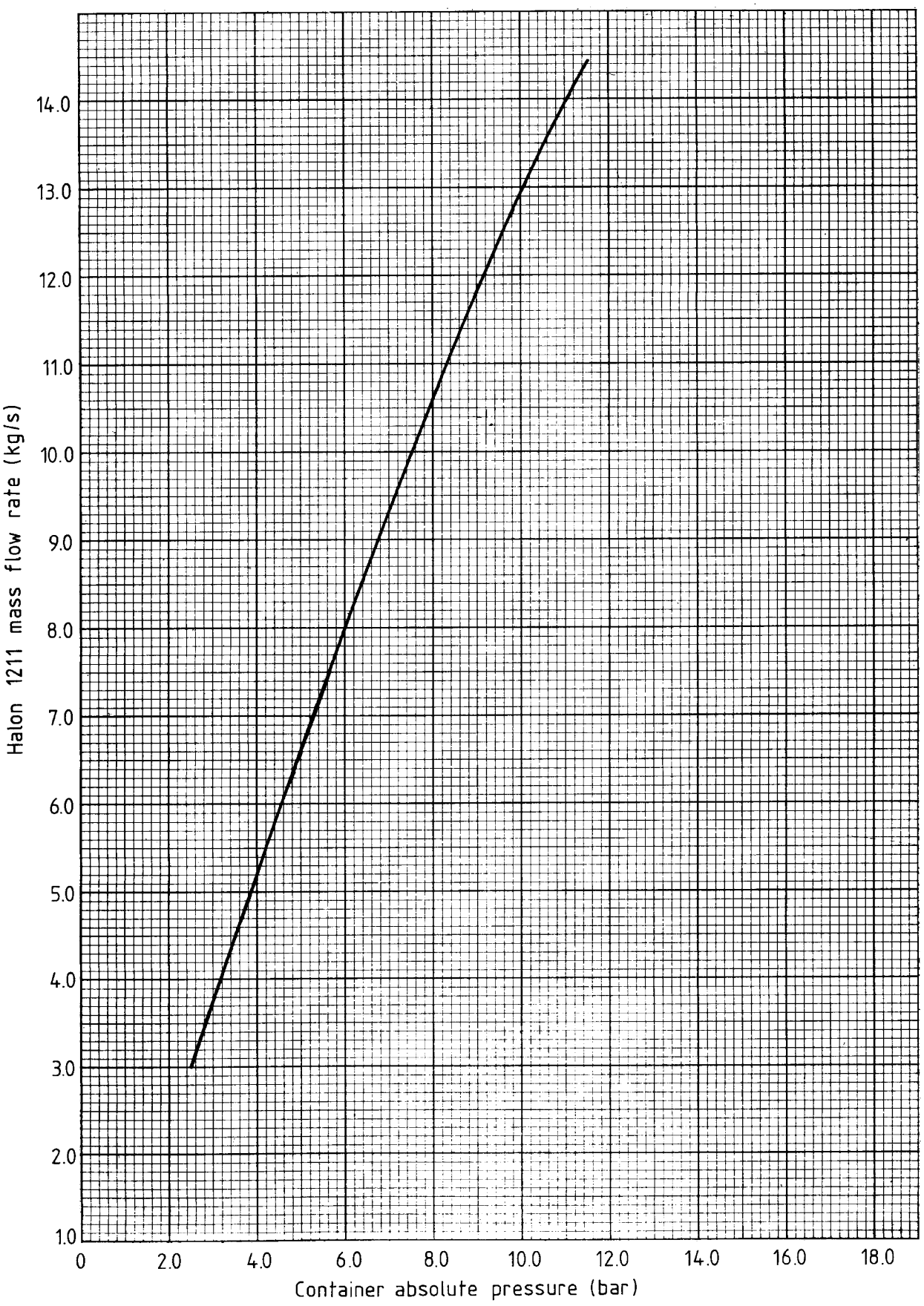
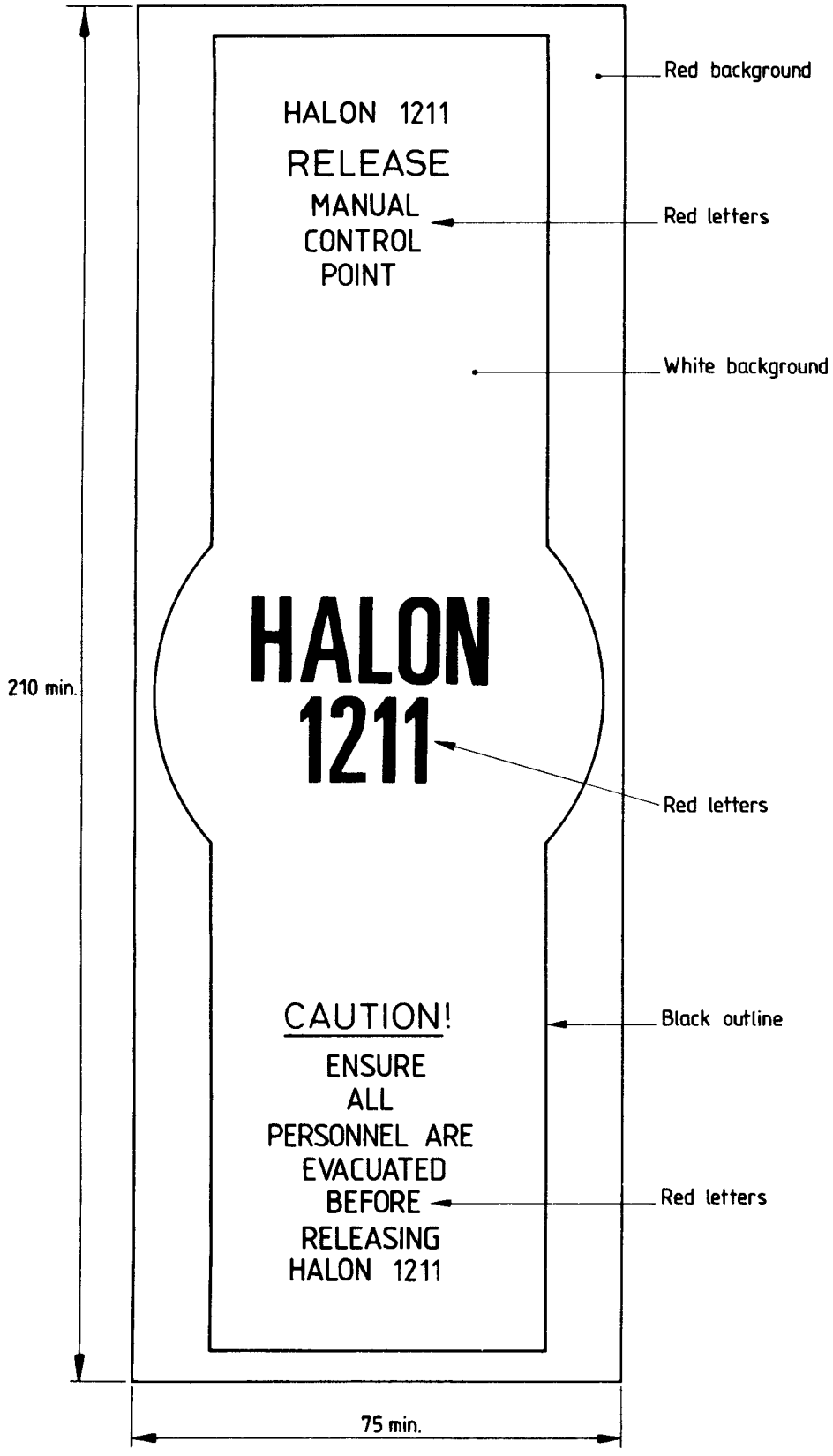


Figure 11 — Example of Halon 1211 mass flow rate against container pressure for unbalanced system



Dimensions are in millimetres.

Figure 12 — Label to be displayed at manual control

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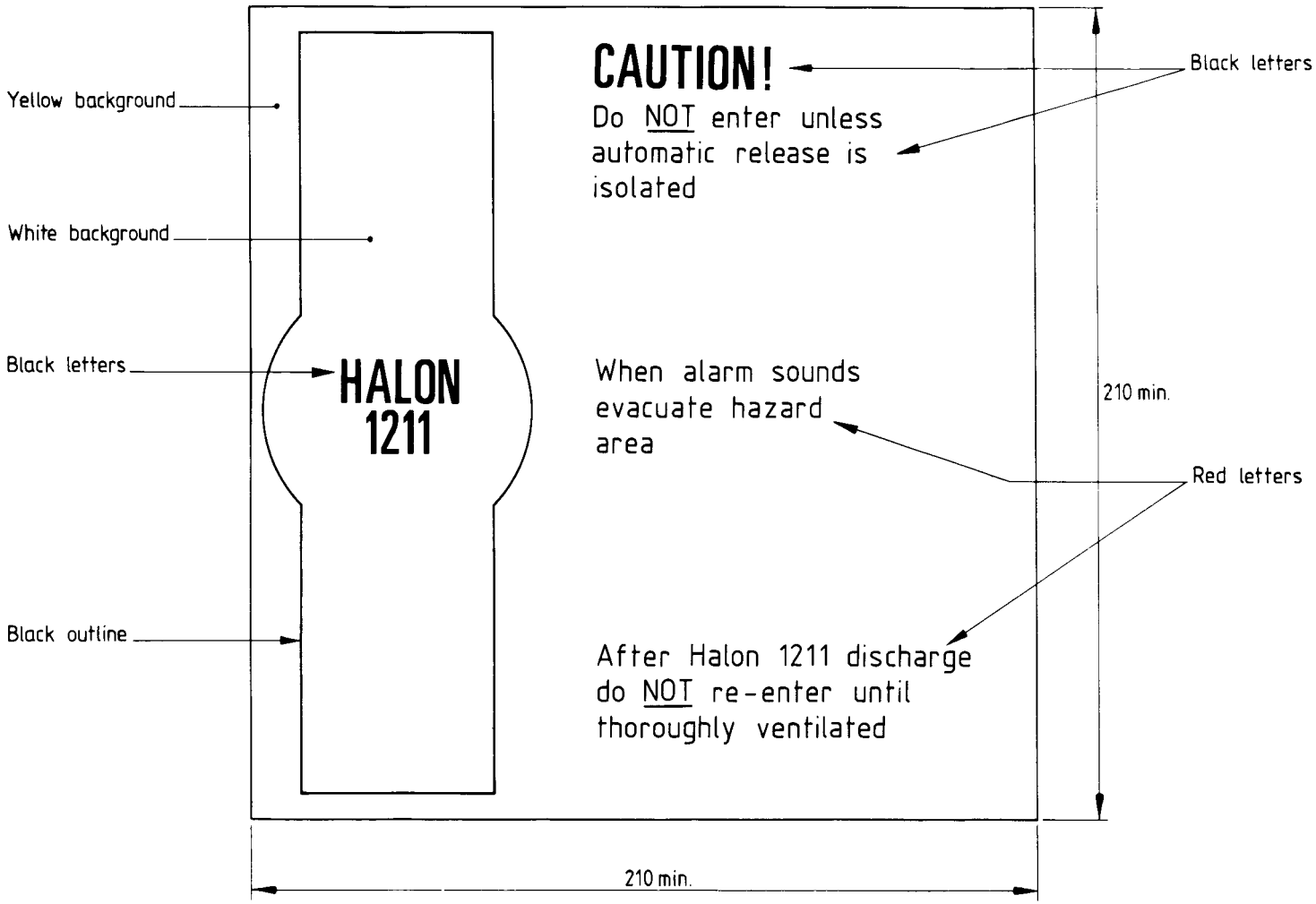

Dimensions are in millimetres.

Figure 13 — Label to be displayed at entrances to hazard

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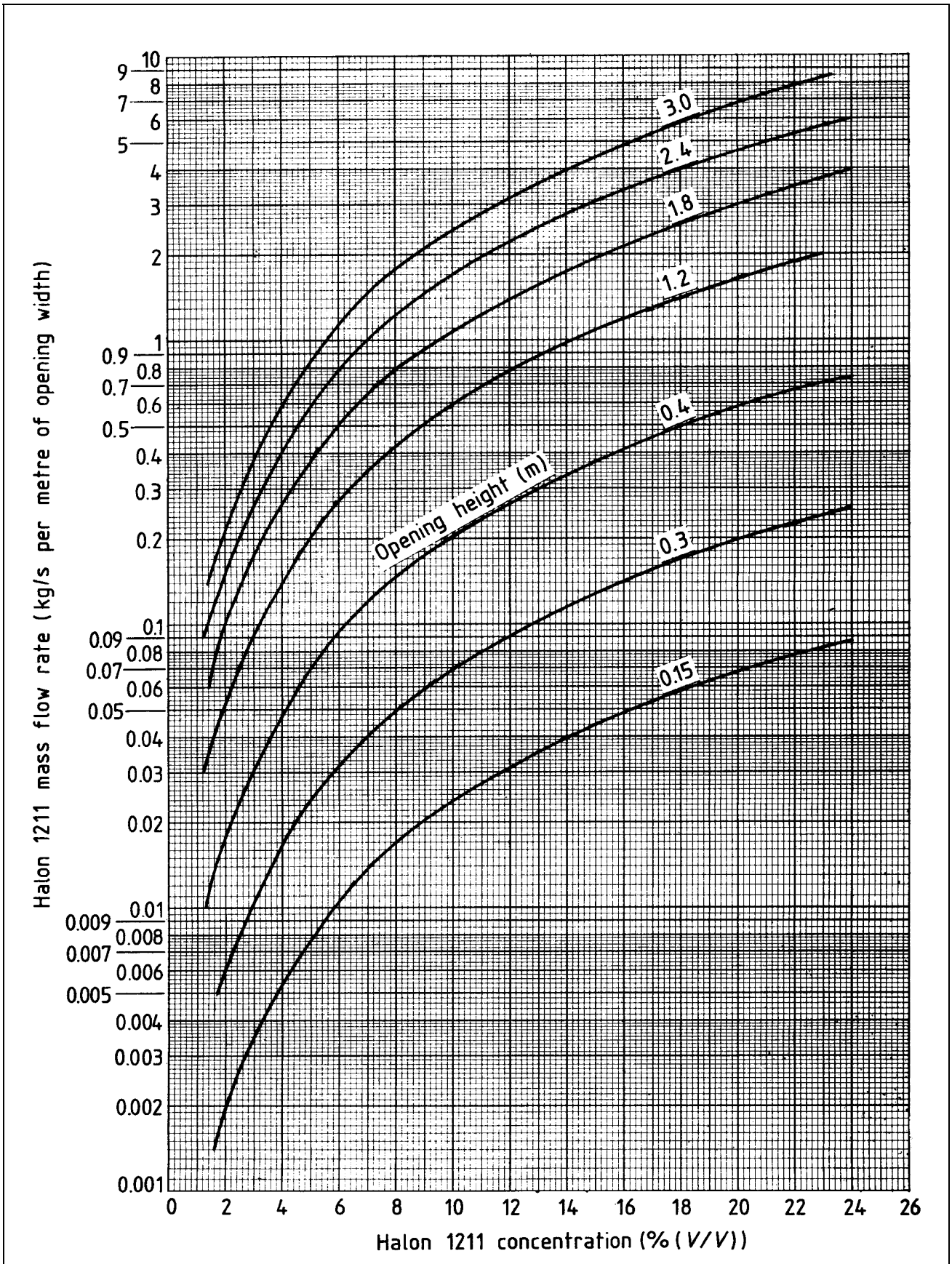

Figure 14 — Extended mass flow rate of Halon 1211 to maintain constant concentration in enclosures with openings

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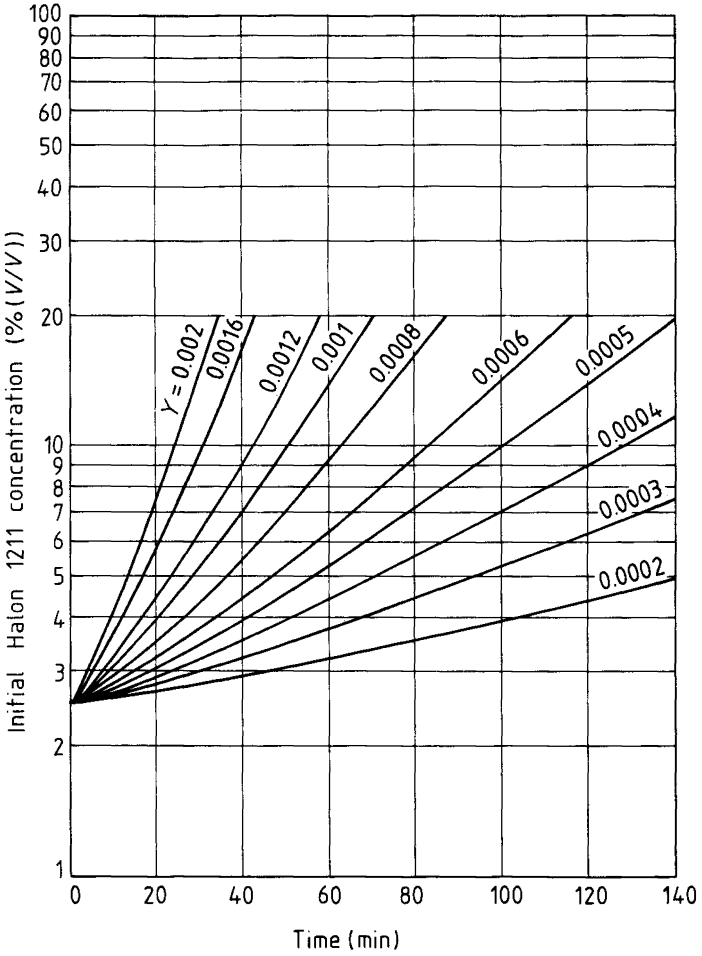

Figure 15 — Initial amounts of Halon 1211 to produce a 2.5 % (*V*/*V*) residual concentration in enclosures equipped for mechanical mixing

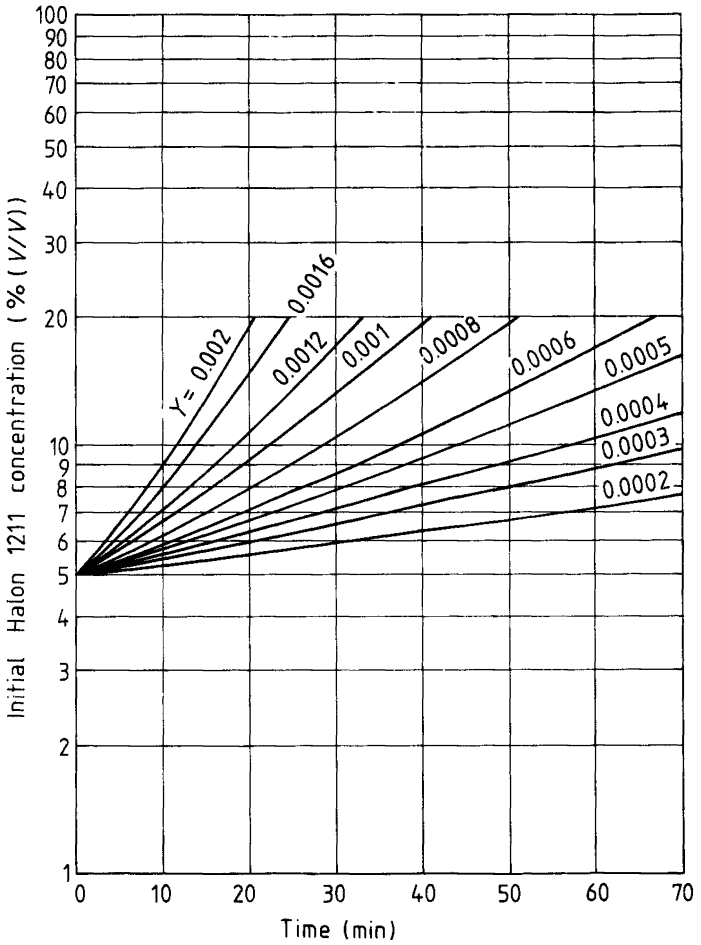

Figure 16 — Initial amounts of Halon 1211 to produce a 5 % (*V*/*V*) residual concentration in enclosures equipped for mechanical mixing

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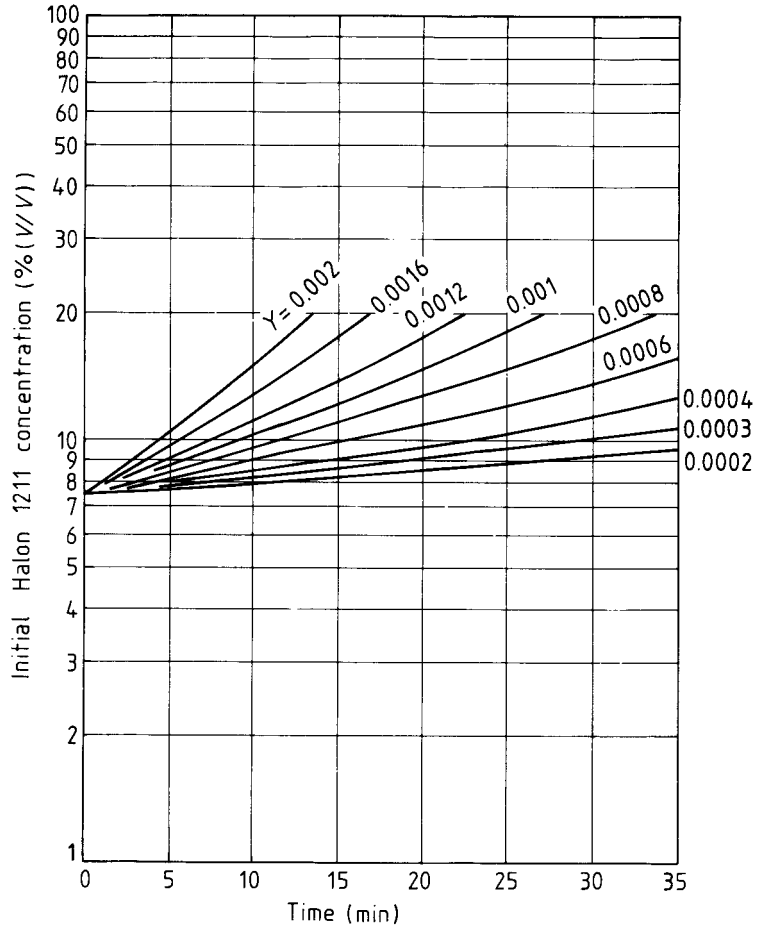

Figure 17 — Initial amounts of Halon 1211 to produce a 7.5 % (*V*/*V*) residual concentration in enclosures equipped for mechanical mixing

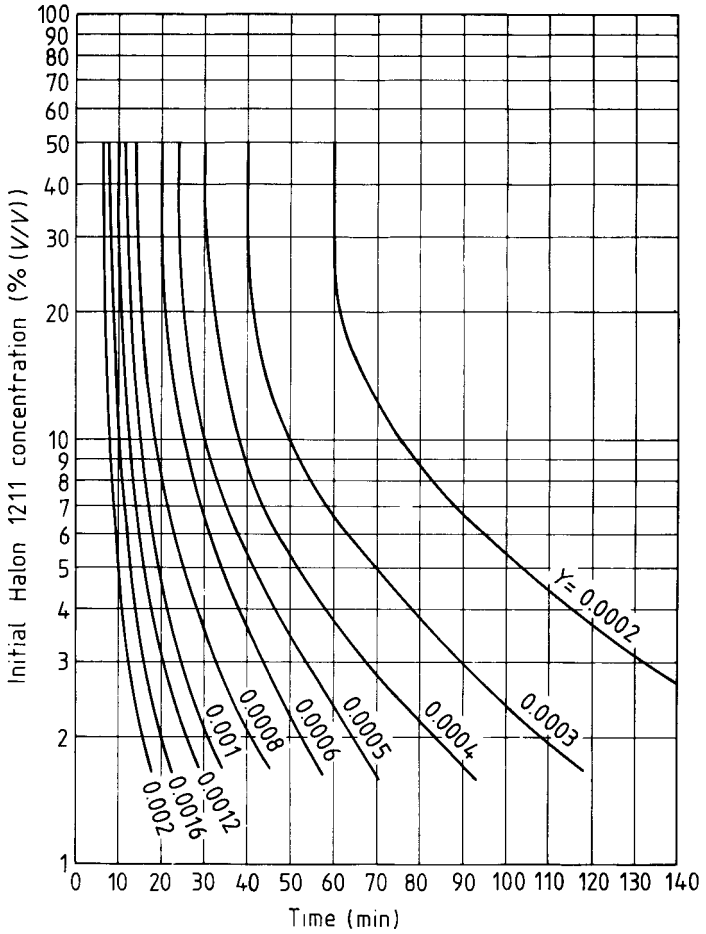

Figure 18 — Time required for interface between effluxing Halon 1211/air mixtures and influxing air to descend to the centre of enclosures not equipped for mixing

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Publications referred to

BS 21, *Pipe threads for tubes and fittings where pressure-tight joints are made on the threads.*

BS 143 & BS 1256, *Malleable cast iron and cast copper alloy screwed pipe fittings for steam, air, water, gas and oil.*

BS 162, *Electric power switchgear and associated apparatus.*

BS 381C, *Specification for colours for identification, coding and special purposes.*

BS 476, *Fire tests on building materials and structures.*

BS 476-4, *Non-combustibility test for materials.*

BS 476-8, *Test methods and criteria for the fire resistance of elements of building construction.*

BS 1387, *Steel tubes and tubulars suitable for screwing to BS 21 pipe threads.*

BS 1560, *Steel pipe flanged and finagled fittings (nominal sizes ½ in to 24 in) for the petroleum industry.*

BS 1560-2, *Metric dimensions.*

BS 1600, *Dimensions of steel pipe for the petroleum industry.*

BS 1600-2, *Metric units.*

BS 1640, *Steel butt-welding pipe fittings for the petroleum industry.*

BS 1640-3, *Wrought carbon and ferritic alloy steel fittings.*

BS 1740, *Wrought steel pipe fittings (screwed BSP thread).*

BS 1740-1, *Metric units.*

BS 1821, *Specification for class 1 oxyacetylene welding of ferritic steel pipework for carrying fluids.*

BS 2051, *Tube and pipe fittings for engineering purposes.*

BS 2051-1, *Copper and copper alloy capillary and compression tube fittings for engineering purposes.*

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BS 2871, *Copper and copper alloys. Tubes.*

BS 2871-2, *Tubes for general purposes.*

BS 3351, *Piping systems for petroleum refineries and petrochemical plants.*

BS 3601, *Steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties.*

BS 3602, *Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties.*

BS 3602-1, *Seamless, electric resistance welded and induction welded tubes.*

BS 3605, *Seamless and welded austenitic stainless steel pipes and tubes for pressure purposes.*

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BS 4366, *Industrial nitrogen.*

BS 4368, *Carbon and stainless steel compression couplings for tubes.*

BS 4422, *Glossary of terms associated with fire.*

BS 4422-4, *Fire protection equipment.*

BS 4547, *Classification of fires.*

BS 4677, *Class 1 arc welding of austenitic stainless steel pipework carrying fluids.*

BS 5045, *Transportable gas containers.*

BS 5045-1, *Specification for seamless steel gas containers above 0.5 litre water capacity.*

BS 5045-2, *Steel containers up to 130 litres water capacity with welded seams.*

BS 5045-3, *Seamless aluminium gas containers (in preparation).*

BS 5252, *Framework for colour co-ordination for building purposes.*

BS 5430, *Specification for periodic inspection, testing and maintenance of transportable gas containers (excluding dissolved acetylene containers).*

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BS 5839, *Fire detection and alarm systems in buildings.*

BS 5839-1, *Code of practice for installation and servicing.*

CP 1013, *Earthing.*

ASTM A106, *Seamless carbon steel pipe for high temperature service.*

ANSI B16.3, *Malleable iron threaded fittings.*

ANSI B16.5, *Steel pipe flanges and flanged fittings.*

ANSI B16.9, *Factory-made wrought steel butt welding fittings.*

API Std 5B, *Specification for threading, gauging and thread inspection of casing, tubing and line pipe threads.*

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