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Code of practice for

# **Fire extinguishing installations and equipment on premises**

Part 5. Halon systems

Section 5.1 Halon 1301 total flooding systems

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Code de bonne pratique des installations et du matériel d'extinction d'incendie dans les locaux

Partie 5. Systèmes utilisant les Halons

Section 5.1 Systèmes d'extinction par protection d'ambiance au Halon 1301

Richtlinien für Feuerlöschanlagen und -geräte im Gebäuden

Teil 5. Systeme mit Halon

Abschnitt 5.1 Raumschutz durch Halon 1301-Löschanlagen

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## Foreword

This British Standard code of practice constitutes Part 5 : Section 5.1 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 : Part 3)
- Part 4 Carbon dioxide systems
- Part 5 Halon systems
  - \*Section 5.2 Halon 1211 total flooding systems
  - \*Section 5.3 Halon 1211 local application systems
- Part 6\* Foam systems
- Part 7\* Extinguishing powder systems

As part of BSI's programme of metrication this code is expressed in metric units. Pressures are, however, expressed

in bar (gauge) unless otherwise stated, and it should be noted that  $1 \text{ bar} = 10^5 \text{ N/m}^2 = 100 \text{ kPa}$ . For information on SI units reference should be made to BS 3763.

Halon 1301 total flooding systems, with which this Section of this code is concerned, are designed to provide a piped or otherwise connected supply of Halon 1301 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 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 regard to local circumstances.

This code of practice represents a standard of good practice and takes the form of recommendations. Compliance with it does not confer immunity from relevant statutory and legal requirements.

\*In course of preparation.

British Standard Code of practice for

# Fire extinguishing installations and equipment on premises

Part 5. Halon systems

Section 5.1 Halon 1301 total flooding systems

## 0. Introduction

It is important that the fire protection of a building or plant should be considered as a whole. Halon 1301 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 1301 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 1301 total flooding fire extinguishing systems in buildings or plant.

Such a system consists of an installation designed to convey Halon 1301 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 1301 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 Halon 1301 systems should play in general schemes of fire protection of premises, having regard to safety as well as efficiency.

NOTE. Unless otherwise stated, all pressures are expressed in bar (gauge).

## 2. References

The titles of the standards publications referred to in this code are listed on the inside back cover.

## 3. Definitions

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

**3.1 authority.** An organization, office or individual responsible for approving equipment, installations or procedures.

**3.2 automatic.** Pertaining to a fire extinguishing system that, under specified conditions, functions without intervention by a human operator.

**3.3 manual.** Pertaining to a fire extinguishing system that, under specified conditions, functions by means of the intervention of a human operator.

**3.4 normally occupied area.** An area that is occupied by people during working hours.

**3.5 normally unoccupied area.** An area that is not occupied by people during working hours but that may be entered occasionally for brief periods.

**3.6 total flooding system.** An automatic or manual Halon 1301 fire extinguishing system consisting of a supply of Halon 1301 arranged to discharge and fill an enclosed space to the proper concentration.

## 4. Characteristics of Halon 1301

**4.1 General.** Halon 1301 is chemically bromotrifluoromethane ( $\text{CBrF}_3$ ), which is sometimes abbreviated to BTM.

The compound is used as a low temperature refrigerant and as a cryogenic fluid, as well as a fire extinguishing agent.

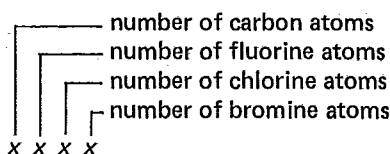
Under normal conditions Halon 1301 is a colourless, odourless, electrically non-conductive gas with a density approximately five times that of air.

A list of important physical properties of Halon 1301 is given in table 1.

According to present knowledge Halon 1301 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.

**4.2 Quality.** Halon 1301 should comply with the specification given in table 2.

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



For example, bromotrifluoromethane ( $\text{CBrF}_3$ ) is referred to as Halon 1301 because the chemical formula shows:

one carbon atom;  
three fluorine atoms;  
no chlorine atoms;  
one bromine atom.

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

**4.4 Use of Halon 1301.** Halon 1301 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 should be carefully considered.

Flammable liquid and gas fires are promptly extinguished when Halon 1301 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 1301, provided the fire is detected quickly and the extinguishing medium is injected promptly, and that the concentration is maintained for an adequate period of time.

Halon 1301 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 1301 is suitable for use on fires involving live electrical apparatus.

#### 4.5 Hazard to personnel

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

Other potential hazards to be considered for individual systems are 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.

(c) *Low temperature.* Direct contact with the vaporizing liquid being discharged from a Halon 1301 system will have a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vaporizes rapidly when mixed with air and thus limits this hazard to the immediate vicinity of the discharge point.

(d) *Visibility.* Discharge of the agent 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. Once discharged into an enclosure, it is difficult to detect its presence through normal human senses; in concentrations above about 3 %, voice characteristics are changed owing to the increased density of the agent/air mixture.

(e) *Uneven distribution.* In total flooding systems, the high density of Halon 1301 vapour requires the use of discharge nozzles that will achieve a well mixed atmosphere in order to avoid local pockets of higher concentration. Halon 1301 and Halon 1301/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.

**4.5.2** The effects of Halon 1301 (meeting the specification in table 2) on humans have been studied extensively and found to produce minimal, if any, effects on the central nervous system at the concentrations of 5 % to 7 % by volume normally used for fire protection.

Exposure to these concentrations for up to 5 min are normally considered to represent a negligible risk to personnel.

Exposure to concentrations above 10 % by volume may entail the risk of cardiac arrhythmia in some people whose blood adrenalin has been raised, as is likely to be the case in the event of fire. In addition, exposure to concentrations above 10 % by volume for over 1 min or above 15 % for over 0.5 min involves the risk of unconsciousness and possible death.

Naturally, inadvertent exposure to Halon 1301 should always be avoided. 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 1301 is not retained in the body. Recovery from any dizziness or light-headedness is usually rapid and complete.

Should anyone suffer as a result of exposure to Halon 1301 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.

**4.5.3** Although Halon 1301 vapour has a low toxicity, its decomposition products can be hazardous. The most

widely accepted theory is that the vapour must decompose before Halon 1301 can inhibit the combustion reactions. The decomposition takes place on exposure to a flame, or to a hot surface at a temperature above 480 °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) and bromine.

The decomposition products of Halon 1301 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 for the agent, but at the same time creates a noxious, irritating atmosphere for those who have to enter the hazard following the fire.

The amount of Halon 1301 that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the concentration of Halon vapour and the length of time that the agent is in contact with flame or heated surfaces above 480 °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 480 °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.

## 5. Planning

**5.1** Where a fixed Halon 1301 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 these authorities should be coordinated in the planning stages of the contract.

**5.2** 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 1301 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.

## 6. Contract arrangements

**6.1 Buying specification.** The buying specification should require the installation and the principal components to conform to 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 hazard, together with the proposed location of the Halon 1301 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\*.

### 6.2 Contract drawings

**6.2.1** Prior to installation, contract drawings 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 hazard and the proposed system. Details of the hazards should be included to show the materials involved, the location and/or limits of the hazard and any other materials likely to become exposed to the hazard in the event of a fire.

**6.2.2** The location and sizes of piping and nozzles should be clearly indicated together with the location of the Halon 1301 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 quantity of Halon 1301. Further information should be given separately if required, indicating the equivalent lengths of pipe and fittings, flow rates and pressure drops throughout the system.

### 6.3 Test and acceptance

**6.3.1** 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.

**6.3.2** 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 1301.) 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 7.2.3).

(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 1301.

**6.3.3** 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.

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

\*For further information on bodies issuing approvals for equipment please contact BSI quoting the number of this standard.

## 7. System design

**7.1 General.** The design of the total flooding system should be such as to ensure that a uniform concentration of Halon 1301 is achieved throughout the volume to be protected.

Care should be taken to ensure that the required concentration of Halon 1301 can be maintained for a sufficient period of time to both extinguish and prevent reignition in the enclosed volume.

The quantity of Halon 1301 required in a given system will vary according to the type of hazard, the combustible material involved, the construction of the enclosure (particularly with regard to leakage), and to the environmental conditions.

### 7.2 Concentration

**7.2.1 Flammable liquids and gases.** The design concentration for a Halon 1301 system should be selected from either flame extinguishment or inerting data.

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

(b) The inerting concentration is the minimum agent concentration required to suppress the propagation of a flame front through a mixture of fuel vapour and air at all concentrations. Design concentrations based on this are given in table 4.

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/agent 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 tables 3 or 4 and for other temperatures and pressures, specific test data should be obtained but no design concentration should be less than 5 % by volume (including the 20 % safety factor).

**7.2.2 Class A fires.** For class A fires a minimum design concentration of 5.0 % (V/V) should be used, but attention is drawn to appendix A.

**7.2.3 Inerting.** Owing to the possible generation of static electricity during the discharge of a Halon 1301 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 1301 concentration had reached the inerting value.

The exception is as discussed in 7.2.1 where the agent would only be discharged in the presence of a fire and where a spark due to static electricity would not add to the hazard.

### 7.3 Quantity of Halon 1301

**7.3.1 General.** The quantity of Halon 1301 required to achieve the required design concentration (see tables 3

and 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 the agent may be required to compensate for openings that cannot be closed, forced ventilation, or other special conditions that might affect the efficiency of the extinguishing system.

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

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

The volume of the enclosure to be used for calculations should be the gross volume. The only permitted reductions in volume are permanent impermeable building elements within the enclosure.

#### 7.3.2 Compensation for leakage

**7.3.2.1 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 agent calculated in accordance with the procedures outlined in 7.3.2.2.

**7.3.2.2 Natural ventilation.** Halon 1301 discharged into an enclosure for total flooding will result in an air/agent mixture that has a higher relative density\* than the air surrounding the enclosure. Therefore, any opening in the walls of the enclosure will allow the heavier air/agent mixture to flow out of the enclosure and to be replaced with lighter outside air flowing into the enclosure through the same opening. The rate at which agent is lost through openings will depend upon the height and width of the opening, the location of the opening in the wall, and the concentration of agent in the enclosure.

Fresh air entering the enclosure may collect toward the top, forming an interface between the air/agent mixture and fresh air. As leakage proceeds, the interface will move toward the bottom of the opening. The space below the interface will contain essentially the original extinguishing concentration of agent, whereas the upper space will be completely unprotected. The rate at which the interface moves downwards increases with increasing concentrations of agent, so that simply injecting an overdose of agent 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 agent throughout the entire protection time, or continuous mechanical mixing of the enclosure contents (e.g. with a fan) following an initial overdose of the agent is recommended. The following three items provide methods for calculating the appropriate concentrations.

(a) **Extended agent discharge.** Halon 1301 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 agent concentration and the height and width of the opening. The agent should be discharged in such a way that uniform mixing of agent and air is obtained. See B.2.

(b) **Enclosure with mechanical mixing.** Additional protection time can be obtained by applying an over

\*Formerly known as 'specific gravity' (sp.gr.).

dose of agent initially to an enclosure provided with mechanical mixing. An adequate overdose of Halon 1301 should be provided initially, so that at the end of the desired protection period, a pre-established minimum concentration of agent still exists.

The necessary initial concentration depends upon the extended protection time required, the height and width of the opening, and the volume of the enclosure. See B.3.

(c) *Descending interface.* The design concentration of Halon 1301 should be established initially in the enclosure. The time required for the interface to reach half-way down the enclosure height is shown in figure 18 as a function of agent concentration and the geometrical constant *G* (defined in B.3). See B.4.

**7.3.2.3 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 1301, or additional agent should be provided to compensate adequately for the losses.

Halon 1301 discharged into a ventilated enclosure for total flooding is subject to loss of agent in the effluent ventilating air. A greater amount of agent may be required to develop a given concentration, and continuous agent discharge is required to maintain the concentration at a given constant level. See appendix C.

**7.4 Discharge time.** The agent discharge 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 1301 container(s) at its ambient storage temperature. A longer discharge time should be permitted only if sanctioned by the relevant authority. The discharge duration should be measured as 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.

## 8. System operation

**8.1 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 hazard to be protected, and will be subject to the requirements of the relevant authority.

**8.2 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 of fire. The manual system control should be clearly identified, so that it cannot be confused with a standard fire alarm point. (See figure 12.)

Where the controls for more than one system are located in the same place, each manual system control should

be properly labelled, identifying the hazard that is protected by the system control.

Manual controls should not require a pull of more than 170 N or a movement of more than 350 mm to achieve system operation.

## 8.3 Automatic systems

**8.3.1 Fire detection.** Automatic systems should be controlled by an appropriate automatic fire detection system, selected according to the requirements of the particular hazard, and should comply with the recommendations of BS 5839 : Part 1. In any automatic fire detection system the detector has to discriminate between a fire and the normal environment existing within the hazard. 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.

Automatic systems should be continuously monitored where the possible loss because of any delay in actuation may be high 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.

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

**8.3.3 Calculation of achieved concentration.** As recommended in 4.5.2, it is important to avoid unnecessary exposure of personnel to Halon 1301. The design concentration should be based on the gross volume to ensure that the enclosure will be protected when there is a minimal amount of furniture, fittings, etc. present.

In practice when a system discharges, the concentration of Halon 1301 could be significantly greater than the design concentration owing to:

- (a) the net volume of the enclosure being low in relation to the gross volume owing to the presence of furniture, fittings, stored materials, etc.;
- (b) additional Halon 1301 being added initially to compensate for leakages.

For normally or intermittently occupied areas the maximum likely concentration should be calculated to decide which of the three sets of conditions (i.e. 8.3.4.1,

8.3.4.2 or 8.3.4.3) applies. This concentration should be calculated on the basis of the total mass of Halon 1301 added and the minimum anticipated net volume of the enclosure, to give a flooding quantity expressed in kg/m<sup>3</sup>. Reference to table 5 will enable this to be checked to see if the concentration will exceed, for example, 6 % by volume at the maximum anticipated temperature.

#### 8.3.4 Normally or intermittently occupied areas

8.3.4.1 *Areas where the achieved concentration is not greater than 6 % by volume.* Systems protecting normally or intermittently occupied areas where the achieved concentration of the medium is not greater than 6 %, are permitted to function in the automatic mode at all times, except during periods of maintenance of the extinguishing system.

To allow personnel to evacuate from the protected area prior to agent discharge, a time delay may be incorporated in the automatic system. The delay period will depend upon the potential speed of fire spread and the means of escape from the protected area, but it should not exceed 30 s unless a longer period is specified by the responsible authority.

Where time delays are incorporated in the system, the system may also be equipped with a biased switch, located within the protected area, the manual operation of which at any time during the delay period can prevent the discharge of the agent.

8.3.4.2 *Areas where the achieved concentration is greater than 6 % but less than 10 % by volume.* Where systems designed for automatic operation are used in normally or intermittently occupied areas and the achieved concentration for the medium is greater than 6 % and less than 10 %, the system should be placed on manual control whilst the area is occupied, and should be returned to automatic control when the area is unoccupied.

Where the level of risk from fire is such that fully automatic operation of the system at all times is agreed to be necessary by the *relevant* authority, or where the protected area cannot *normally* be occupied by people, i.e. shallow floor voids, the recommendations of 8.3.4.1 should apply.

Automatic detection and alarm with manual release of the extinguishing agent should be available at all times.

While the connection between the fire detection system and the agent release is interrupted, the operation of a fire detector should activate the fire alarms. It should also be possible for the extinguishing agent to be released by the operation of the manual control, without additional action.

Clear visual indication should be provided outside the protected area at each entrance, to show whether the system control is in the automatic/manual position or on manual control only.

8.3.4.3 *Areas where the achieved concentration is 10 % or greater by volume.* Systems protecting normally or intermittently occupied areas where the achieved concentration of the medium is 10 % or greater by volume should not be permitted to function in the automatic mode at any time.

8.3.5 *Unoccupied areas.* Systems protecting areas that cannot be occupied at any time may function in the automatic mode at any concentration of extinguishing agent deemed essential for fire-fighting purposes provided

there would be no adverse effect on adjacent areas that may be occupied.

8.3.6 *Statement of achieved concentration.* A written statement should be provided by the system supplier or installer to the system user specifying the maximum concentration that is likely to be achieved within the protected area.

## 9. Enclosure

9.1 **Fire resistance.** A well enclosed space is required to maintain the designed extinguishing concentration. The walls of the enclosure should have a fire rating of not less than 30 min in accordance with BS 476 : Part 8.

9.2 **Pressure relief ventilation.** Venting of an enclosure may be necessary to relieve pressure buildup due to the discharge of Halon 1301. Appropriate pressure relief depends on the injection rate of Halon 1301 and the enclosure strength.

Porosity and leakage around, for example, doors, windows and dampers, though not readily apparent or easily calculated, will usually provide sufficient relief for Halon 1301 flooding systems without need for additional venting. Record storage rooms, refrigerated spaces and duct work also generally need no additional venting. For very tight enclosures the area necessary for free venting may be calculated from the expression

$$X = \frac{2.62 \times 10^{-3} \times vQ}{\sqrt{(v'P)}}$$

where

$X$  is the free-venting area (in m<sup>2</sup>);

$P$  is the allowable strength of enclosure (in bar (absolute));

$Q$  is the Halon 1301 discharge rate (in kg/s);

$v$  is the specific volume of Halon 1301 vapour at 1 bar (absolute) pressure and the enclosure temperature (in m<sup>3</sup>/kg);

$v'$  is the specific volume of gas vented (in m<sup>3</sup>/kg).

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.

9.3 **Services.** All services within 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 1301.

## 10. System components

10.1 **General.** Various operating devices are necessary to control the flow of the extinguishing agent 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 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.

## 10.2 Storage containers

**10.2.1 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 hazard or hazards 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.

**10.2.2 Design recommendations.** The Halon 1301 supply should be stored in containers designed to hold Halon 1301 in liquefied form at ambient temperatures. Containers should not be charged to a filling density greater than 1.121 kg/litre. The filling density of a container is defined as the number of kilograms of Halon 1301 per litre of container volume. Isometric diagrams for Halon 1301 superpressurized with dry nitrogen (see figures 1 and 2) show the relationship of the storage container pressure versus temperature with lines of constant filling density. Containers should be clean and dry before filling, to prevent corrosion.

Superpressurization (the addition of nitrogen to Halon 1301 storage containers to pressurize the agent 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 1301. This solubility is related both to the degree of superpressurization and to the temperature. Containers holding more than 10 kg of Halon 1301 or connected to discharge pipework should be superpressurized with dry nitrogen in accordance with the requirements of BS 4366 to pressures of 25 bar  $\pm$  5 % or 42 bar  $\pm$  5 % at 20 °C. Containers should be distinctively and permanently marked with the type and quantity of Halon contained therein, together with the degree of superpressurization.

Halon 1301 should be stored in containers designed, constructed and tested and marked in accordance with one of the following:

- (a) BS 5045 : Part 1;
- (b) BS 5045 : Part 2;
- (c) specification HOAL 2, HOAL 3 or HOAL 4\*.

NOTE. BS 5045 : Part 3 is being prepared to cover seamless aluminium alloy transportable gas containers and upon its publication, specifications HOAL 2, 3 and 4 will be withdrawn.

Halon 1301 containers should be periodically maintained, inspected and tested in accordance with the requirements of BS 5430 : Part 1 or Part 2 as appropriate to the type of container.

A reliable means of indication should be provided to determine the pressure in containers. The means of

indication should account for 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 in any one battery should be of the same size, mass and pressurization level.

Halon 1301 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 agent loss from the manifold if the system is operated when any containers are removed for maintenance.

Each container should have a permanent nameplate specifying the filling quantity, in kg, and pressurization level, in bar, of the container.

## 10.2.3 Container valve

**10.2.3.1 General.** Each container should be equipped with a discharge valve capable of discharging liquid Halon 1301 at the required rate. Containers with top-mounted valves should be provided with an internal dip tube to ensure discharge of liquid Halon 1301. Container valves should be protected by a suitable means during transportation.

### 10.2.3.2 Pressure

- (a) *Static pressure.* The valve body should withstand a pressure of not less than 140 bar (for 25 bar systems) or 180 bar (for 42 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 70 bar (for 25 bar systems) or 90 bar (for 42 bar systems).

## 10.3 Pipework

**10.3.1 General.** Piping should be non-combustible in accordance with BS 476 : Part 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.

Pipes and fittings should be free of burrs, spelter and rust. Steel pipe and fittings should conform to the recommendations given in 10.3.3, 10.3.4 and 10.3.5.

Manifolds should be tested at the manufacturer's works to a minimum pressure of 90 bar, for 25 bar systems, or 130 bar, for 42 bar systems. A test certificate should be provided on request.

All pipework intended to carry Halon 1301 should be painted signal red in accordance with the requirements

\*HOAL 2 'Aluminium alloy seamless cylinders'. HOAL 3 'Seamless aluminium alloy containers for the conveyance of compressed gases'. HOAL 4 'Seamless aluminium alloy containers for the conveyance of compressed gases'. These specifications are obtainable from the Health and Safety Executive, Explosives Inspectorate, Baynards House, 1 Chepstow Place, Westbourne Grove, London W2. The specifications were originally published by the Home Office.

of BS 381C or Red 04E53 in accordance with the requirements of BS 5252.

**10.3.2 Earthing of pipework.** To minimize the risk of electrostatic discharge all Halon pipework should be adequately earthed.

**10.3.3 Pipes.** Open and closed sections\* of pipe for 25 bar and 42 bar systems should be of the types given in table 6.

**10.3.4 Pipe 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 25 bar and 42 bar systems*

(1) *Fittings: all sizes*

Forged steel screwed or socket-welding fittings complying with the requirements of BS 3799; or butt-welding fittings complying with the requirements of BS 1640 : Part 3 or class 300 of ANSI B16.9.

*Up to and including 100 mm*

Screwed fittings complying with the requirements of BS 1740 : Part 1.

*Up to and including 80 mm*

Screwed fittings complying with the requirements of class 300 of ANSI B16.3.

*Up to and including 20 mm*

Screwed fittings complying with the requirements of BS 1256 or class 150 of ANSI B16.3.

(2) *Flanges: all sizes*

Forged carbon steel, raised face complying with the requirements of class 300 of table PE 1 of BS 1560 : Part 2 or class 300 of ANSI B16.5.

(3) *Gaskets for flanges*

Compressed asbestos fibre gaskets are recommended. The recommendations of the manufacturer should be followed in selecting the grade, specification and thickness to be used.

(b) *Closed sections of pipe for 25 bar systems only*

(1) *Fittings: all sizes*

Forged steel screwed or socket-welding fittings complying with the requirements of BS 3799; or butt-welding fittings complying with the requirements of BS 1640 : Part 3 or class 300 of ANSI B16.9.

*Up to and including 80 mm*

Screwed fittings complying with the requirements of class 300 of ANSI B16.3.

(2) *Flanges: all sizes*

Forged carbon steel, raised face complying with the requirements of class 300 of table PE 1 of BS 1560 : Part 2 or class 300 of ANSI B16.5.

(3) *Gaskets for flanged joints*

Compressed asbestos fibre gaskets are recommended. The recommendations of the manufacturer should be followed in selecting the grade, specification and thickness to be used.

(c) *Closed sections of pipe for 42 bar systems only*

(1) *Fittings: all sizes*

Forged steel screwed or socket-welding fittings complying with the requirements of BS 3799; or butt-welding fittings complying with the requirements of BS 1640 : Part 3 or class 600 of ANSI B16.9.

*Up to and including 50 mm*

Screwed fittings complying with the requirements of class 300 of ANSI B16.3.

(2) *Flanges: all sizes*

Forged carbon steel, raised face complying with the requirements of class 600 of table PE 1 of BS 1560 : Part 2.

(3) *Gaskets for flanges*

Compressed asbestos fibre gaskets are recommended. The recommendations of the manufacturer should be followed in selecting the grade, specification and thickness to be used.

**10.3.5 Screw threads.** Screwed threads should conform to the dimensions specified in BS 21 or API STD 5B. These threads are not compatible and it is recommended that threads of only one type be used on any particular system.

**10.3.6 Flexible hose connections.** Where flexible hoses are required to be fitted, these 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.

**10.3.7 Installation of pipework**

**10.3.7.1 General.** Pipework should be installed generally in accordance with the requirements of BS 3351 : 1971 with particular reference to sections five, six and seven and the tables and diagrams referred to therein, except where modified by 10.3.7 or clause 11 of this code.

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.

**10.3.7.2 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 steel work, adequate external protection should be given against normal corrosion due to atmospheric or local chemical conditions that are likely to affect the materials used.

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

\*A closed section of pipe is the section between two valves that may be intentionally or unintentionally closed, or between valves and Halon 1301 storage containers including filling and gas balance lines. 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.

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 maker's recommendations for the particular application should be strictly adhered to (see also 10.3.1).

**10.3.7.3 Pipework supports.** The recommended maximum span between supports to take into account the total mass of pipe and Halon 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 a potentially explosive risk area, the piping system should be hung from supports that are least likely to be displaced.

**10.3.7.4 Pipe anchors.** Anchors should be designed for the working temperature and should 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.

**10.3.7.5 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 13.6 of this code.

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.

**10.3.7.6 Pressure relief devices.** Where there is a possibility of liquid Halon entrapment in pipework (as, for example, between valves) a suitable excess pressure relief device should be fitted. For 25 bar systems the device should be designed to operate at  $68 \text{ bar} \pm 5\%$ . For 42 bar systems the device should be designed to operate at  $88 \text{ bar} \pm 5\%$ .

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.

**10.3.7.7 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.

**10.4 Distribution valves.** If several risks are protected separately but connected to one Halon 1301 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 1301 pressure. Valves should be equipped so that they can be opened manually.

All valves should be suitable for the intended use, particularly with 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.

Where liquid Halon 1301 could become trapped between two valves, adequate automatic pressure relief should be provided.

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

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 to show the equivalent single orifice diameter. 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 hazard 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 hazard enclosure, and such that the discharge will not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion, or otherwise adversely affect the contents of the enclosure. Nozzles vary in design and discharge characteristics and should be selected on the basis of their adequacy for the use intended.

## 11. Pipework design

**11.1 Symbols.** Symbols used in this clause are as follows.

| Symbol          | Quantity                                                                          | Unit of measurement    |
|-----------------|-----------------------------------------------------------------------------------|------------------------|
| $A$ and $B$     | factors for steel pipe in the two-phase flow equation                             | —                      |
| $D$             | inside diameter of pipe                                                           | mm                     |
| $g_n$           | gravitational acceleration (standard value)                                       | $(9.81) \text{ m/s}^2$ |
| $K_1$ and $K_2$ | constants to determine percentage of extinguishing medium in piping (see table 8) | —                      |
| $L$             | equivalent length of pipe                                                         | m                      |
| $m$             | initial charge mass of Halon 1301                                                 | kg                     |
| $P$             | terminal pressure                                                                 | bar                    |
| $Q$             | flow rate                                                                         | kg/s                   |
| $V_p$           | internal volume of each section of piping                                         | $\text{m}^3$           |
| $Y$ and $Z$     | factors depending on density and pressure                                         | —                      |
| $\Delta_H$      | change of elevation (+ or -)                                                      | m                      |
| $\Delta_P$      | pressure drop or gain                                                             | bar                    |
| $\rho$          | pipeline density at point of elevation change                                     | $\text{kg/m}^3$        |
| $\rho_{av}$     | average pipeline density of agent for each section of piping                      | $\text{kg/m}^3$        |
| $\Sigma_1^n$    | summation of $V_p$ and $\rho$ values for all pipeline sections                    | —                      |

NOTE 1. Values of  $Y$  and  $Z$  at discrete points in the system pipework are suffixed, e.g.  $Y_1$ ,  $Z_3$ , etc. Values for  $Y$  and  $Z$  at appropriate filling densities and initial storage container pressure and line pressure are given in tables 9 to 16 inclusive.

NOTE 2. The value  $10^5$  is used in some expressions to give the resultant  $P$  in bar (see 11.3.2).

**11.2 Pipe and orifice size determination.** Pipe sizes and orifice areas should be calculated to ensure the required rate of flow at each nozzle.

### 11.3 Piping flow characteristics

**11.3.1 General.** The flow of nitrogen-pressurized Halon 1301 has been demonstrated to be a two-phase phenomenon, i.e. the fluid in the piping consists of a mixture of liquid and vapour. This mixture causes the pressure drop to be non-linear, with an increasing rate of pressure drop as the line pressure is reduced by pipeline friction.

Friction losses occur as the liquid Halon 1301 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, time delays, and other installed equipment through which the agent flows. Equivalent lengths for these components should be obtained from the approval laboratory listings for the individual components. Equivalent lengths of common pipe fittings and valves are given in tables 17 and 18.

**11.3.2 Changes in elevation.** Upward flow of Halon 1301 produces a pressure loss, and downward flow a pressure gain, owing to gravity. The pressure change,  $\Delta p$ , is given by the expression

$$\Delta p = \frac{\rho \Delta H g_n}{10^5}$$

Pipeline density values are given in figures 3 and 4 as a function of filling density, pipeline pressure, and initial storage pressure.

Nozzle orifice sizes should be selected to match the design flow rate at the calculated terminal pressure. The discharge characteristics of the nozzle should be provided in the manufacturer's listed design manual.

### 11.4 Halon flow

**11.4.1 General.** Flow should be calculated on the basis of an average container pressure during discharge, taking into account the original pressurization level, storage filling density, and the percentage of agent in piping for 20 °C storage temperature as shown in figure 5.

**11.4.2 Percentage of agent in piping.** The quantity of agent in the piping system during discharge is a function of the actual volume of the piping times the average density of the agent. The average density cannot be accurately determined until after the terminal pressure has been calculated. The problem does not have a direct solution; however, the following expression may be used to estimate the percentage of agent in piping for calculation purposes. This expression is based on the probability that the terminal pressure will be near to but not less than 50 % of the mid-discharge storage pressure.

$$\text{percentage of agent in piping} = \frac{K_1}{(m/V_p) + K_2}$$

An alternative solution for the percentage of agent in piping after terminal pressures have been calculated is to use the following expression. Average density values can be obtained from figure 3 for the 42 bar systems and figure 4 for the 25 bar systems.

The percentage of agent in piping is defined by the following expression and should not exceed 80 %.

$$\text{percentage of agent in piping} = \frac{100 \sum_1^n V_p \rho_{av}}{m}$$

**11.4.3 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\* 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.

For balanced piping systems, figures 6 and 7 should be used to calculate the pressure drop where the minimum design terminal pressure is not less than 50 % of the average container pressure during discharge. When these curves are used, a multiplication factor is applied to this pressure drop to correct for the percentage of agent in piping and filling density in accordance with figures 8 and 9.

**11.4.4 Sample calculation for a balanced system.** A 35 kg supply is to be discharged through the piping system illustrated in figure 10. The agent is stored in one container pressurized to 25 bar, with a filling density of 1000 kg/m<sup>3</sup>. The pipeline terminates at nozzles 3 and 4, each of which is to discharge one-half of the agent supply within 10 s.

Flow rates in each section are as follows:

$$\text{Section 1-2} \quad \text{Flow} = \frac{35 \text{ kg}}{10 \text{ s}} = 3.5 \text{ kg/s}$$

$$\text{Section 2-3} \quad \text{Flow} = \frac{3.5}{2} = 1.75 \text{ kg/s}$$

$$\text{Section 2-4} \quad \text{Flow} = \text{same as for section 2-3.}$$

Select pipe sizes, using figures 6 or 7:

$$\begin{aligned} \text{Section 1-2} &= 29 \text{ mm, therefore select 1 in Sch 40} \\ \text{Sections 2-3 and 2-4} &= 21 \text{ mm, therefore select } \frac{3}{4} \text{ in Sch 40} \end{aligned}$$

Determine equivalent lengths:

**Section 1-2** (1 in Sch 40, i.d. = 26.6 mm = 0.0266 m)

$$\begin{aligned} \text{Actual length} &= 8.0 \text{ m} \\ \text{Valve, siphon tube and flexible connector†} &= 9.5 \text{ m} \\ \text{3 elbows (see table 17)} &= 3 \times 0.0266 \times 32 = 2.6 \text{ m} \\ \text{1 tee, entering branch (see table 17)} &= 0.0266 \times 90 = 2.4 \text{ m} \\ \text{Total equivalent length} &= 22.5 \text{ m} \end{aligned}$$

**Sections 2-3 and 3-4** ( $\frac{3}{4}$  in Sch 40, i.d. = 20.9 mm = 0.0209 m)

$$\begin{aligned} \text{Actual length} &= 5.5 \text{ m} \\ \text{2 elbows (see table 17)} &= 2 \times 0.0209 \times 32 = 1.3 \text{ m} \\ \text{Total equivalent length} &= 6.8 \text{ m} \end{aligned}$$

Determine total piping volume using the inside diameters of each pipe by calculation:

$$\begin{aligned} V_p &= 8\pi \times \frac{0.0266^2}{4} + 2 \left( 5.5 \times \pi \times \frac{0.0209^2}{4} \right) \\ &= 8.22 \times 10^{-3} \text{ m}^3 \end{aligned}$$

\*See tables 17 and 18 for fittings.

†Taken from manufacturers' data.

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Estimate percentage of agent in piping, using  $K_1$  and  $K_2$  factors from table 8:

$$\begin{aligned} \text{percentage of agent in piping} &= \frac{K_1}{\left(\frac{m}{V_p} + K_2\right)} \\ &= \frac{115.9 \times 10^3}{\left[\left(\frac{35}{8.22 \times 10^{-3}}\right) + 332\right]} \\ &= 25\% \end{aligned}$$

Determine mid-discharge storage pressure:

Using figure 5, based on estimated 25 % in piping and 1000 kg/m<sup>3</sup> filling density, mid-discharge storage pressure is 17.9 bar.

Calculate rate of pressure drop:

Using figure 6, the uncorrected rate of pressure drop in section 1-2 is 0.165 bar/m and in sections 2-3 and 2-4 is 0.14 bar/m. The correction factor from figure 9 is 1.08. The corrected rate of pressure drop in section 1-2 is  $0.165 \times 1.08 = 0.178$  bar/m and in sections 2-3 and 2-4 is  $0.14 \times 1.08 = 0.151$  bar/m.

Calculate terminal pressures:

The pressure drop due to friction in section 1-2 is  $22.5 \times 0.178 = 4.0$  bar and in sections 2-3 and 2-4 is  $6.8 \times 0.151 = 1.0$  bar. In addition, the pressure drop due to the change in elevation, from 11.3.2, is:

$$\Delta P = \frac{\rho \Delta H g_n}{10^5}$$

The pipeline density from figure 4 at a pressure of 17.9 bar and filling density of 1000 kg/m<sup>3</sup> is 1310 kg/m<sup>3</sup>.  $\Delta H$  is 2 m. Therefore, the pressure drop due to the elevation change is:

$$\frac{1310 \times 2 \times 9.81}{10^5} = 0.3 \text{ bar}$$

The terminal pressure is the mid-discharge storage pressure, less the elevation loss, less friction losses. The total pressure drop in section 1-2 is  $4.0 + 0.3 = 4.3$  bar. The pressure at point 2 is  $17.9 - 4.3 = 13.6$  bar. The pressure drop in sections 2-3 and 3-4 is 1.0 bar (there is no elevation change). The pressure at points 3 and 4 is  $13.6 - 1.0 = 12.6$  bar. Since the nozzle pressures are not less than 50 % of the mid-discharge storage pressure, the estimated pipe sizes are adequate.

The solution may be tabulated as shown in tabulated example 1.

**11.4.5 Sample calculation: balanced system using two-phase method.** Refer to figure 10. Flow rates, pipe sizes equivalent lengths, mid-discharge storage pressure and percentage of agent in pipeline are the same as in 11.4.4.

*Tabulated example 1*

| Section | Pipe        | Actual length | Equivalent length | Change in elevation | Flow rate | Pressure |      |
|---------|-------------|---------------|-------------------|---------------------|-----------|----------|------|
|         |             |               |                   |                     |           | Start    | End  |
|         |             | m             | m                 | m                   | kg/s      | bar      | bar  |
| 1-2     | 1 in Sch 40 | 8.0           | 22.5              | 2                   | 3.5       | 17.9     | 13.6 |
| 2-3     | ¾ in Sch 40 | 5.5           | 6.8               | 0                   | 1.75      | 13.6     | 12.6 |
| 3-4     | ¾ in Sch 40 | 5.5           | 6.8               | 0                   | 1.75      | 13.6     | 12.6 |

\*If metric pipe sizes had been selected, table 20 is appropriate.

Elevation correction:

Section 1-2 begins with a change in elevation. As in 11.4.4, the pressure loss due to this change is:

$$\Delta P = \frac{1310 \times 2 \times 9.81}{10^5} = 0.3 \text{ bar}$$

The new starting pressure is the mid-discharge storage pressure less the loss due to elevation change, or  $17.9 - 0.3 = 17.6$  bar.

Determine  $Y$  from table 13:

For a starting pressure of 17.6 bar,

$$Y_1 = 2969$$

$$Z_1 = 0.220$$

Select  $A$  and  $B$  factors from table 19\*:

$$A = 73.30 \times 10^{-3}$$

$$B = 36$$

Determine  $Y_2$  from the expression

$$\begin{aligned} Y_2 &= Y_1 + (LQ^2/A) + B(Z_2 - Z_1)Q^2 \\ &= 2969 + [(22.5)(3.5)^2 / (73.30 \times 10^{-3})] \\ &\quad + 36(Z_2 - 0.220)(3.5)^2 \end{aligned}$$

The last term containing the  $Z$  factors is small and may be neglected for this initial solution.

$$Y_2 = 2969 + 3760 = 6729$$

Determine terminal pressure  $P_2$ :

From table 13 the pressure corresponding to a  $Y$  value of 6729 is 14.3 bar. At this point, the  $Z$  value is 0.587. Using the value for  $Z_2$ , recalculate  $Y_2$ .

$$\begin{aligned} Y_2 &= 6729 + 36(0.587 - 0.220)(3.5)^2 \\ &= 6729 + 162 \\ &= 6891 \end{aligned}$$

$$P_2 = 14.1 \text{ bar}$$

Determine  $Y_3$  for section 2-3 from the expression

$$\begin{aligned} Y_3 &= Y_2 + [LQ^2/A] + B(Z_3 - Z_2)Q^2 \\ &= 6891 + [(6.8)(1.75)^2 / (20.66 \times 10^{-3})] \\ &\quad + \text{neglect last term containing the } Z \text{ factors} \\ &= 6891 + 1008 \\ &= 7899 \end{aligned}$$

Determine terminal pressure  $P_3$ :

From table 13, the pressure corresponding to a  $Y$  value of 7899 is 12.8 bar. At this point, the  $Z$  value is 0.907. Using this value for  $Z_3$ , we can recalculate  $Y_3$ .

$$\begin{aligned} Y_3 &= 7899 + 93(0.907 - 0.587)(1.75)^2 \\ &= 7899 + 91 \\ &= 7990 \end{aligned}$$

$$P_3 = 12.7 \text{ bar}$$

The solution may be tabulated as shown in tabulated example 2.

## Tabulated example 2

| Section | Pipe        | Actual length | Equivalent length | Change of elevation | Flow rate | Pressure |      |
|---------|-------------|---------------|-------------------|---------------------|-----------|----------|------|
|         |             |               |                   |                     |           | Start    | End  |
|         |             | m             | m                 | m                   | kg/s      | bar      | bar  |
| 1-2     | 1 in Sch 40 | 8.0           | 22.5              | 2                   | 3.5       | 17.9     | 14.1 |
| 2-3     | ¾ in Sch 40 | 5.5           | 6.8               | 0                   | 1.75      | 14.1     | 12.7 |
| 2-4     | ¾ in Sch 40 | 5.5           | 6.8               | 0                   | 1.75      | 14.1     | 12.7 |

**11.4.6 Unbalanced systems.** An unbalanced system is one in which any one or more of the three criteria for balanced systems (see 11.4.3(a), (b) and (c)) are not met.

The following two-phase flow equation may be used for calculating the pressure drop in balanced or unbalanced systems:

$$Q^2 = \frac{2.677 \times 10^{-9} \times D^{5.25} \times Y}{L + (0.04319 \times D^{1.25} \times Z)}$$

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

Alternatively, figures 6 and 7 may be used to calculate the pressure drop where the minimum design terminal pressure is not less than 50 % of the average container pressure during discharge.

**11.4.7 Sample calculation for an unbalanced system.**

A 90 kg supply is to be discharged through the piping system illustrated in figure 11. The agent is stored in two containers pressurized to 42 bar with a filling density of 800 kg/m<sup>3</sup>. The piping terminates at nozzles 5, 6 and 7, which are to discharge the following agent quantities within 10 s:

|          |       |
|----------|-------|
| Nozzle 5 | 30 kg |
| Nozzle 6 | 40 kg |
| Nozzle 7 | 20 kg |

Flow rates in each section are as follows:

|             |          |
|-------------|----------|
| Section 1-2 | 4.5 kg/s |
| Section 2-3 | 9.0 kg/s |
| Section 3-5 | 3.0 kg/s |
| Section 3-4 | 6.0 kg/s |
| Section 4-6 | 4.0 kg/s |
| Section 4-7 | 2.0 kg/s |

Determine pipe sizes, using figures 6 or 7:

|             |                                        |
|-------------|----------------------------------------|
| Section 1-2 | = 32 mm, therefore select 1 in Sch 40  |
| Section 2-3 | = 45 mm, therefore select 1½ in Sch 40 |
| Section 3-5 | = 26 mm, therefore select ¾ in Sch 40  |
| Section 3-4 | = 37 mm, therefore select 1½ in Sch 40 |
| Section 4-6 | = 30 mm, therefore select 1 in Sch 40  |
| Section 4-7 | = 22 mm, therefore select ¾ in Sch 40  |

Calculate equivalent lengths:

|                                                      |         |
|------------------------------------------------------|---------|
| Section 1-2 (1 in Sch 40, i.d. = 26.6 mm = 0.0266 m) |         |
| Actual length                                        | = 0.5 m |
| Valve, siphon tube and flex loop*                    | = 6.3 m |
| Total equivalent length                              | = 6.8 m |

**Section 2-3 (1½ in Sch 40, i.d. 35.1 mm = 0.0351 m)**

|                                      |                       |
|--------------------------------------|-----------------------|
| Actual length                        | = 9.5 m               |
| One tee, entering run (see table 17) | = 0.0351 × 60 = 2.3 m |
| One 90° elbow (see table 17)         | = 0.0351 × 32 = 1.1 m |
| Total equivalent length              | = 12.9 m              |

**Section 3-5 (¾ in Sch 40, i.d. 20.9 mm = 0.0209 m)**

|                                      |                       |
|--------------------------------------|-----------------------|
| Actual length                        | = 3.0 m               |
| One tee, entering run (see table 17) | = 0.0209 × 60 = 1.3 m |
| One 90° elbow (see table 17)         | = 0.0209 × 32 = 0.7 m |
| Total equivalent length              | = 5.0 m               |

**Section 3-4 (1½ in Sch 40, i.d. = 35.1 mm = 0.0351 m)**

|                           |             |
|---------------------------|-------------|
| Actual length             | = 4.5 m     |
| One tee, straight through | = (neglect) |
| Total equivalent length   | = 4.5 m     |

**Section 4-6 (1 in Sch 40, i.d. = 26.6 mm = 0.0266 m)**

|                                         |                       |
|-----------------------------------------|-----------------------|
| Actual length                           | = 4.5 m               |
| One tee, entering branch (see table 17) | = 0.0266 × 90 = 2.4 m |
| One 90° elbow (see table 17)            | = 0.0266 × 32 = 0.9 m |
| Total equivalent length                 | = 7.8 m               |

**Section 4-7 (¾ in Sch 40, i.d. 20.9 mm = 0.0209 m)**

|                                         |                       |
|-----------------------------------------|-----------------------|
| Actual length                           | = 3.0 m               |
| One tee, entering branch (see table 17) | = 0.0209 × 90 = 1.9 m |
| One 90° elbow (see table 17)            | = 0.0209 × 32 = 0.7 m |
| Total equivalent length                 | = 5.6 m               |

Determine total piping volume using the inside diameters of each pipe by a similar calculation to that used in 11.4.4. In this case,

$$V_p = 18.668 \times 10^{-3} \text{ m}^3$$

Estimate percentage of agent in piping, using  $K_1$  and  $K_2$  factors from table 8.

$$\begin{aligned} \text{percentage of agent in piping} &= \frac{K_1}{\left(\frac{m}{V_p} + K_2\right)} \\ &= \frac{109.1 \times 10^3}{\left[\left(\frac{90}{18.7 \times 10^{-3}}\right) + 260\right]} \\ &= 21.5 \% \end{aligned}$$

The mid-discharge container pressure, from figure 17, is 29.4 bar.

\*Taken from manufacturers' listing data.