

Fire extinguishing installations and equipment on premises —

Part 5: Halon systems —

Section 5.1 Specification for halon 1301 total flooding systems

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Fire Standards Policy Committee (FSM/-) to Technical Committee FSM/18, upon which the following bodies were represented:

British Automatic Sprinkler Association
 British Fire Protection Systems Association Ltd.
 British Fire Services' Association
 British Nuclear Fuels plc
 Chartered Institution of Building Services Engineers
 Chemical Industries' Association
 Chief and Assistant Chief Fire Officers' Association
 Convention of Scottish Local Authorities
 Department of Health
 Department of the Environment (Building Research Establishment)
 Department of the Environment — Central (DCSS Fire Branch)
 Department of Transport — Marine Directorate
 Electricity Association
 Fire Brigades Union
 Fire Extinguishing Trades' Association
 Health and Safety Executive
 Hevac Association
 Home Office
 Incorporated Association of Architects and Surveyors
 Institute of Petroleum
 Institution of Fire Engineers
 Lloyd's Syndicates Survey Department
 London Fire and Civil Defence Authority
 Loss Prevention Council
 Ministry of Defence
 National Association of Fire Officers
 Royal Institute of British Architects
 Society of Fire Protection Engineers
 Society of Motor Manufacturers and Traders Limited
 United Kingdom Atomic Energy Authority
 Warrington Fire Research Centre

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Engineering Equipment and Materials Users' Association

This British Standard, having been prepared under the direction of the Fire Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 July 1992

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Foreword

This Part of BS 5306 has been prepared under the direction of the Fire Standards Policy Committee and supersedes BS 5306-5.1:1982 which is withdrawn.

BS 5306 comprises the following Parts and Sections:

- *Part 0: Guide for the selection of installed systems and other fire equipment;*
- *Part 1: Hydrant systems, hose reels and foam inlets;*
- *Part 2: Specification for sprinkler systems;*
- *Part 3: Code of practice for selection, installation and maintenance of portable fire extinguishers;*
- *Part 4: Specification for carbon dioxide systems;*
- *Part 5: Halon systems;*
- *Section 5.2: Halon 1211 total flooding systems;*
- *Part 6: Foam systems;*
- *Section 6.1: Specification for low expansion foam systems;*
- *Section 6.2: Specification for medium and high expansion foam systems;*
- *Part 7: Specification for powder systems.*

Halon systems are designed to provide a piped supply of gaseous extinguishing medium for the extinction of fire.

Several different methods of piping supplies of halon to, and applying it at, the required points of discharge for fire extinction have been developed in recent years, and there is a need for dissemination of information on established systems and methods. This Section of BS 5306 has been prepared to meet this need.

Advice is given on the selection of the system most suited to a particular need, on suitable methods of operation and on the part these systems may play in general schemes of fire protection on premises. Requirements and recommendations are given on the design, maintenance and efficient operation of systems.

In particular, new requirements and recommendations to eliminate the need to release halon 1301 during testing and commissioning procedures have been included. These are linked to the inclusion of the new fan test method given in Appendix A.

The requirements and recommendations of this Section of BS 5306 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 the recommendations.

It has been assumed in the preparation of this standard that the execution of its provisions is entrusted to people appropriately qualified and experienced in the specification, design, installation, testing, approval, inspection, operation and maintenance of halon systems and equipment, for whose guidance it has been prepared, and who can be expected to exercise a duty of care to avoid unnecessary release of halon 1301.

Attention is drawn to the Montreal Protocol on Substances that deplete the ozone layer.

Product certification. Users of this British Standard are advised to consider the desirability of independent certification of product conformity with this British Standard based on testing and continuing surveillance, which may be coupled with assessment of a supplier's quality systems against the appropriate Part of BS 5750.

NOTE This standard has been written in the form of a practice specification (see clause 6 of PD 6501-1:1982). To comply with this specification, the user has to comply with all its requirements. He may depart from recommendations, but this would be on his own responsibility and he would be expected to have good reasons for doing so.

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. In particular, attention is drawn to the Pressure Systems and Transportable Gas Containers Regulations 1981 SI 1981 No. 2169.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 68, 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.

Section 1. General

0 Introduction

It is important that the fire protection of a building or other construction work 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.

Halon 1301 total flooding systems convey halon 1301 from storage containers for the protection of a particular part or parts of the building or other construction work against fire. The systems may be piped or otherwise connected, and may use containers at a central location, or dispersed at several locations in the protected area.

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

It is essential that the 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 BS 5306 specifies requirements and gives recommendations for the design, installation, testing, maintenance and safety of halon 1301 total flooding fire extinguishing systems in building or plant, and the characteristics of halon 1301 and the types of fire for which it is a suitable extinguishing medium. This standard covers only systems operating at 25 bar or 42 bar (at 20 °C) with nitrogen propellant; design data for other pressures and propellants are not available at this time.

This standard does not cover explosion suppression systems, systems in which halon is discharged to inert a flammable or explosive gas mixture, or small fixed fire extinguishers which are covered by BS 7327-1.

This Section of BS 5306 covers halon 1301 systems for use in buildings and other construction works. The systems are also widely used on ships and in aircraft, and while its requirements may apply in general for such applications, additional requirements may be necessary. Some information on marine applications is given in Appendix E.

NOTE 1 Unless otherwise specified in this standard all pressures are gauge pressures expressed in bars.

1 bar = 10^5 N/m² = 10² kPa

NOTE 2 The titles of the publications referred to in this standard are listed on inside back cover.

2 Definitions

For the purposes of this Section of BS 5306, the definitions given in BS 4422-4 apply, together with the following.

2.1

achievable maximum concentration

concentration (as a percentage by volume) which would be produced in the net volume of the protected enclosure, by the uniform distribution of the halon, including any for extended discharge, discharged by the system

2.2

authority

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

2.3

automatic system

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

2.4

design concentration

concentration (as a percentage by volume) which would be produced in the gross volume of the protected enclosure by the uniform distribution of the halon, excluding any for extended discharge, discharged by the system

2.5

extinguishing concentration

minimum concentration (as a percentage by volume) of halon 1301 necessary to extinguish a flame of a particular fuel under defined experimental conditions

2.6

flooding quantity

mass of halon per unit volume of an enclosure

2.7

gross volume of a protected enclosure

volume enclosed by the building elements around the protected enclosure, less the volume of any permanent impermeable building elements within the enclosure

2.8

hold time

recommended period of time, measured from when the design concentration is achieved in the enclosure, for which halon is to be retained around the hazard to ensure extinction

2.9

inerting concentration

minimum concentration (as a percentage by volume) of halon 1301 necessary to suppress the propagation of flame through a mixture of particular fuel and air, in any proportion, under defined experimental conditions

2.10

manual system

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

2.11

minimum design concentration

minimum halon concentration given in the design specification (see clause 11)

2.12

net volume of a protected enclosure

gross volume (see 2.7) less the volume of any fittings, fixtures, or furniture in the enclosure, including any enclosed volume in, for example, closed cabinets or drawers

2.13

normally unoccupied area

area, not occupied by people during working hours, that may be entered occasionally for brief periods

2.14

sector value

value used to direct halon into a particular section of pipework

2.15**total flooding system**

automatic or manual fire extinguishing system arranged to fill an enclosed space to the design concentration

2.16**user**

person(s) responsible for or having effective control over the fire safety provisions adopted in or appropriate to the premises or building

3 Characteristics and uses of halon 1301**3.1 General**

Halon 1301 used in the system shall comply with BS 6535-2.1.

COMMENTARY AND RECOMMENDATIONS ON 3.1. *Halon 1301 is bromotrifluoromethane (CBrF₃).*

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

BS 6535-2.1 gives details of the physical properties and a specification for halon 1301 which are reproduced in Table 1 and Table 2.

Halon 1301 extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. Any extinguishing effect due to cooling, dilution of oxygen or fuel vapour is minimal.

The most widely accepted theory of the extinguishing effect of halon 1301 is that the vapour breaks down and inhibits the combustion reactions. The decomposition takes place on exposure to a flame, or to a hot surface at a temperature above 480 °C.

Table 1 — Physical properties of halon 1301^a

Property	Value
Relative molecular mass	148.93
Boiling point at 1.013 bar (absolute)	– 57.8 °C
Freezing point	– 168 °C
Critical temperature	67.0 °C
Critical pressure	39.6 bar (absolute)
Critical volume	0.00134 m ³ /kg
Critical density	745 kg/m ³
Vapour pressure at 20 °C	14.63 bar (absolute)
Vapour pressure at 60 °C	34.58 bar (absolute)
Liquid density at 20 °C	1 575 kg/m ³
Saturated vapour density at 20 °C	115.6 kg/m ³
Specific volume of superheated vapour at 1.013 bar (absolute) and 20 °C	0.159 m ³ /kg
^a Reproduced from BS 6535-2.1:1990.	

Table 2 — Specification for halon 1301^a

Property	Requirement
Purity	99.6 % (mol/mol) min.
Acidity	3×10^{-4} % (m/m) max. (3 p.p.m. max.)
Water content	1×10^{-3} % (m/m) max. (10 p.p.m. max.)
Non-volatile residue	0.01 % (m/m) max.
Halon ion	Passes test
Suspended matter or sediment	Non visible

^a Reproduced from BS 6535-2.1:1990.

3.2 Use of halon 1301 systems

Halon 1301 total flooding systems shall be used only for extinguishing fires of class A within the limits specified in 11.2, and class B and class C as defined in BS 4547.

COMMENTARY AND RECOMMENDATIONS ON 3.2. *Class B and class C fires are promptly extinguished by halon 1301 in the appropriate concentration.*

In the case of class C fires, the risk of explosion after extinction should be carefully considered (see 11.1). Where appropriate and possible the flammable gas flow should be isolated before, or as soon as possible after, extinction.

Provided a class A fire is detected quickly and the halon is discharged promptly, and provided that the concentration is maintained for an adequate period of time to allow embers to cool, surface fires and embers associated with the burning of solid materials are also quickly extinguished with halon 1301. (See also 11.2).

Halon 1301 is suitable for use on fires involving live electrical apparatus and is widely used to protect electronic data processing installations (see BS 6266 and BS 5306-0).

Halon 1301 is not effective in extinguishing fires involving:

- a) chemicals containing their own supply of oxygen, such as cellulose nitrate; or
- b) mixtures containing oxidizing agents, such as sodium chlorate or sodium nitrate; or
- c) chemicals capable of undergoing autothermal decomposition, such as some organic peroxides.

Halon 1301 should not be used to fight fires involving:

- 1) reactive metals (such as sodium, potassium, magnesium, titanium and zirconium), reactive hydrides, or metal amides, all of which can react violently with any halon; or
- 2) solid materials in which fires quickly become deep seated (see 11.2) where there may be an extended period of contact with fire conditions.

Under both these types of circumstances halons break down forming acid halides and other compounds which are much more toxic than the halon itself.

3.3 Hazard to personnel

Any hazard to personnel created by the discharge of halon 1301 shall be considered in the design of the system.

COMMENTARY AND RECOMMENDATIONS ON 3.3. *Potential hazards are as follows:*

- a) *Toxicity. Hazard may result from one or more of the following:*
 - 1) *the natural halon 1301 itself;*
 - 2) *the breakdown products (principally bromine and halogen acids) that result from exposure of the medium to the fire or other hot surfaces (which though much more toxic than halon 1301 itself will be present in only small amounts);*
 - 3) *the combustion products of the fire.*

Particularly where rapid detection of the fire and release of halon 1301 are employed, the halon 1301 breakdown products will rarely exceed 1 % of the combustion products produced by the fire before extinction. Vastly greater amounts of toxic products will result from an uncontrolled fire.

In practice, exposure to halon 1301 is generally of less concern than the exposure to the breakdown products which in turn is generally of less concern than exposure to the combustion products. However, unnecessary exposure of personnel to either halon 1301 or to the decomposition products should be avoided.

The effects of halon 1301 complying with BS 6535-2.1 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.

Tests on human volunteer subjects have shown that the maximum safe exposure is 7 % (V/V) to 10 % (V/V) of halon 1301 for 1 min.

At these concentrations the volunteers experienced symptoms of dizziness and slight tingling of the fingers and toes after 1 min exposure. Exposures to concentrations less than these for several minutes would be unlikely to produce any significant effect but prolonged exposure to concentrations greater than these is hazardous and should be avoided.

At higher concentrations or for longer exposures, narcotic effects such as dizziness, impaired coordination and reduced mental activity, can occur, with a risk of irregular heart action, particularly in cases where the adrenalin level is raised (see note).

Once halon has been discharged into an enclosure, its presence is difficult to detect through normal human senses; in concentrations above about 3 %, voice characteristics are changed owing to the increased density of the halon/air mixture.

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.

NOTE Anyone who suffers as a result of exposure to halon 1301 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.

The breakdown products of halon 1301 have a characteristic sharp, acrid odour, even in concentrations of only a few parts per million. This provides a built-in warning system for the medium, but at the same time creates a noxious, irritating atmosphere for those who have to enter the area following the fire.

The amount of halon 1301 decomposed in extinguishing a fire depends to a large extent on the size of the fire, the concentration of halon vapour, the duration of contact with flame or heated surfaces, and the temperature. There is little decomposition below 480 °C. If there is very rapid build-up of concentration to the design value, the fire is extinguished quickly, and the decomposition minimized.

The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the vapour to the elevated temperature to reduce the formation of breakdown products.

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

c) Turbulence. High velocity discharge from nozzles may be sufficient to dislodge substantial objects which are close to the nozzles. System discharge may cause enough general turbulence in the enclosures to move light objects such as paper or unsecured tiles in suspended ceilings.

d) Cooling effect. Direct contact with the liquid halon 1301 discharged from the system has a strong chilling effect on objects and can cause cold 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(s).

e) Mist formation. Discharge of the medium may create a light mist resulting from condensation of moisture in the air. The mist rarely persists after discharge is completed and little hazard is created by reduced visibility.

f) Dispersal after discharge. The halon 1301/air mixture produced in the enclosure is more dense than air and can accumulate in low spaces, such as cellars, pits and floor voids, if these are not ventilated effectively after system discharge.

4 Types of system

For the purposes of this Section of BS 5306 halon total flooding systems shall be distinguished by the arrangement of the halon storage containers as follows:

- a) central storage systems with one halon container, or two or more halon containers manifolded together with pipework, to protect one or more adjacent or remote hazards; or
- b) distributed storage systems with halon containers in separate locations within or without the hazard area; or
- c) modular systems in which each halon container is complete with a discharge nozzle.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 4. *Halon total flooding systems are also divided into engineered systems in which the quantity of halon and each section of pipework are designed by calculation to give the specified discharge rate at each nozzle, and pre-engineered systems in which the system is not larger than a defined maximum size with a defined number of nozzles and has been tested for performance at the maximum pipe lengths.*

5 Planning

Where a halon 1301 extinguishing system is being considered for new or existing buildings, the following shall be consulted:

- a) the fire authority; and
- b) other appropriate public authorities; and
- c) the insurers.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 5. *The authorities mentioned above should be informed as early as possible of the type of system to be installed and the system design engineers should be fully informed of the protection required in any area. There may be statutory or local bye-law requirements and other requirements of these authorities to be coordinated in the planning stages of the contract.*

Section 2. Contract arrangements

6 Contract drawings and information documents

6.1 General

The information specified in **6.2** and **6.3**, together with details of the authorities consulted (see clause **5**) and any response to the consultation, shall be provided to the user.

COMMENTARY AND RECOMMENDATIONS ON **6.1**. *The authorities listed in clause 5 may wish to be provided with this or other information before the system is installed.*

6.2 Preliminary or estimating stage

The information provided to the user shall include a general specification of the proposed system(s) including particulars of major items of equipment, and a block plan of the premises showing the type and extent of the system(s).

6.3 Design stage

6.3.1 The information provided to the user prior to installation shall include contract drawings, which shall be to scale or be fully dimensioned with sufficient detail to define clearly the extent of the hazard and the proposed system.

COMMENTARY AND RECOMMENDATIONS ON **6.3.1**. *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.*

6.3.2 The location and sizes of piping and nozzles shall 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 shall be shown, together with details of all calculations used in assessing the quantity of halon 1301.

COMMENTARY AND RECOMMENDATIONS ON **6.3.2**. *Further information, for example, the equivalent lengths of pipe and fittings, flow rates and pressure drops throughout the system, should be given separately if requested by the user.*

7 Commissioning and acceptance

7.1 Tests

The installer of the system or his supervising supplier shall arrange for the completed system to be inspected and tested to determine that it is properly installed and that it will function as designed to the satisfaction of the user and the relevant authorities. A commissioning test programme shall be submitted by the installer to the user.

The programme shall include instructions to:

- a) check that all components of the system have been installed in accordance with the contract drawings; and
- b) check that all nuts, bolts and fittings have been correctly tightened; and
- c) check that all electrical connections are safe and in working order; and
- d) check that closed sections of pipework are gas-tight; and
- e) test discharge a gas (which may be air, carbon dioxide or nitrogen but shall not be halon) into each enclosure to ensure that the piping is continuous and that the nozzles have not become blocked (see **17.1**); and

CAUTION. Do not discharge the test gas into flammable or explosive atmospheres because of the danger of the generation of static electricity (see commentary and recommendations on **11.1**). Take care to avoid this and other hazards to personnel during the test.

- f) determine the hold time using the fan test method described in Appendix A, and if necessary carry out the procedure of Appendix B (see commentary and recommendations on clause **12**).

COMMENTARY AND RECOMMENDATIONS ON **7.1**. *The authorities listed in clause 5 may wish to witness the tests.*

7.2 Completion certificate and documentation

The installer shall provide to the user two copies of a completion certificate, a complete set of instructions and drawings showing the system as installed, and a statement that the system complies with all the appropriate requirements of this standard, and giving details of any departure from appropriate recommendations. The certificate shall give the design and achievable maximum concentrations, the report of the fan test (see **A.9**), and if appropriate the actions taken in accordance with Appendix B (see commentary and recommendations on clause **12**).

COMMENTARY AND RECOMMENDATIONS ON **7.2**. *The user may also require certificates or letters of conformity for pressure vessels, in order to meet obligations under Regulation 5 of the Pressure Systems and Gas Container Regulations 1989.*

Section 3. Restoration after use, inspection, testing and maintenance

8 Restoration after use

The installer shall provide appropriate instruction on restoration and replenishment of the system after discharge.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 8. *Systems may include a permanently connected duplicate supply of halon. Spare filled replacement containers may be held on the premises, or should be available for delivery in 24 h. It is essential that nozzles are inspected and if necessary cleaned after any discharge.*

9 Inspection, testing and maintenance

9.1 General

The user shall carry out a programme of inspection (see 9.2) and shall arrange a service and maintenance schedule (see 9.3), and shall keep records of the inspections and servicing.

COMMENTARY AND RECOMMENDATIONS ON 9.1. *The continued capability for effective performance of a halon system depends on fully adequate maintenance procedures with, where possible, periodic testing.*

Installers should provide the user with a logbook in which inspection and maintenance records can be entered.

9.2 User's programme of inspection

The installer shall provide the user with an inspection programme for the system and components. The programme shall include instruction on the action to be taken in respect of faults.

COMMENTARY AND RECOMMENDATIONS ON 9.2. *The user's inspection programme is intended to detect faults at an early stage to allow rectification before the system may have to operate. A suitable programme is as follows.*

- a) *Weekly. Visually check the hazard and the integrity of enclosure for changes which might reduce the efficiency of the system. Carry out a visual check that there is no obvious damage to pipework and that all operating controls and components are properly set and undamaged. Check pressure gauges for correct reading. Replace any containers showing a loss of more than 10 %.*
- b) *Monthly. Check that all personnel who may have to operate the equipment or system are properly trained and authorized to do so; and in particular that new employees have been instructed in its use.*

9.3 Service and maintenance schedule

The schedule shall include all appropriate requirements for periodic inspection and test given in BS 5430 for halon 1301 and propellant gas containers.

The schedule shall be carried out by a competent person who shall provide to the user a signed, dated report of the inspection advising any rectification carried out or needed.

COMMENTARY AND RECOMMENDATIONS ON 9.3. *During servicing and maintenance every care and precaution should be taken to avoid release of halon. When containers are emptied for internal inspection, the halon should not be discharged to atmosphere, but should be recovered as recommended in BS 6535-2.2.*

A suitable schedule is as follows.

- a) *Every 3 months. Test and service all actuating mechanisms and electrical detection and alarm systems as recommended in BS 5839-1.*
- b) *Every 6 months. Perform the following checks and inspections.*
 - 1) *Externally examine pipework to determine its condition. Replace or pressure test and repair as necessary pipework showing corrosion or mechanical damage.*
 - 2) *Check all control valves for correct manual function and automatic valves additionally for correct automatic function.*
 - 3) *Externally inspect containers.*
 - 4) *Check weigh, or use a liquid level indicator, to verify correct content of containers. Replace or refill any showing a loss of more than 5 %.*

c) *Every 12 months. Carry out a check of enclosure integrity using the method given in Appendix A. If the measured aggregate area of leakage has changed significantly from that measured during installation, carry out work to reduce the leakage.*

d) *As required by statutory regulations, but otherwise when convenient. Internally inspect containers.*

BS 5430-1, BS 5430-2 and BS 5430-3 specify requirements for the periodic inspection, testing and maintenance of transportable gas containers for seamless steel containers, welded steel containers and seamless aluminium containers, respectively, at prescribed intervals. BS 5430 also specifies that any container that has not been inspected and tested within the specified intervals is not to be refilled.

Section 4. System design

10 Basis of system design

The design of the system shall be based on the fire hazard assumed to exist in the enclosure.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 10. *The requirements of clauses 11 to 21 ensure that the system will discharge quickly enough to produce a concentration not less than the minimum design concentration throughout the enclosure to be protected, and that halon will be held in the enclosure for long enough for the fire to be extinguished and reignition prevented.*

11 Design concentration

11.1 Class B and C fires (flammable liquids and gases)

The design concentration shall be not less than 5 % (V/V), and as follows:

- a) for class C fires, not less than 1.1 times the inerting concentration;
- b) for class B fires involving a liquid of flashpoint not above 40 °C, not less than 1.1 times the inerting concentration;
- c) for class B fires involving a liquid of flashpoint above 40 °C:
 - 1) not less than 1.1 times the inerting concentration, if the liquid is maintained at a temperature lower than the temperature 20 °C below its flashpoint; or
 - 2) not less than 1.2 times the extinguishing concentration, if the liquid is maintained at a temperature not lower than the temperature 20 °C below its flashpoint.

Extinguishing concentrations not given in Table 3, and inerting concentrations not given in Table 4, shall be determined experimentally using the method of Appendix D.

COMMENTARY AND RECOMMENDATIONS ON 11.1. *After extinction of gases and volatile liquids, a potentially explosive fuel vapour/air/halon mixture may result if the design concentration is based on the extinguishing concentration (see item c) 2) and Table 3). Reignition of such mixtures is prevented at the higher minimum design concentrations based on the inerting concentrations (see items a), b) and c) 1) and Table 4). See also commentary and recommendations on 3.2.*

Halon 1301 systems should be discharged only in the presence of a fire and because of the possible generation of static electricity during the discharge, should not be used for inerting a potentially explosive atmosphere where a spark caused by static electricity would add to the hazard. 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.

11.2 Class A fires

For class A fires the design concentration shall be not less than 5.0 % (V/V).

COMMENTARY AND RECOMMENDATIONS ON 11.2. *Most class A fires burn initially at the surface and at this stage are rapidly and efficiently extinguished by halon 1301 with minimum breakdown of halon. However, many class A materials in later stages of combustion produce significant amounts of glowing embers and may not be totally extinguished by halon 1301 at the concentrations normally employed. Such fires are said to be deep-seated, and whilst halon 1301 will extinguish the flames, smouldering may continue with the production of considerable quantities of breakdown products and tar, which can cause corrosion damage. Halon 1301 is therefore not suitable for this type of fire.*

Fires involving materials such as cloth, rags, cardboard, and shredded or crumpled paper can rapidly become deep-seated.

Materials such as baled cotton, in which fires can start spontaneously from inside a bulk, are similarly deep-seated and halon 1301 is not recommended for use on these.

11.3 Halon 1301 systems protecting electronic data processing installations

For the purposes of this specification, fires in electronic data processing installations shall be regarded as class A fires and the minimum design concentration shall be not less than 5 % (V/V).

12 Predicted minimum hold time

The predicted minimum hold time shall be determined by the method of Appendix A, using the assumptions that at the beginning of the hold time the concentration throughout the enclosure is the design concentration, and one of the following, as applicable.

- Enclosure without mixing. At the end of the hold time the halon concentration at the height of the highest hazard is the design concentration.
- Enclosure with mixing. At the end of the hold time the halon concentration throughout the enclosure is 80 % of the minimum design concentration (see clause 11).

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 12. *The hold time is necessary to ensure extinction and/or prevent reignition (see 2.8). For most applications 10 min is sufficient but for some applications longer may be necessary. If the predicted minimum hold time determined by the method of Appendix A is less than the necessary value see Appendix B. Appendix C gives an example of the application of the fan test method to an enclosure, and the use of Appendix B.*

**Table 3 — Halon 1301 extinguishing and minimum design concentrations
[in air at 1.013 bar (absolute)]**

Fuel	Measured extinguishing concentration (at 25 °C unless otherwise stated)	Minimum design concentration
	% (V/V)	% (V/V)
acetone	4.0	5.0
acrylonitrile	4.7	5.6
aviation gasoline	4.2	5.0
benzene	4.2	5.0
biphenyl/diphenyl ether eutectic	2.1 (at 200 °C)	5.0
buta-1, 3-diene	4.5	5.4
<i>n</i> -butane	4.0	5.0
crankcase oil (typical marine grade)	2.4 (at 250 °C)	5.0
diesel fuel	2.1	5.0
diethyl ether	4.2	5.0
ethane	5.0	5.3
ethanediol	5.7	5.0
ethanol	4.1	5.0
ethyl acetate	4.2	5.0
ethylene	6.8	8.2
fuel oil (typical residual grade)	1.5 (at 185 °C)	5.0
gasoline, 94 octane	3.0	5.0
gasoline, 98 octane	3.5	5.0
heat transfer oil (typical mineral grade)	2.9 (at 230 °C)	5.0
<i>n</i> -hexane	4.5	5.0
<i>n</i> -heptane	4.1	5.0
hydraulic oil (typical aviation grade)	3.1 (at 150 °C)	5.0
hydraulic oil (typical marine grade)	3.7 (at 220 °C)	5.0
isobutane	3.8	5.0
isopropanol	3.9	5.0
methane	4.2	5.0
methanol	7.5	9.0
methyl ethyl ketone	4.1	5.0
methyl methacrylate	6.2	7.4
nitromethane	7.7 (at 85 °C)	9.2
<i>n</i> -pentane	3.6	5.0
propane	4.3	5.2
pyridine	3.7	5.0
tetrahydrofuran	4.7	5.6
toluene	3.5	5.0
xylene (mixed)	3.1	5.0

Table 4 — Halon 1301 inerting and minimum design concentrations [in air at 1.013 bar (absolute)]

Fuel	Measured inerting concentration, at 25 °C	Minimum design concentration
	% (V/V)	% (V/V)
acetone	6.9	7.6
benzene	4.5	5.0
ethanol	10.1	11.1
ethylene	12.0	13.2
<i>n</i> -heptane	6.3	6.9
hydrogen	28.4	31.4
methane	7.0	7.7
propane	6.1	6.7

The discharge of halon 1301 into an enclosure results in an air/halon mixture that has a density greater than that of the air surrounding the enclosure. Any opening in the enclosure will allow the heavier air/halon mixture to flow out of the enclosure and to be replaced with lighter outside air flowing into the enclosure through the same, or another, opening. The rate at which halon is lost through openings will depend upon the locations and sizes of the opening(s), the concentration of halon, and the height of the enclosure.

In enclosures without mechanical or other means of mixing, the incoming air will collect towards the top of the enclosure, forming an interface between the air/halon 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 design concentration whereas the upper space may be completely unprotected. The rate at which the interface moves downwards increases with increasing concentrations of halon so that simply using a higher design concentration may not provide protection for a longer period.

In enclosures with mechanical or other means of mixing, the incoming air mixes with the air/halon mixture. No interface is formed and the halon concentration throughout the enclosure is uniform but decreases as leakage continues.

13 Quantity of halon

13.1 General

13.1.1 Systems at sea-level

The quantity of halon discharged from the system (assumed to be equal to the quantity of halon in the halon containers) shall be the sum of the basic quantity specified in **13.2**, plus the additional quantities specified in **13.3** to compensate for leakage or ventilation.

13.1.2 Systems not at sea-level

The quantity of halon discharged from the system shall be the quantity specified in **13.1.1** for a system at sea-level multiplied by the appropriate value of the correction factor, β , given in Table 5.

Table 5 — Correction factor for halon quantity in systems not at sea-level

Altitude above sea-level	Correction factor, β
m	
– 4 500	1.770
– 4 000	1.640
– 3 500	1.540
– 3 000	1.450
– 2 500	1.360
– 2 000	1.275
– 1 500	1.205
– 1 000	1.130
– 750	1.105
– 500	1.060
– 250	1.025
0	1.000
+ 250	0.975
+ 500	0.945
+ 750	0.915
+ 1 000	0.885
+ 1 500	0.830
+ 2 000	0.785
+ 2 500	0.735
+ 3 000	0.690
+ 3 500	0.650
+ 4 000	0.610
+ 4 500	0.565

NOTE 1 Values may be interpolated

NOTE 2 The specific volume of halon 1301 at any altitude is equal to the specific volume at 1.013 bar (i.e. at sea-level) divided by the correction factor

COMMENTARY AND RECOMMENDATIONS ON 13.1.2. *At elevations above sea-level, halon 1301 has a greater specific volume because of the reduced atmospheric pressure. A system designed for sea-level conditions will therefore develop an actual higher concentration at levels above sea-level and an actual lower concentration at levels below sea-level. For example, a system designed to produce a 6 % halon 1301 concentration at sea-level would actually produce an 8.7 % concentration if installed at 3 000 m elevation, which is higher than the maximum concentration specified for automatic operation in normally occupied areas (see 15.3.2).*

13.2 Basic quantity

13.2.1 Single enclosures

The basic quantity, in kilograms, of halon 1301 discharged from the system shall be:

$$\frac{V_g}{v_{\min.}} \times \frac{c \times \beta}{100 - c}$$

where

$v_{\min.}$ = $0.14781 + 0.000567 T_{\min.}$, and is the specific volume of halon 1301 at temperature $T_{\min.}$ (in m^3/kg);

c is the design concentration at temperature $T_{\min.}$ [in % (V/V)];

- $T_{\min.}$ is the design temperature, the expected minimum ambient temperature in the hazard area (in °C);
- V_g is the gross volume of the enclosure (in m³);
- β is the altitude correction factor (see Table 5).

COMMENTARY AND RECOMMENDATIONS ON 13.2.1. *Table 6 gives the specific volume at the design temperature $V_{\min.}$ and the value of the flooding quantity, $c/\{v(100 - c)\}$, at an absolute pressure of 1.013 bar at various temperatures and values of concentration c .*

13.2.2 Two interconnected enclosures

Where halon may flow freely between two or more enclosures, the quantity of halon shall be the sum of the quantities calculated for each enclosure. If a higher minimum design concentration is specified for one enclosure, that minimum design concentration shall be applied to all enclosures.

13.3 Additional quantity for extended discharge in enclosures with mixing

Where the basic quantity of halon is insufficient to give a satisfactory hold time, additional halon shall be provided (see clause 12).

COMMENTARY AND RECOMMENDATIONS ON 13.3. *Throughout the hold time, halon 1301 should be added at a rate that will compensate for leakage out of the enclosure. The halon should be discharged in such a way that the concentration of halon and air is uniformly maintained at not less than 80 % of the minimum design concentration. This method is particularly suitable for enclosed rotating electrical apparatus, such as generators and converters, but should not be used to compensate for leakage which can be eliminated or reduced (see 16.3).*

14 Design discharge time

The design discharge time used in calculations shall be not more than 10 s, and the quantity of halon calculated as discharged in 10 s, with the halon 1301 container(s) at the normal ambient storage temperature, shall be not less than the basic quantity specified in 13.2.

15 System operation

15.1 General

In addition to any means of automatic operation, the system shall be provided with the following:

- a) one or more means, remote from the containers, of manual operation; and
- b) a mechanical device for direct operation of the system.

The mechanical device shall be outside the protected area and shall incorporate a double action or other safety device to restrict accidental operation. The device shall be provided with a means of preventing operation during maintenance of the system.

COMMENTARY AND RECOMMENDATIONS ON 15.1. *The choice of the means of operation will depend upon the nature of the hazard to be protected. Automatic fire detection and alarm equipment will normally be provided on a manual system to indicate the presence of a fire.*

15.2 Manual operation

Direct emergency manual operation of the system shall be possible.

Each manual control shall be prominently labelled to identify the hazard protected.

Manual release push buttons or pull handles shall be housed in a box with a quick access front.

Manual controls shall not require a pull of more than 150 N or a movement of more than 300 mm to effect operation.

COMMENTARY AND RECOMMENDATIONS ON 15.2. *Manual control points should be designed so that they cannot be confused with fire alarm manual call points.*

The design of fire alarm manual call points is specified in BS 5839-2.

Emergency manual operation of individual system components is usually by direct manual operation of the device to be operated.

Consideration should be given to the incorporation of a time delay and predischARGE alarm between actuation of the manual control and the commencement of system discharge, to allow time for personnel to leave the hazard area.

Table 6 — Specific volumes and flooding quantities at various concentrations of halon 1301 at different temperatures [at 1.013 bar (absolute)]

Design temperature in hazard area, t	Specific volume of halon 1301 vapour at the design temperature $V_{\min.}$	Flooding quantity $\frac{c}{v(100-c)}$					
		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
– 50	0.119 46	0.440 6	0.534 3	0.630 1	0.727 9	0.827 9	0.930 1
– 45	0.122 30	0.430 4	0.521 9	0.615 5	0.711 0	0.808 7	0.908 5
– 40	0.125 13	0.420 6	0.510 5	0.601 5	0.694 9	0.790 4	0.887 9
– 35	0.127 97	0.411 3	0.489 8	0.588 2	0.679 5	0.722 9	0.868 3
– 30	0.130 80	0.402 4	0.488 0	0.575 4	0.664 8	0.756 1	0.849 5
– 25	0.133 64	0.393 8	0.477 8	0.563 2	0.650 7	0.740 1	0.831 4
– 20	0.136 47	0.385 7	0.467 7	0.551 5	0.637 2	0.724 7	0.814 2
– 15	0.139 31	0.377 8	0.458 2	0.540 3	0.624 2	0.709 9	0.797 6
– 10	0.142 14	0.370 3	0.449 1	0.529 5	0.611 8	0.695 8	0.781 7
– 5	0.144 98	0.363 0	0.440 3	0.519 2	0.599 8	0.682 2	0.766 4
0	0.147 81	0.356 1	0.431 8	0.509 2	0.588 3	0.669 1	0.751 7
5	0.150 65	0.349 4	0.423 7	0.499 6	0.577 2	0.656 5	0.737 6
10	0.153 48	0.342 9	0.415 9	0.490 4	0.566 6	0.644 4	0.723 9
15	0.156 32	0.336 7	0.408 3	0.481 5	0.556 3	0.632 7	0.710 8
20	0.159 15	0.330 7	0.401 1	0.472 9	0.546 4	0.621 4	0.698 1
25	0.161 99	0.324 9	0.394 0	0.464 7	0.536 8	0.610 5	0.685 9
30	0.164 82	0.319 3	0.387 3	0.456 7	0.527 6	0.600 0	0.674 1
35	0.167 66	0.313 9	0.380 7	0.448 9	0.518 7	0.589 9	0.662 7
40	0.170 49	0.308 7	0.374 4	0.441 5	0.510 0	0.580 1	0.651 7
45	0.173 33	0.303 7	0.368 3	0.434 3	0.501 7	0.570 6	0.641 0
50	0.176 16	0.298 9	0.362 3	0.427 3	0.493 6	0.561 4	0.630 7
55	0.179 00	0.294 0	0.356 6	0.420 5	0.485 8	0.552 5	0.620 7
60	0.181 83	0.289 5	0.351 0	0.431 9	0.478 2	0.543 9	0.611 1
65	0.184 67	0.285 0	0.345 6	0.407 6	0.470 9	0.535 6	0.601 7
70	0.187 50	0.280 7	0.340 4	0.401 4	0.463 8	0.527 5	0.592 6
75	0.190 34	0.276 5	0.335 3	0.395 4	0.456 9	0.519 6	0.583 8
80	0.193 17	0.272 5	0.330 4	0.389 6	0.450 1	0.512 0	0.575 2
85	0.196 01	0.268 5	0.325 6	0.384 0	0.443 6	0.504 6	0.566 9
90	0.198 94	0.264 7	0.321 0	0.378 5	0.437 3	0.497 4	0.558 8
95	0.201 68	0.261 0	0.316 5	0.373 2	0.431 2	0.490 4	0.550 9

The label identifying the hazard is additional to that specified in 21.4.1. The manual control point or points should be located outside the protected enclosure so as to be conveniently and easily accessible at all times, including the time of fire. It may be a mechanical, or electromechanical device.

If the housing is protected by a frangible glass front this should be of a type which when broken does not leave jagged or sharp edges which might cause injury when the manual release is operated.

15.3 Automatic operation

15.3.1 General

Automatic systems shall be controlled by automatic fire detection and actuation systems suitable for the system and hazard, and shall also be provided with a means of manual operation.

Electrically operated fire detection systems shall comply with BS 5839-1. The electric power supply shall be independent of the supply for the hazard area with an emergency secondary power supply with automatic changeover in case the primary supply fails.

Where two or more rapid response fire detectors are used, such as those for detecting smoke or flame, the system shall operate only after signals from two detectors have been received.

Electrically operated actuation systems shall comply with BS 7273-1.

Provision shall be made for manual operation (see 15.2) of the fire extinguishing system by means of a control situated outside the protected space or adjacent to the main exit from the space.

15.3.2 Safety limitations for automatic operation

15.3.2.1 General

If the achievable maximum concentration is greater than 6 % (V/V) in normally or intermittently occupied areas, arrangements shall be made to limit the automatic operation of the system as specified in 15.3.2.2 or 15.3.2.3.

COMMENTARY AND RECOMMENDATIONS ON 15.3.2.1. *The achievable maximum concentration is based on the mass of halon initially discharged, i.e. excluding any extended discharge but including any initial excess, and the net volume of the enclosure, and is calculated from the following equation:*

$$C_{\max.} = \frac{100 M v_{\max.}}{V_n + M v_{\max.}}$$

where

$C_{\max.}$	<i>is the achievable maximum concentration [in % (V/V)];</i>
M	<i>is the mass of halon initially discharged (in kg);</i>
$v_{\max.}$	<i>is the specific density of halon 1301 at the expected maximum ambient temperature $t_{\max.}$ (in kg/m³);</i>
V_n	<i>is the net volume of the protected enclosure (in m³).</i>

If $C_{\max.}$ is not greater than 6 % (V/V), the system may function in the automatic mode at all times, except during periods of maintenance of the extinguishing system.

To allow personnel to evacuate the protected area prior to discharge of halon 1301, 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 normally exceed 30 s.

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 halon discharge. A fault signal should be given if the switch is operated in the non-alarm mode.

Systems protecting areas that cannot be occupied at any time may function in the automatic mode at any concentration of halon 1301 provided there would be no adverse effect on adjacent areas that may be occupied.

15.3.2.2 Achievable maximum concentration greater than 6 % (V/V) but less than 10 % (V/V)

Automatic systems protecting normally or intermittently occupied areas where the achievable maximum concentration (see 2.1) is greater than 6 % (V/V) and less than 10 % (V/V) shall be provided with a device which can be used to prevent automatic operation of the system.

COMMENTARY AND RECOMMENDATIONS ON 15.3.2.2. *Preferably the system should be under manual control only whilst the area is occupied, and only on automatic control when the area is unoccupied; however where the level of risk from fire is high, fully automatic operation of the system at all times may be agreed to by the relevant authorities. Where the protected area cannot normally be occupied by people, for example shallow floor voids, the system may be under automatic control.*

Automatic detection and alarm with manual operation of the system should be available at all times.

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

15.3.2.3 Achievable maximum concentration 10 % (V/V) or greater

Automatic systems protecting normally or intermittently occupied areas where the achievable maximum concentration (see 2.1) is 10 % (V/V) or greater shall be provided with a device which can be used to prevent automatic operation of the system.

COMMENTARY AND RECOMMENDATIONS ON 15.3.2.3. *The system should always be switched to manual only control before anyone enters the protected area, and should not be returned to automatic control until all persons have left.*

16 Enclosure

16.1 Bounding elements

The protected enclosure shall be bounded by rigid elements of building construction.

COMMENTARY AND RECOMMENDATIONS ON 16.1. *The ceiling should be not less than 0.5 m above the hazard.*

The rigid elements should have a fire resistance of not less than 30 min when tested in accordance with BS 476-20, BS 476-21, BS 476-22 or BS 476-23, as appropriate.

16.2 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 shall be shut down prior to or simultaneously with the discharge of halon 1301.

16.3 Sealing

Cable and pipe entries, gaps around doors or windows, and porous structural elements, such as unfinished blocks, shall be sealed to reduce leakage of halon.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 16. *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.

Air-handling systems in the protected area should be shut down and/or closed before or simultaneously with the start of the discharge. Building regulations may require that in the event of fire in some types of recirculating ventilating systems the fans be turned off and the system vented to the open air.

17 System components

17.1 General

Components shall be marked with the recommended temperature limits of operability if these do not cover the range from – 20 °C to + 50 °C.

COMMENTARY AND RECOMMENDATIONS ON 17.1. *Various operating components are necessary to control the flow of the extinguishing medium and to operate the associated equipment. These include halon containers, valves, distribution valves, automatic and manual controls, pressure trips and switches and discharge nozzles.*

All components, especially those having external moving parts, should be suitable for use with halon 1301 systems and should be located, installed or suitably protected so that they are not subject to mechanical, chemical or other damage that would render them inoperative.

17.2 Halon container and valve assemblies

17.2.1 Halon container

17.2.1.1 Containers shall comply with BS 5045-1, BS 5045-2, BS 5045-3, BS 5045-5 or BS 5045-6.

COMMENTARY AND RECOMMENDATIONS ON 17.2.1.1. *Halon 1301 containers for firefighting purposes should be painted signal red reference number 537 of BS 381C equivalent to reference number 04 E 53 of BS 5252.*

17.2.1.2 Containers shall be pressurized with nitrogen, with a moisture content not more than 0.006 % (m/m), to an equilibrium pressure of either (25 ± 1.25) bar or (42 ± 2.1) bar, when measured at 20 °C.

17.2.2 Arrangement and location

Container and valve assemblies and accessories shall be accessible for inspection, testing, and other maintenance.

Containers shall be adequately mounted and suitably supported so as to provide for convenient individual servicing or content weighing. Automatic check valves in the manifold connection shall be provided to prevent loss of halon from the manifold if the system is operated when any container is removed for maintenance.

COMMENTARY AND RECOMMENDATIONS ON 17.2.2. *Easy accessibility facilitates the procedures and minimizes interruption to fire protection.*

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.

17.2.3 Filling density

The filling density shall be not greater than 1.12 kg/l and not less than 0.5 kg/l.

17.2.4 Pressure gauge

A pressure gauge with means to show the relationship between internal pressure and temperature shall be fitted to each container and valve assembly.

17.2.5 Pressure relief device

Each container and valve assembly shall be fitted with a bursting disc complying with BS 2915.

17.2.6 Manifolded containers

Halon containers connected to a common manifold in a system shall be as follows:

- a) of the same form and capacity;
- b) filled with the same mass of halon 1301; and
- c) pressurized to the same working pressure.

COMMENTARY AND RECOMMENDATIONS ON 17.2.6. *BS 5355 specifies filling ratios and developed pressures for halon 1301 at various reference temperatures.*

Figure 1 and Figure 2 which are derived from these data, are isometric diagrams for halon 1301 superpressurized with dry nitrogen, and show the relationship of the container pressure versus temperature with lines of constant filling density.

Superpressurization (the addition of nitrogen to pressurize the halon 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 should be clean and dry before filling, to prevent corrosion.

17.2.7 Marking

Containers shall be marked with the halon 1301 content in kilograms and the working pressure in bars.

COMMENTARY AND RECOMMENDATIONS ON 17.2.7. *These markings are additional to those markings provided to meet statutory requirements or those specified in BS 5045.*

17.3 Selector valves

Selector valves shall be openable when subjected to the maximum halon 1301 pressure. Valves shall be equipped for manual opening.

Valves shall be rated for equivalent length in terms of the pipe or tubing sizes with which they will be used. Distribution valves shall be suitable for operation at 1.5 times the maximum working pressure of the system.

17.4 Discharge nozzles

Nozzle orifice sizes shall be as recommended by the manufacturer to match the design flow rate at the calculated terminal pressure.

Discharge nozzles shall be permanently marked, so as to be discernible after installation, with the equivalent single orifice area.

COMMENTARY AND RECOMMENDATIONS ON 17.4. *Discharge nozzles and any associated shields or baffles should be of corrosion resistant material and should be of adequate strength to withstand expected working temperatures and pressures.*

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.

18 Pipework

18.1 General

Pipework shall be able to withstand the expected pressures and temperatures without damage. Pipework except for flexible connectors shall be of metal. Steel pipework shall be as given in Table 7. Stainless steel pipe shall comply with BS 3605. Copper and copper alloy pipe shall comply with BS 2871-2.

COMMENTARY AND RECOMMENDATIONS ON 18.1. *The grade of stainless steel, copper and copper alloy should be chosen in consultation with the manufacturer with regard to the duty to be performed.*

Container and valve manifolds should be hydraulically tested at the manufacturer's works to a minimum pressure of 90 bar for 25 bar systems, and 130 bar for 42 bar systems.

18.2 Flanges

18.2.1 42 bar systems

18.2.1.1 For closed sections of pipe, flanges shall be of forged carbon steel, raised face, complying with either:

- a) class 600 of Table 11 of BS 1560-3.1:1989; or
- b) class 600 of ANSI B16.5.

18.2.1.2 For open sections of pipe, flanges shall be of forged carbon steel, raised face, complying with either:

- a) class 300 of Table 10 of BS 1560-3.1:1989; or
- b) class 300 of ANSI B16.5.

18.2.2 25 bar systems

For closed or open sections of pipe, the flanges shall be of forged carbon steel, raised face complying with either:

- a) class 300 of Table 10 of BS 1560-3.1:1989; or
- b) class 300 of ANSI B16.5.

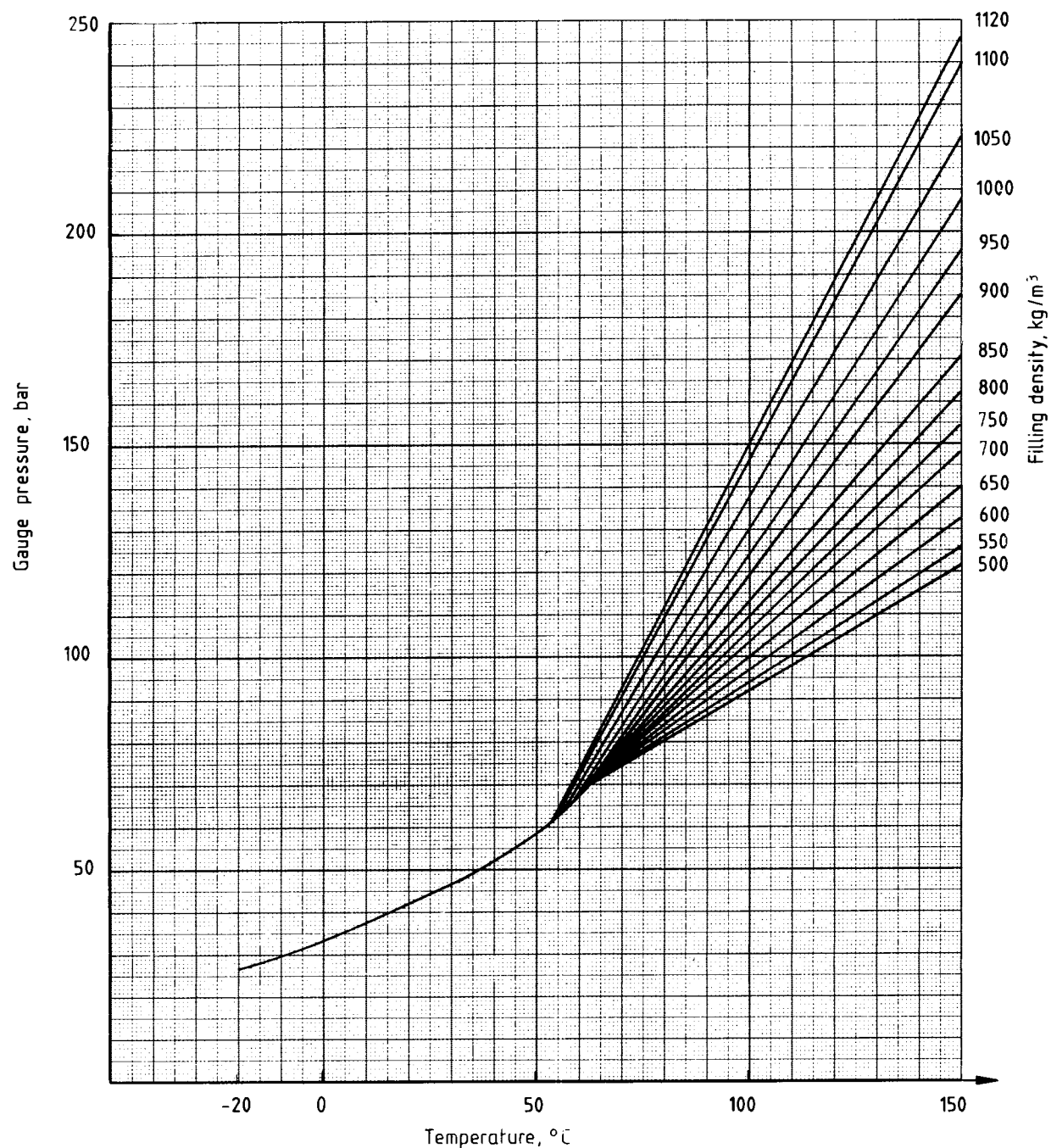


Figure 1 — Pressure/temperature relationship for halon 1301 containers in 42 bar systems

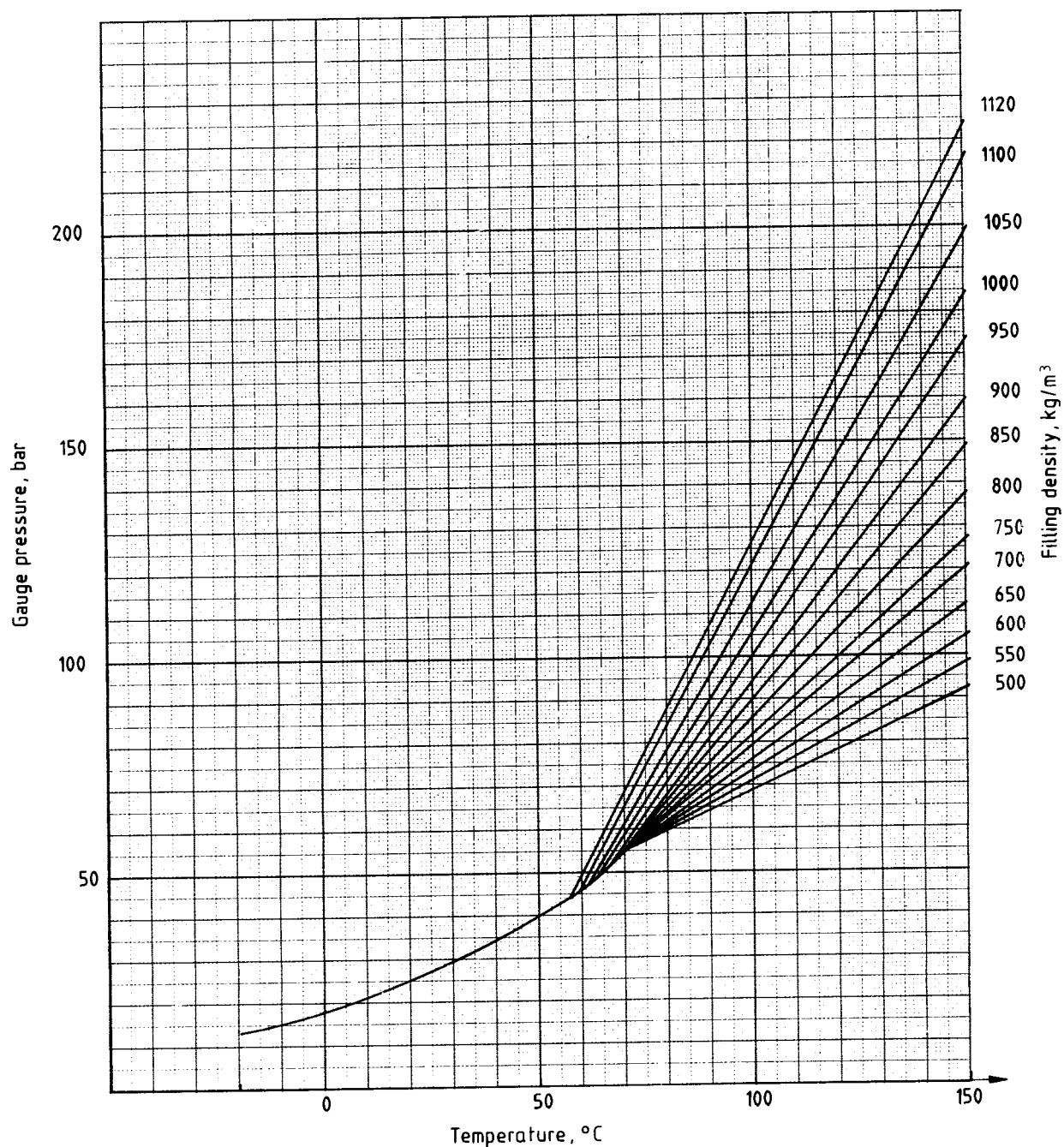


Figure 2 — Pressure/temperature relationship for halon 1301 containers in 25 bar systems

Table 7 — Steel pipework

Nominal pipe size	Publication	Type of pipe ^a	Grade of steel	Minimum wall thickness ^b
25 bar systems				
Up to and including 50 mm	BS 1387	BW	—	Heavy
	BS 3601	S	430	
	BS 3602-1	HFS or CFS	360 or 430	
	ASTM A106-77	HF or CD	A or B	
Over 50 mm up to and including 100 mm	BS 3601	S	430	Schedule 40 (Schedule 80 for screwed joints)
	BS 3602-1	HFS or CFS	360 or 430	
Above 100 m	BS 3601	S	430	Schedule 80
	BS 3602-1	HFS or CFS	360 or 430	Schedule 40 (Schedule 80 for screwed joints)
	ASTM A106-77	HF or CD	A or B	
42 bar systems				
All sizes	BS 3601	S	430	Schedule 80
	BS 3602-1	HFS or CRS	360 or 403	Schedule 40 (Schedule 80 for screwed joints)
	ASTM A106-77	HF or CD	A or B	
^a Abbreviations: BW butt welded HF hot finished CD cold drawn HFS hot finished seamless CFS cold finished seamless S seamless				
^b Where schedule numbers are given, these determine the minimum wall thickness in accordance with BS 1600. Where the specified pipe is not obtainable in these dimensions, the next larger thickness should be used.				

18.3 Flange bolts, studs, nuts and washers

Bolts and studs shall comply with grade B7 or B7M of BS 4882. Nuts shall comply with grade 2H or 2HM of BS 4882. Washers shall comply with BS 3410.

COMMENTARY AND RECOMMENDATIONS ON 18.3. *Plain washers should be fitted under bolt head and nut. A minimum of two threads should project above the nut when fully tightened.*

18.4 Gaskets for flanged joints

Flanged joints shall be fitted with a gasket.

COMMENTARY AND RECOMMENDATIONS ON 18.4. *BS 7076 specifies gaskets suitable for flanges complying with BS 1560-3.1.*

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

18.5 Fittings for steel pipe**18.5.1 42 bar systems**

18.5.1.1 For closed sections of pipe, fittings shall be as follows:

- a) up to and including 50 mm in diameter:
 - 1) forged steel, screwed, complying with grade WPA or WPB of BS 3799, or class 300 of ANSI B16.3; or
 - 2) forged steel, butt weld, complying with grade WPA or grade WPB of BS 1640-3; or
 - 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 4) with due regard to the pressure ratings and where tubes complying with BS 3605 are to be used, stainless steel compression couplings complying with BS 4368.
- b) above 50 mm:
 - 1) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 2) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 600 of ANSI B16.9.

18.5.1.2 For open-ended pipe, fittings shall be as follows:

- a) up to and including 20 mm in diameter:
 - 1) screwed, complying with BS 1256¹⁾, BS 1740 or class 150 of ANSI B16.3; or
 - 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
 - 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9;
- b) above 20 mm, up to and including 80 mm in diameter:
 - 1) screwed, complying with BS 1740 or class 300 of ANSI B16.3; or
 - 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
 - 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9;
- c) above 80 mm up to and including 100 mm in diameter:
 - 1) screwed, complying with BS 1740; or
 - 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
 - 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3;
- d) above 100 mm:
 - 1) screwed, complying with BS 1740; or
 - 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
 - 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
 - 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3;

COMMENTARY AND RECOMMENDATIONS ON 18.5.1.2. *BS 1256 specifies a maximum working pressure of 25 bar in the temperature range – 20 °C to 120 °C for malleable iron fittings. Additional checks may be necessary if these fittings are to be used outside this range.*

Malleable iron fittings are liable to deformation. It is essential that any female malleable iron fittings should be assembled into pipework only once; they should not be reused.

18.5.2 25 bar systems

18.5.2.1 For closed sections of pipe, fittings shall be as follows:

- a) up to and including 80 mm in diameter;
 - 1) forged steel, screwed, complying with grade WPA or WPB of BS 3799 or class 300 of ANSI B16.3; or

¹⁾ Published as BS 143 & BS 1256.

- 2) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 3) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9;

b) above 80 mm:

- 1) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 2) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9.

18.5.2.2 For open-ended pipe, fittings shall be as follows:

a) up to and including 20 mm in diameter:

- 1) screwed, complying with BS 1256¹⁾, BS 1740 or class 150 of ANSI B16.3; or
- 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
- 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9;

b) above 20 mm up to and including 80 mm in diameter:

- 1) screwed, complying with BS 1740 or class 300 of ANSI B16.3; or
- 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
- 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3 or class 300 of ANSI B16.9

c) above 80 mm, up to and including 100 mm in diameter:

- 1) screwed, complying with BS 1740; or
- 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
- 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3;

d) above 100 mm:

- 1) screwed, complying with BS 1740; or
- 2) forged steel, screwed, complying with grade WPA or WPB of BS 3799; or
- 3) forged steel, socket weld, complying with grade WPA or WPB of BS 3799; or
- 4) forged steel, butt weld, complying with grade WPA or WPB of BS 1640-3.

18.6 Fittings for stainless steel pipe

Fittings for stainless steel pipe shall comply with BS 4368.

18.7 Fittings for copper and copper alloy pipe

Fittings for copper and copper alloy pipe shall comply with BS 2051.

18.8 Pipe threads

Pipe threads shall comply with the dimensions specified in BS 21 or API 5B.

COMMENTARY AND RECOMMENDATIONS ON 18.8. *Threads complying with BS 21 and with API 5B are not compatible and it is recommended that threads of only one type be used on any particular system.*

18.9 Flexible hose assemblies

Flexible hose assemblies shall be suitable for service at the halon 1301 pressure and the expected maximum and minimum temperatures.

19 Installation of pipework

19.1 General

Before final assembly, pipe and fittings shall be inspected visually to ensure they are free of burrs, spelter and rust and that no foreign matter is inside and the full bore is clean. After assembly the system shall be thoroughly blown through with air or other compressed gas (see item e) of 7.1).

Provision shall be made for access to concealed pipes at fittings.

19.2 Protective finish

Adequate external protection shall be given to pipes, fittings or support brackets and steelwork that are likely to be affected by corrosion due to atmospheric or local chemical conditions.

COMMENTARY AND RECOMMENDATIONS ON 19.2. *Copper, copper alloy or stainless steel tube may be used without additional protection against corrosion.*

Fittings complying with BS 3799 should be painted externally after installation with a zinc-based paint.

Galvanizing of prefabricated pipe sections is recommended generally. It is not suitable, however, in certain atmospheres where chemical fumes, dust or moisture may attack the coating.

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 coating.

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

19.3 Pipework supports

The maximum distance between supports shall be as given in Table 8.

Table 8 — Maximum distance between pipework supports

Pipe size	Maximum distance between supports
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

COMMENTARY AND RECOMMENDATIONS ON 19.3. *The distances specified take into account the total mass of pipe and halon. 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.*

Pipe supports complying with BS 3974-1 are suitable.

19.4 Pipe anchors

Anchors shall be suitable for the working temperature and be able to withstand the dynamic and static forces involved.

COMMENTARY AND RECOMMENDATIONS ON 19.4. *It is important to ensure that pipework is securely supported, making due allowance for expansion and contraction.*

Core should be taken to ensure that the anchor bolts, and the supporting structure to which the anchor points are fixed, are adequate to take the proposed load.

19.5 Welding of pipework

Welding shall comply with BS 2633 or BS 4677 for metal arc welding or with BS 1821 for oxyacetylene welding.

COMMENTARY AND RECOMMENDATIONS ON 19.5. *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.*

19.6 Pressure relief devices

Where liquid halon may become trapped in pipework (as, for example, between valves) a pressure relief device shall be fitted. For 25 bar systems the device shall operate at (68 ± 3.5) bar. For 42 bar systems the device shall operate at (88 ± 4.5) bar.

COMMENTARY AND RECOMMENDATIONS ON 19.6. *Pressure 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.*

20 Pipework design

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 20. *Symbols used in this clause are as follows.*

Symbol	Quantity	Unit of measurement
A	} factors for steel pipe in the two-phase flow equation (see Table 11 and Table 12)	$(\text{kg m}^4/(\text{bar s}^2))$
B		$(\text{bar s}^2)/(\text{m}^3 \cdot \text{kg})$
D	Inside diameter of pipe	mm
g_n	gravitational acceleration (= 9.81)	m/s^2
K_1 and K_2	constants to determine percentage of total halon content in piping (see Table 10)	kg/m^2
L	equivalent length of pipe and fittings (see Table 9)	m
m	initial charge mass of halon 1301	kg
P	terminal pressure	bar
Q_m	mass flow rate	kg/s
V_p	internal volume of each section of piping	m^3
Y Z	} factors depending on density and pressure (see Table 13 to Table 20)	$(\text{kg bar})/\text{m}^3$ dimensionless

Values of Y and Z at discrete points in the system pipework are suffixed, e.g. Y_1 , Z_3 . Values for Y and Z at filling densities and initial storage container pressure are given in Table 13 to Table 20 inclusive.

%H	change of elevation (+ or -)	m
%P	pressure difference	bar
R	percentage halon 1301 in piping	%
ρ	pipeline density at point of elevation change	kg/m^3
ρ_{av}	average pipeline density of halon for each section of piping	kg/m^3
$\sum_i^n$	summation of V_p and ρ values for all pipeline sections	m^3 or kg/m^3

20.1 Piping flow characteristics

20.1.1 Friction losses

Allowance shall be made for the friction losses in pipes, and in container valves, dip tubes, flexible connectors, selector valves, time delays and other equipment through which the medium flows.

COMMENTARY AND RECOMMENDATIONS ON 20.1.1. *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. The proportions are dependent on pressure. The result is that pressure drop is non-linear, with an increasing rate of pressure drop as the line pressure is reduced by pipeline friction.*

Equivalent lengths of common pipe fittings and valves are given in Table 9.

Table 9 — Equivalent lengths of common pipe fittings and valves

Fitting	Equivalent length in pipe diameters
Screwed fittings	
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
Welded pipe elbows	
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

20.1.2 Changes in elevation

Allowance shall be made for changes in elevation.

COMMENTARY AND RECOMMENDATIONS ON 20.1.2. *The pressure change, Δp , is given by the expression:*

$$\Delta p = \Delta H g_n \times 10^{-5}$$

Δp is positive where there is a decrease in elevation (ΔH positive), negative where there is an increase in elevation (ΔH negative).

Halon 1301 densities in pipelines, based on constant enthalpy expansion, are given as a function of filling density and pipeline pressure in Figure 3 for 42 bar systems and Figure 4 for 25 bar systems.

20.1.3 Prevention of phase-separated flow

Pipe sizes shall be small enough to maintain turbulent flow.

COMMENTARY AND RECOMMENDATIONS ON 20.1.3. *Figure 5 shows limiting pipe sizes.*

If turbulent flow is not maintained, separation of the liquid and gaseous phases will occur, which can lead to incorrect division of flow at junctions.

20.1.4 Division of flow

Any imbalance of flow division at a tee shall not exceed 10 to 1.

COMMENTARY AND RECOMMENDATIONS ON 20.1.4. *There is a tendency for phase separation to occur at a tee, which can cause incorrect division of flow particularly where the flow division is unequal.*

Incorrect division of flow is more likely where the flow is divided vertically, and horizontal division is therefore preferred. Figure 6 shows preferred and deprecated arrangements for division of flow.

Correct division of flow is particularly important when halon is to be discharged into two or more separate enclosures, to ensure that the appropriate quantity of halon is discharged into each.

20.2 Halon flow rates

20.2.1 General

Flow rates shall be calculated on the basis of the average container pressure during discharge, taking into account the original pressurization level, filling density and the percentage of total halon content in piping for 20 °C storage temperature as shown in Figure 7.

COMMENTARY AND RECOMMENDATIONS ON 20.2.1. *The percentage of halon in the piping system during discharge is a function of the actual volume of the piping times the average density of the halon 1301. The average density cannot be determined accurately until after the terminal pressure has been calculated. The problem does not have a direct solution. However, based on the probability that the terminal pressure will be near to but not less than 50 % of the mid-discharge storage pressure, the following equation may be used:*

$$R = \frac{K_1}{(m/V_p) + K_2}$$

where the values of K_1 and K_2 are given in Table 10.

Alternatively the percentage of total halon content in piping after terminal pressures have been calculated maybe obtained using the following:

$$\text{Percentage of total halon content in piping} = \frac{100 \sum_1^n V_p \rho_{av}}{m}$$

Average density values are given in Figure 3 for 42 bar systems and Figure 4 for 25 bar systems.

The percentage of total halon content in piping defined by the expression should not exceed 80 %.

20.2.2 Balanced and unbalanced systems

For the purposes of this Section of BS 5306, a balanced system shall be considered to be one in which:

- a) each actual length of pipe from container to each nozzle is greater than 90 % of the longest pipe length; and
- b) each equivalent length of pipe from container to each nozzle is greater than 90 % of the longest equivalent pipe length; and
- c) the discharge rate at each nozzle is equal.

Any system which does not meet all three of these criteria shall be considered to be an unbalanced system.

COMMENTARY AND RECOMMENDATIONS ON 20.2.2. *The two types are illustrated in Figure 8 and Figure 9.*

The discharge rate at each nozzle depends on the orifice size, the nozzle flow characteristics, and the terminal pressure. Nozzle manufacturer's design manuals give the necessary information.

20.2.3 Determination of pressure drops

Pressure drops in commercial steel pipes shall be calculated either:

- a) from the following flow equation:

$$Q_m^2 = \frac{2.424 \times 10^{-9} YD^{5.25}}{L + (0.04319 Z D^{1.25})}$$

or,

- b) where the minimum design terminal pressure is not less than 50 % of the average container pressure during discharge, from Figure 10 and Figure 11, using the appropriate multiplication factor, to correct for the percentage of halon in piping and filling density, given in Figure 12 and Figure 13.

COMMENTARY AND RECOMMENDATIONS ON 20.2.3. *The flow equation describes the two phase flow of halon 1301 and includes a friction factor applicable to commercial steel pipe.*

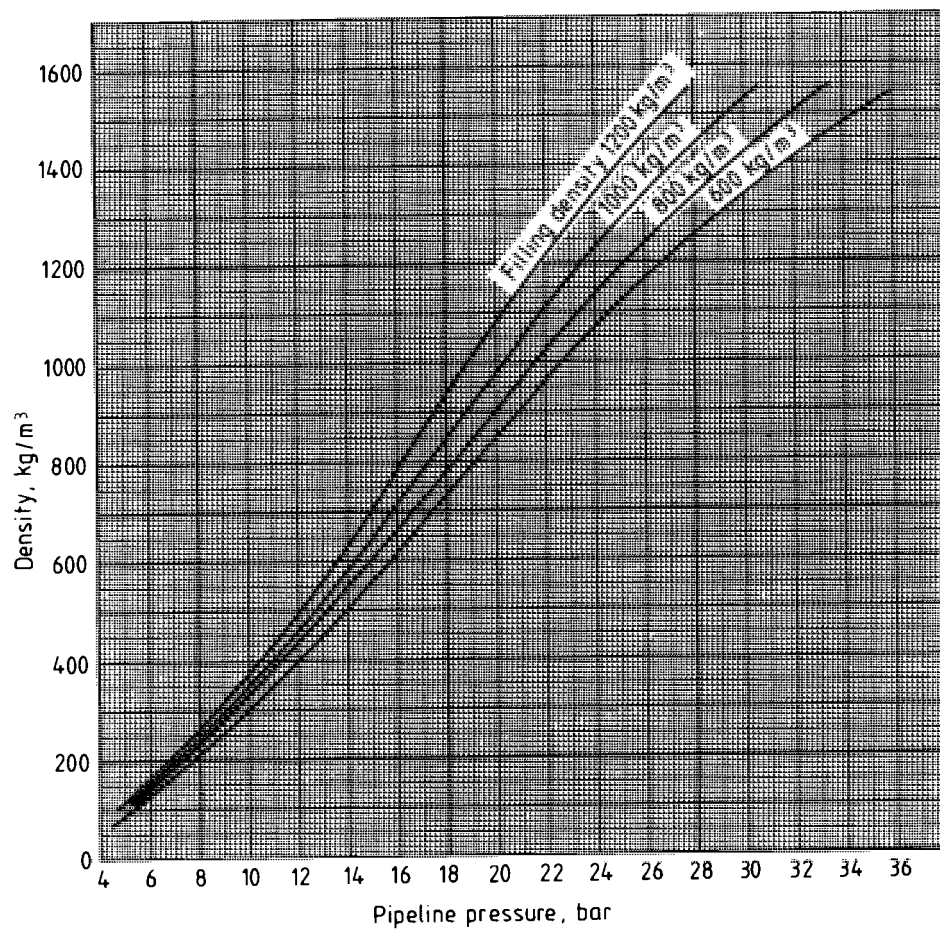


Figure 3 — Halon density in pipelines for 42 bar systems

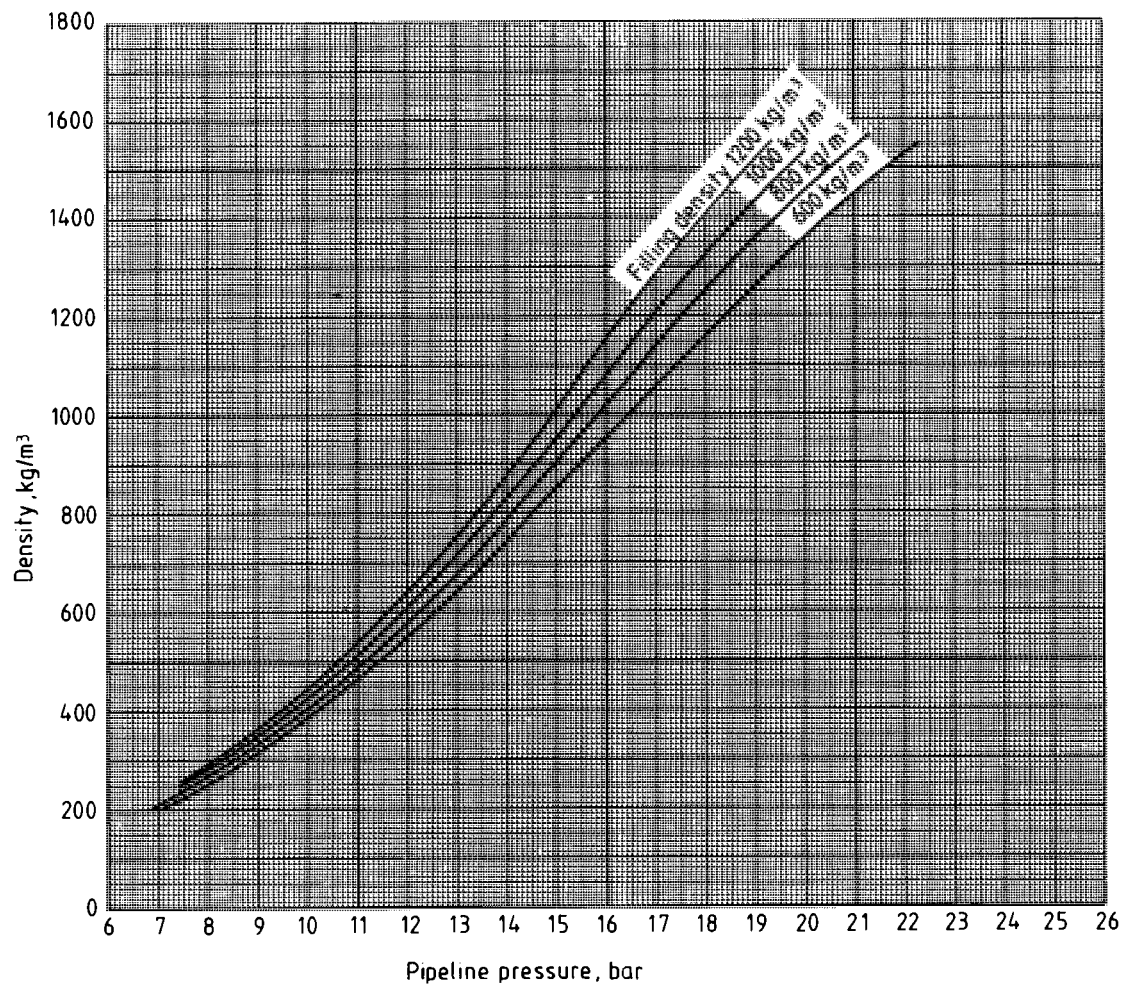


Figure 4 — Halon density in pipelines for 25 bar systems

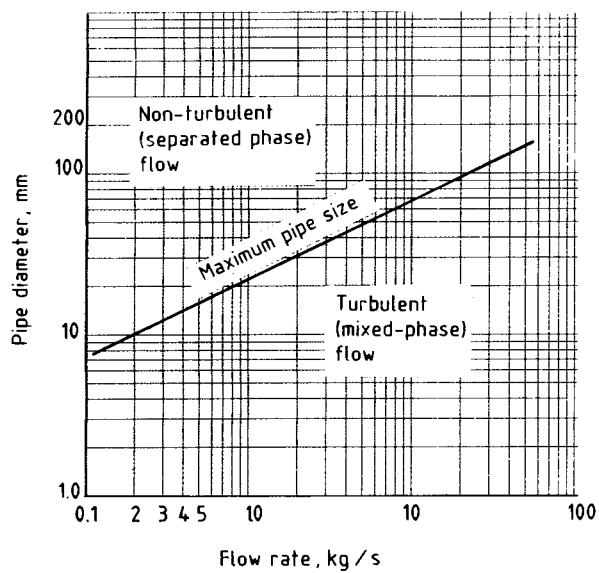
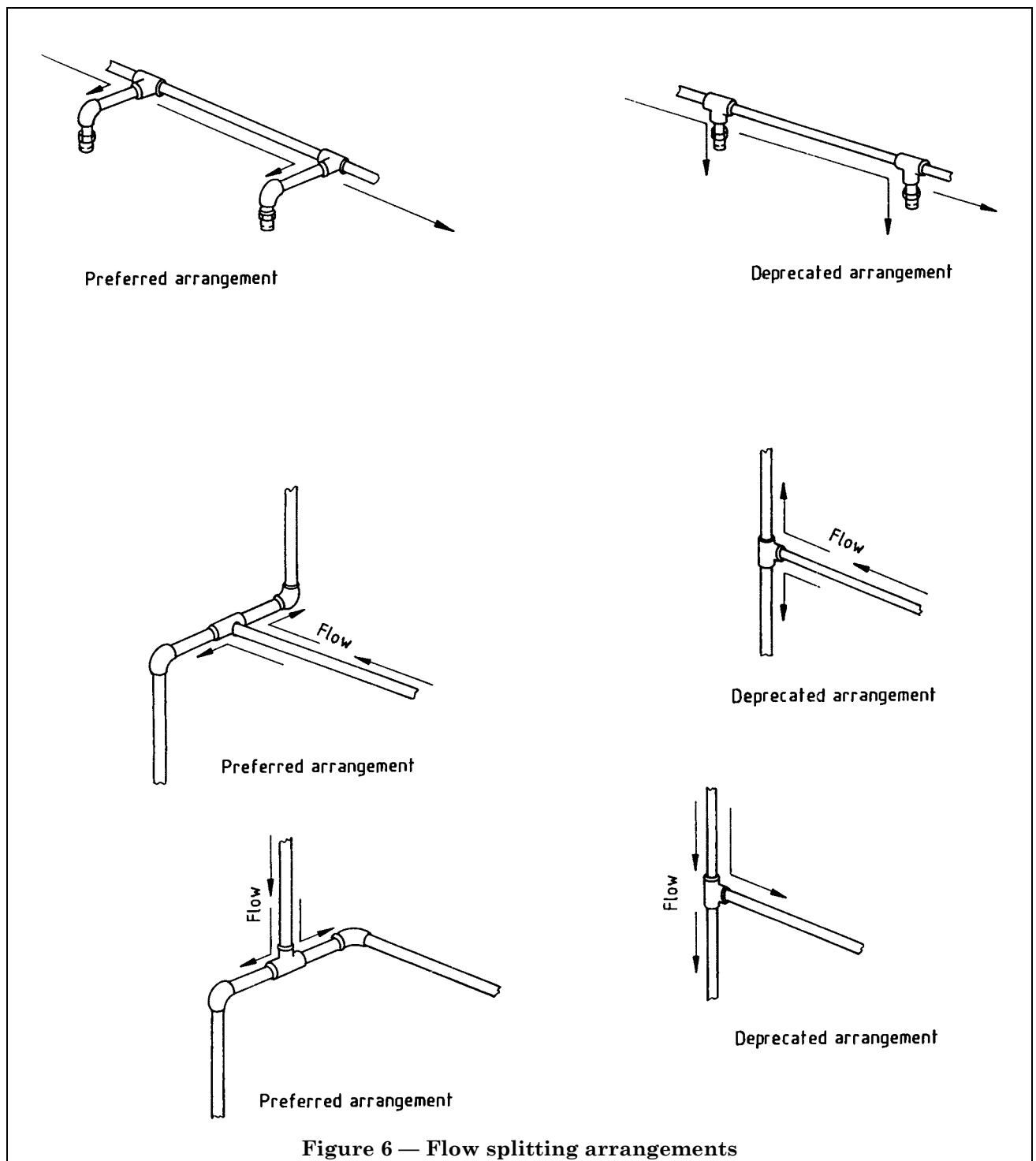


Figure 5 — Maximum pipe size to maintain turbulent flow



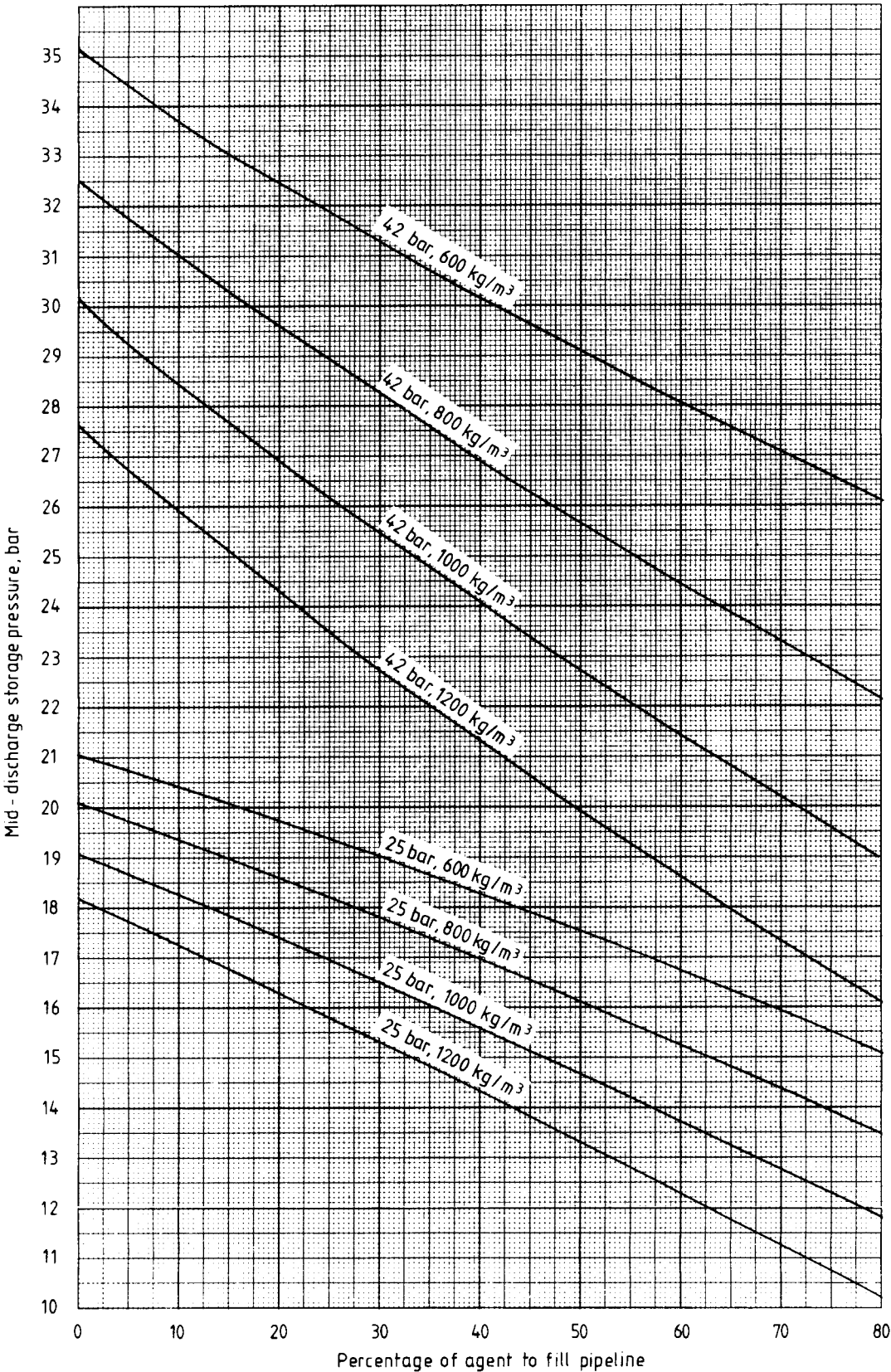


Figure 7 — Mid-discharge storage pressure versus percentage of halon to fill pipeline

Table 10 — Constants to determine percentage of halon in piping

Storage pressure	Filling density	K_1	K_2
bar	kg/m ³	kg/m ³	kg/m ³
25	600	109 900	520
25	700	109 500	580
25	800	109 100	640
25	900	108 700	700
25	1 000	108 300	760
25	1 100	107 900	820
25	1 121	107 777	833
25	1 200	107 500	880
42	600	118 700	424
42	700	118 000	484
42	800	117 300	544
42	900	116 600	604
42	1 000	115 900	664
42	1 100	115 200	724
42	1 121	115 050	735
42	1 200	114 500	784

The equation cannot be solved directly, but can be rearranged to give

$$Y_2 = Y_1 + (LQ^2/A) + B(Z_2 - Z_1)Q^2$$

where

$$A = 2.424 \times 10^{-9} D^{5.25},$$

$$B = 1.78 \times 10^7 / D^4;$$

Y_1 is the value of Y at the initial point of the pipework;

Y_2 is the value of Y at the end point of the pipework;

Z_1 is the value of Z at the initial point of the pipework;

Z_2 is the value of Z at the end point of the pipework.

Values for A and B are given in Table 11 and Table 12.

Y and Z are related to pressure. From the known initial pressure P_1 , Y_1 and Z_1 are found using Table 13 to Table 20 and Y_2 is calculated by approximation to find the final pressure P_2 and hence ΔP .

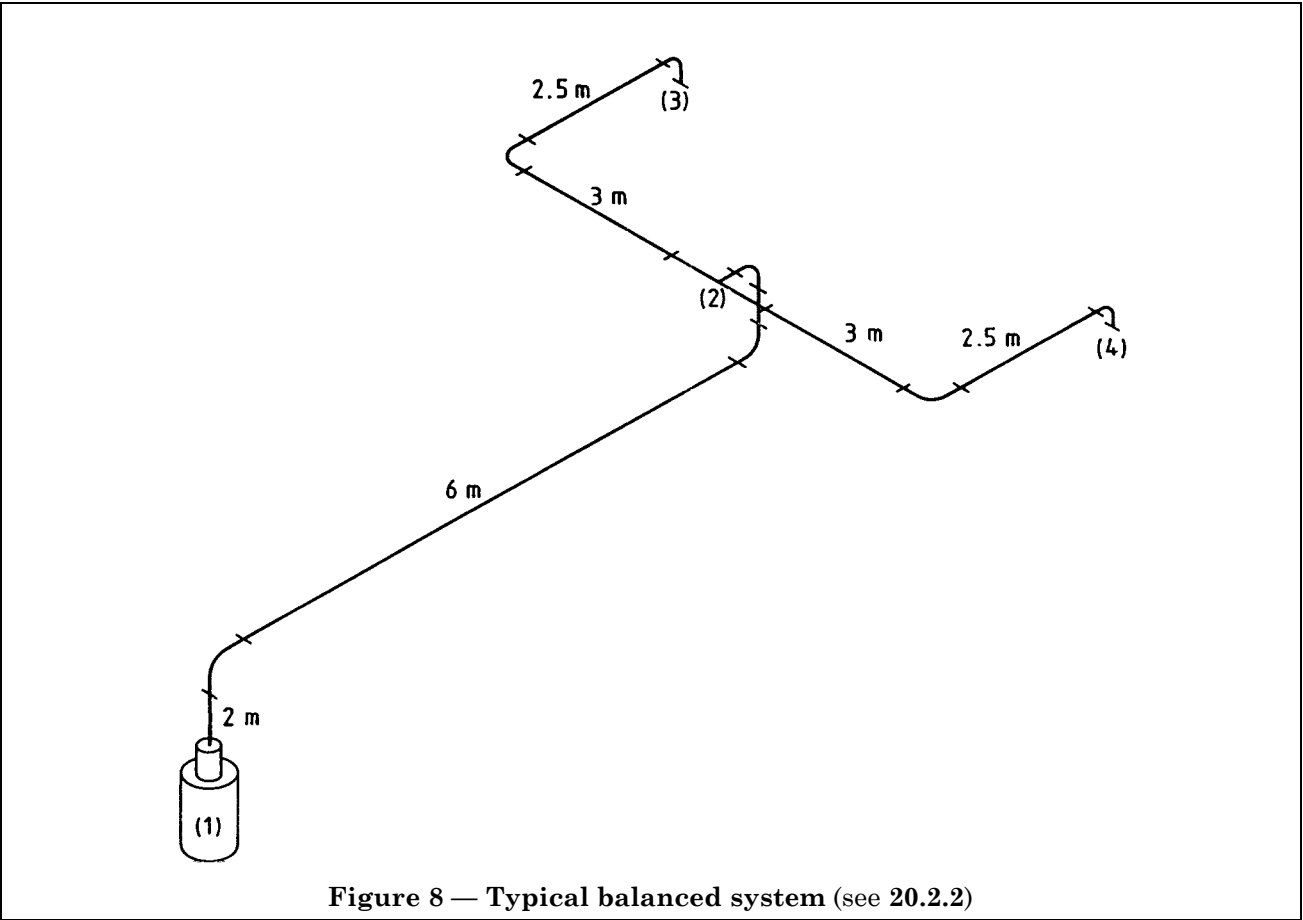


Figure 8 — Typical balanced system (see 20.2.2)

Table 11 — A and B factors for steel pipe (inch sizes)

Nominal pipe size in	Schedule 40		Schedule 80	
	A factor	B factor	A factor	B factor
1/8	56.90×10^{-6}	8.3×10^3	18.68×10^{-6}	19.0×10^{-3}
1/4	278.2×10^{-6}	2.5×10^3	109.3×10^{-6}	5.1×10^{-3}
3/8	1.391×10^{-3}	730.0	614.8×10^{-6}	1.4×10^{-3}
1/2	4.758×10^{-3}	290.0	2.428×10^{-3}	480.0
3/4	20.66×10^{-3}	93.0	11.85×10^{-3}	140.0
1	73.30×10^{-3}	36.0	45.59×10^{-3}	51.0
1 1/4	314.3×10^{-3}	12.0	209.8×10^{-3}	16.0
1 1/2	701.5×10^{-3}	6.4	483.4×10^{-3}	8.5
2	2.602	2.3	1.870	3.0
2 1/2	6.609	1.2	4.802	1.5
3	20.66	480.0×10^{-3}	15.44	600.0×10^{-3}
3 1/2	44.34	270.0×10^{-3}	33.47	340.0×10^{-3}
4	85.04	160.0×10^{-3}	66.03	200.0×10^{-3}
5	280.1	66.0×10^{-3}	217.7	80.0×10^{-3}
6	739.5	32.0×10^3	558.9	39.0×10^{-3}

Table 12 — *A* and *B* factors for steel pipe (metric sizes)

Actual inside diameter	<i>A</i> factor	<i>B</i> factor
mm		
4	3.510×10^{-6}	70.0×10^3
6	29.50×10^{-6}	14.0×10^3
8	133.6×10^{-6}	4.4×10^3
10	431.0×10^{-6}	1.8×10^3
12	1.122×10^{-3}	860.0
14	2.521×10^{-3}	460.0
16	5.083×10^{-3}	270.0
18	9.433×10^{-3}	170.0
20	16.40×10^{-3}	110.0
25	52.92×10^{-3}	46.0
30	137.8×10^{-3}	22.0
35	309.6×10^{-3}	12.0
40	624.1×10^{-3}	7.0
45	1.158	4.3
50	2.014	2.9
55	3.322	1.9
60	5.245	1.4
65	7.985	1.0
70	11.78	740.0×10^{-3}
75	16.93	560.0×10^{-3}
80	23.75	440.0×10^{-3}
85	32.65	340.0×10^{-3}
90	44.08	270.0×10^{-3}
95	58.55	220.0×10^{-3}
100	76.64	180.0×10^{-3}
110	126.4	120.0×10^{-3}
120	199.6	86.0×10^{-3}
130	303.9	62.0×10^{-3}
140	448.4	46.0×10^{-3}
150	644.1	35.0×10^{-3}

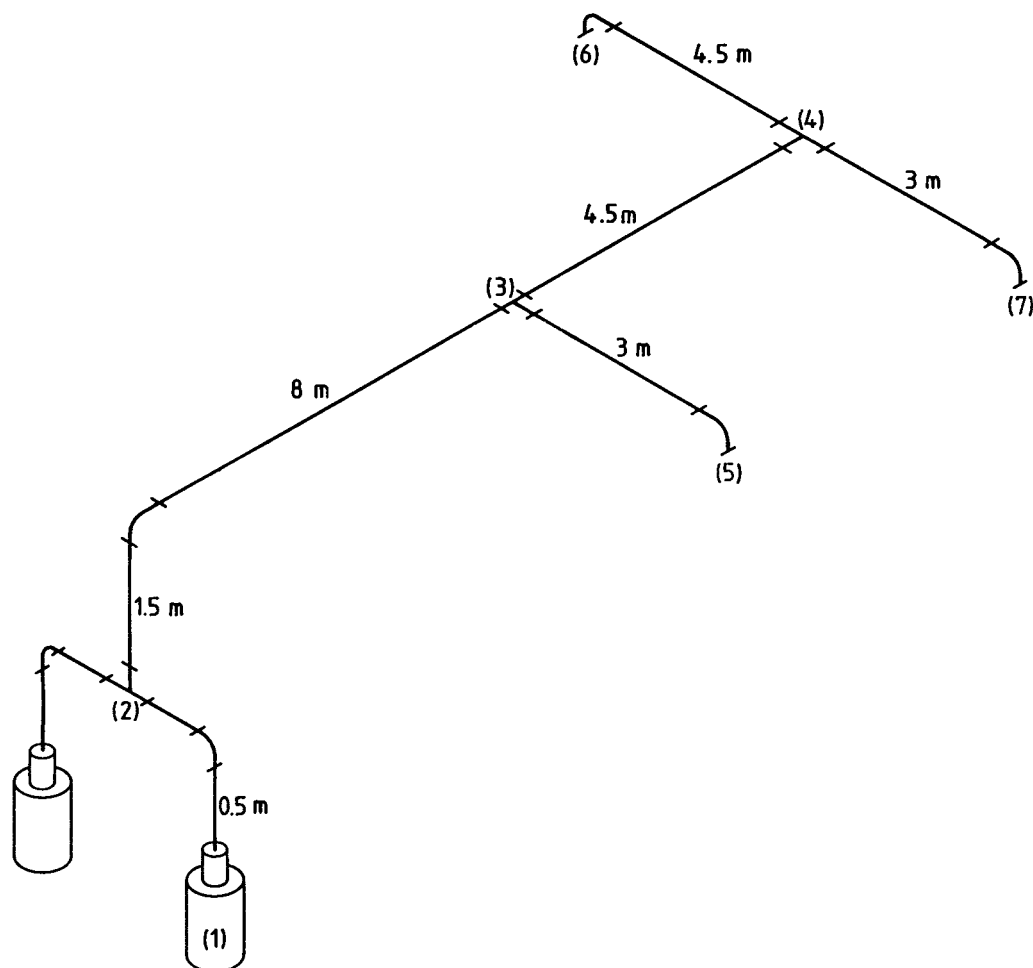


Figure 9 — Typical unbalanced system (see 20.2.2)

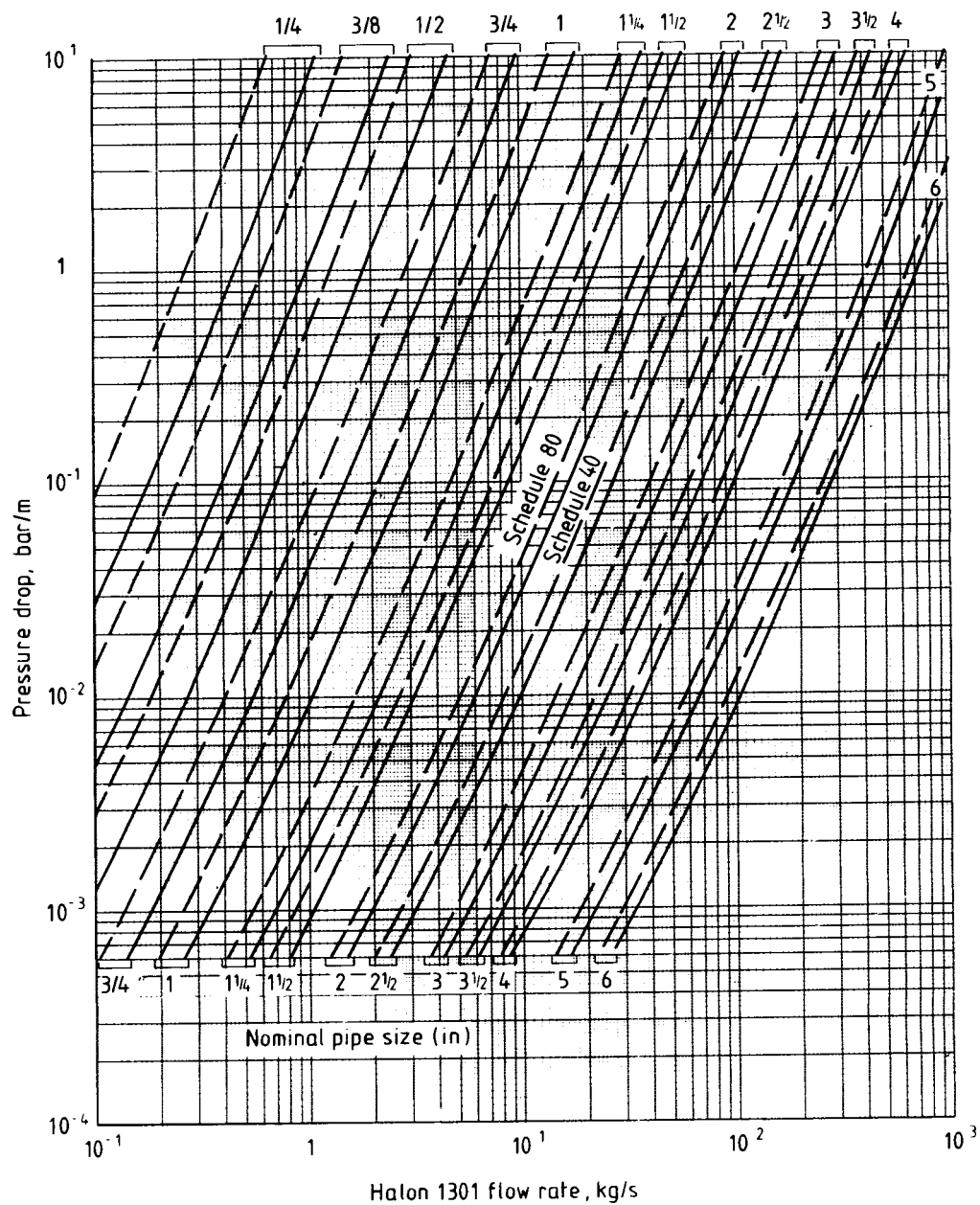


Figure 10 — Pressure drop at 20 °C in steel pipe (inch sizes)

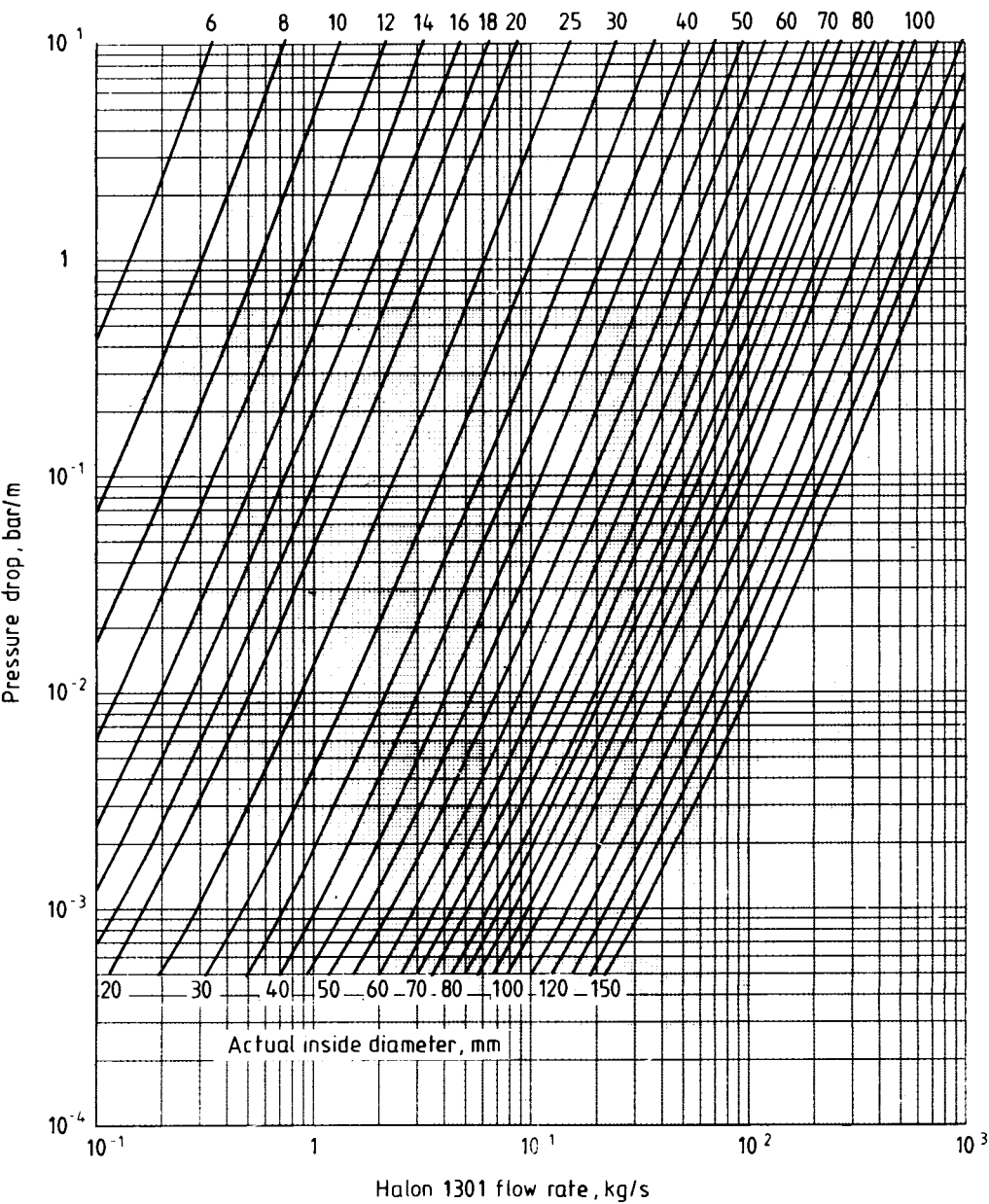


Figure 11 — Pressure drop at 20 °C in steel pipe (metric sizes)

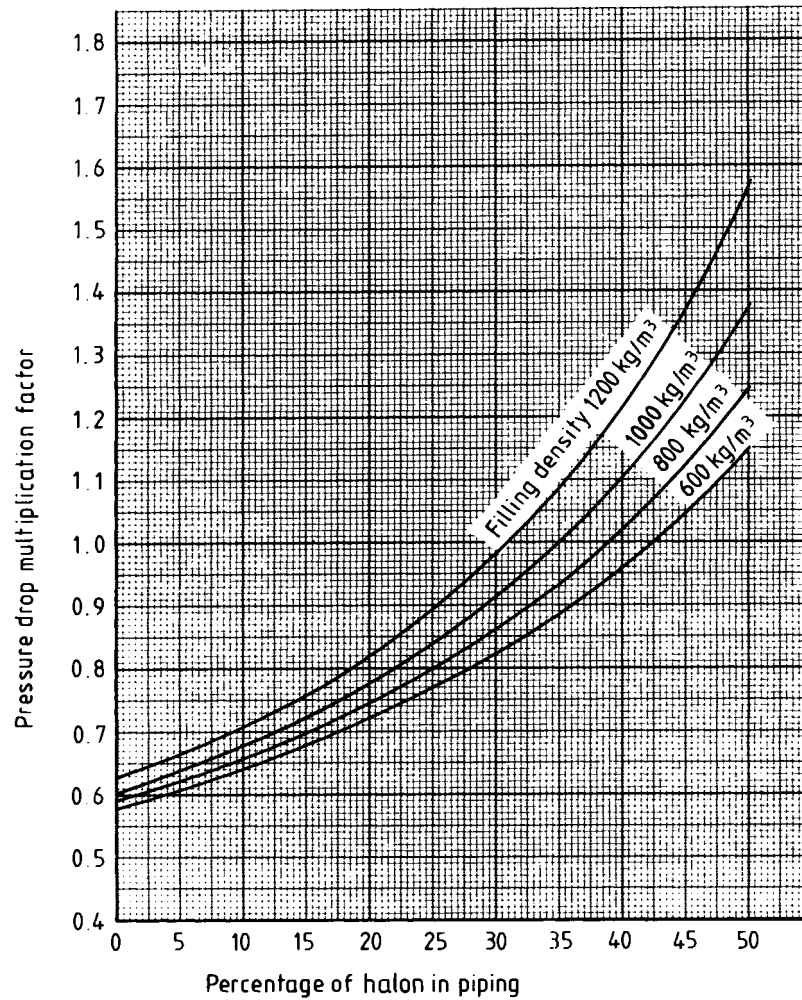


Figure 12 — Pressure drop multiplication factor for 42 bar systems

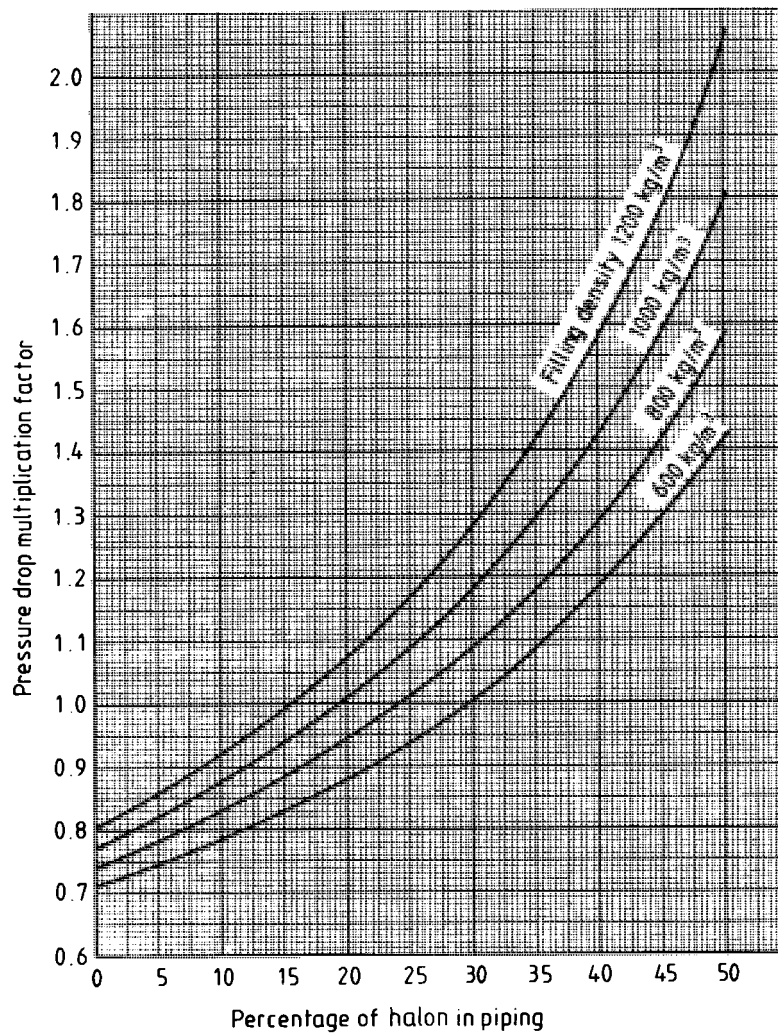


Figure 13 — Pressure drop multiplication factor for 25 bar systems

Table 13 — Y and Z factors for 42 bar systems at a filling density of 1 000 kg/m³ to 1 121 kg/m³

Pressure ^a	Y factor, in (kg·bar)/m ³										Z factor
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
28	1 227	1 075	923	770	617	463	309	154	0	0	0.026
27	2 717	2 571	2 423	2 275	2 127	1 978	1 829	1 679	1 529	1 378	0.057
26	4 156	4 015	3 873	3 730	3 587	3 443	3 299	3 155	3 009	2 864	0.094
25	5 541	5 405	5 268	5 131	4 994	4 855	4 717	4 577	4 438	4 297	0.135
24	6 868	6 738	6 607	6 476	6 344	6 212	6 079	5 945	5 811	5 676	0.180
23	8 136	8 012	7 887	7 762	7 636	7 510	7 383	7 255	7 127	6 998	0.229
22	9 341	9 223	9 105	8 986	8 867	8 746	8 626	8 504	8 382	8 259	0.282
21	10 481	10 370	10 258	10 146	10 033	9 919	9 805	9 690	9 574	9 458	0.340
20	11 553	11 449	11 344	11 239	11 133	11 026	10 918	10 810	10 701	10 591	0.403
19	12 556	12 459	12 361	12 262	12 163	12 063	11 963	11 861	11 759	11 657	0.473
18	13 487	13 397	13 306	13 215	13 123	13 030	12 937	12 843	12 748	12 652	0.551
17	14 345	14 262	14 179	14 095	14 010	13 925	13 839	13 752	13 664	13 576	0.636
16	15 130	15 054	14 979	14 902	14 825	14 746	14 668	14 588	14 508	14 427	0.731
15	15 841	15 773	15 704	15 635	15 565	15 494	15 423	15 351	15 278	15 204	0.834
14	16 479	16 419	16 357	16 295	16 233	16 169	16 105	16 040	15 974	15 908	0.948
13	17 047	16 993	16 939	16 884	16 828	16 772	16 715	16 657	16 599	16 539	1.071
12	17 546	17 499	17 452	17 403	17 354	17 305	17 255	17 204	17 152	17 100	1.205
11	17 980	17 939	17 898	17 856	17 814	17 771	17 727	17 683	17 638	17 592	1.351
10	18 352	18 318	18 282	18 247	18 210	18 173	18 136	18 098	18 059	18 020	1.509
9	18 668	18 629	18 609	18 579	18 543	18 517	18 485	18 453	18 420	18 386	1.681
8	18 932	18 907	18 883	18 858	18 832	18 806	18 779	18 752	18 725	18 696	1.869
7	19 148	19 129	19 108	19 088	19 067	19 045	19 024	19 001	18 972	18 955	2.077
6	19 323	19 307	19 291	19 275	19 258	19 241	19 223	19 205	19 186	19 168	2.309
5	19 459	19 447	19 435	19 422	19 409	19 396	19 382	19 368	19 353	19 338	2.570

^a Example. The Y factor for a pressure of 28.5 bar is 463 (kg·bar)/m³

Table 14 — *Y* and *Z* factors for 42 bar systems at a filling density of 850 kg/m³ to 999 kg/m³

Pressure ^a	<i>Y</i> factor, in (kg·bar)/m ³										<i>Z</i> factor
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
30	1 012	860	708	555	402	248	94	0	0	0	0.019
29	2 508	2 360	2 212	2 064	1 915	1 765	1 616	1 465	1 315	1 164	0.048
28	3 958	3 815	3 672	3 528	3 383	3 239	3 093	2 948	2 801	2 655	0.079
27	5 361	5 223	5 084	4 945	4 806	4 666	4 525	4 384	4 242	4 101	0.114
26	6 714	6 581	6 447	6 313	6 179	6 044	5 908	5 772	5 636	5 498	0.151
25	8 015	7 887	7 759	7 630	7 501	7 371	7 241	7 110	6 978	6 846	0.193
24	9 261	9 138	9 016	8 893	8 769	8 645	8 520	8 394	8 268	8 142	0.238
23	10 450	10 333	10 216	10 999	9 981	9 862	9 743	9 623	9 503	9 382	0.287
22	11 579	11 469	11 358	11 247	11 135	11 022	10 909	10 795	10 680	10 565	0.341
21	12 647	12 543	12 439	12 333	12 228	12 121	12 014	11 906	11 798	11 689	0.400
20	13 652	13 554	13 456	13 357	13 258	13 158	13 057	12 955	12 853	12 751	0.464
19	14 591	14 500	14 408	14 316	14 223	14 130	14 035	13 940	13 845	13 749	0.534
18	15 463	15 379	15 294	15 209	15 122	15 036	14 948	14 860	14 771	14 681	0.610
17	16 268	16 191	16 113	16 034	15 955	15 874	15 794	15 712	15 630	15 547	0.695
16	17 005	16 935	16 863	16 791	16 719	16 645	16 571	16 497	16 421	16 345	0.787
15	17 675	17 611	17 546	17 481	17 415	17 348	17 281	17 213	17 145	17 075	0.888
14	18 277	18 220	18 162	18 103	18 044	17 984	17 923	17 862	17 800	17 738	0.999
13	18 814	18 763	18 711	18 659	18 607	18 553	18 499	18 445	18 389	18 333	1.119
12	19 288	19 243	19 198	19 152	19 105	19 058	19 011	18 962	18 913	18 864	1.249
11	19 701	19 662	19 623	19 583	19 543	19 502	19 460	19 418	19 375	19 332	1.391
10	20 058	20 024	19 991	19 956	19 921	19 886	19 850	19 814	19 777	19 739	1.545
9	20 361	20 333	20 304	20 275	20 246	20 216	20 185	20 154	20 122	20 090	1.713
8	20 616	20 592	20 569	20 544	20 520	20 494	20 469	20 442	20 416	20 389	1.896
7	20 826	20 807	20 787	20 768	20 747	20 726	20 705	20 683	20 661	20 639	2.098
6	20 996	20 981	20 965	20 949	20 933	20 916	20 889	20 881	20 863	20 845	2.325
5	21 129	21 128	21 105	21 093	21 080	21 067	21 054	21 040	21 026	21 011	2.583

^a Example. The *Y* factor for a pressure of 30.5 bar is 248 (kg·bar)/m³

Table 15 — Y and Z factors for 42 bar systems at a filling density of 700 kg/m³ to 849 kg/m³

Pressure ^a	Y factor, in (kg·bar)/m ³										Z factor
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
32	797	645	493	341	188	34	0	0	0	0	0.013
31	2 294	2 140	1 998	1 849	1 700	1 550	1 400	1 250	1 099	948	0.039
30	3 751	3 607	3 463	3 318	3 173	3 028	2 882	2 735	2 589	2 442	0.067
29	5 167	5 027	4 887	4 746	4 606	4 464	4 323	4 180	4 038	3 895	0.098
28	6 538	6 403	6 267	6 131	5 995	5 858	5 720	5 583	5 444	5 306	0.131
27	7 863	7 732	7 601	7 470	7 338	7 206	7 073	6 940	6 806	6 672	0.166
26	9 139	9 014	8 888	8 761	8 634	8 507	8 379	8 251	8 122	7 992	0.205
25	10 365	10 245	10 124	10 003	9 881	9 759	9 636	9 512	9 388	9 264	0.247
24	11 539	11 424	11 308	11 192	11 076	10 959	10 841	10 723	10 604	10 485	0.293
23	12 657	12 548	12 438	12 328	12 217	12 105	11 993	11 880	11 767	11 653	0.343
22	13 720	13 616	13 512	13 407	13 302	13 196	13 089	12 982	12 874	12 766	0.397
21	14 723	14 626	14 527	14 428	14 329	14 229	14 128	14 027	13 925	13 823	0.456
20	15 667	15 575	15 483	15 390	15 297	15 203	15 108	15 013	14 917	14 820	0.520
19	16 549	16 464	16 378	16 291	16 204	16 116	16 027	15 938	15 848	15 758	0.590
18	17 369	17 290	17 210	17 130	17 049	16 967	16 885	16 802	16 718	16 634	0.667
17	18 126	18 053	17 979	17 905	17 830	17 755	17 679	17 602	17 525	17 447	0.751
16	18 819	18 752	18 685	18 618	18 549	18 480	18 410	18 340	18 269	18 198	0.842
15	19 449	19 389	19 328	19 267	19 205	19 142	19 079	19 015	18 950	18 885	0.942
14	20 018	19 964	19 909	19 854	19 798	19 741	19 684	19 626	19 568	19 509	1.050
13	20 526	20 477	20 429	20 379	20 330	20 279	20 228	20 176	20 124	20 071	1.168
12	20 975	20 932	20 889	20 846	20 802	20 757	20 712	20 666	20 620	20 573	1.296
11	21 368	21 331	21 294	21 256	21 217	21 178	21 138	21 098	21 058	21 016	1.435
10	21 708	21 676	21 644	21 611	21 578	21 544	21 510	21 475	21 440	21 404	1.585
9	21 998	21 971	21 944	21 916	21 888	21 859	21 830	21 800	21 770	21 739	1.750
8	22 243	22 220	22 197	22 174	22 150	22 126	22 101	22 076	22 051	22 025	1.930
7	22 445	22 427	22 408	22 389	22 369	22 349	22 329	22 308	22 287	22 265	2.128
6	22 610	22 595	22 580	22 564	22 549	22 532	22 516	22 499	22 481	22 464	2.348
5	22 740	22 729	22 717	22 705	22 692	22 679	22 666	22 653	22 639	22 625	2.594

^a Example. The Y factor for a pressure of 32.5 bar is 34 (kg·bar)/m³

Table 16 — Y and Z factors for 42 bar systems at a filling density of 600 kg/m³ to 669 kg/m³

Pressure ^a	Y factor, in (kg·bar)/m ³										Z factor
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
34	689	537	386	233	81	0	0	0	0	0	0.011
33	2 183	2 035	1 887	1 738	1 589	1 440	1 291	1 141	990	840	0.034
32	3 642	3 498	3 353	3 208	3 063	2 917	2 771	2 625	2 478	2 331	0.059
31	5 063	4 923	4 782	4 641	4 499	4 358	4 215	4 072	3 929	3 786	0.086
30	6 445	6 309	6 172	6 035	5 897	5 759	5 621	5 482	5 343	5 203	0.115
29	7 786	7 654	7 521	7 388	7 255	7 121	6 986	6 852	6 717	6 581	0.146
28	9 083	8 955	8 827	8 699	8 569	8 440	8 310	8 180	8 049	7 919	0.180
27	10 336	10 213	10 089	9 965	9 840	9 715	9 590	9 464	9 337	9 210	0.217
26	11 541	11 423	11 304	11 185	11 065	10 945	10 824	10 702	10 581	10 458	0.257
25	12 698	12 585	12 471	12 357	12 242	12 126	12 010	11 894	11 777	11 659	0.300
24	13 805	13 696	13 588	13 478	13 368	13 258	13 147	13 036	12 924	12 811	0.347
23	14 859	14 756	14 652	14 548	14 444	14 338	14 233	14 127	14 020	13 913	0.397
22	15 859	15 761	15 663	15 565	15 465	15 366	15 265	15 165	15 063	14 961	0.452
21	16 803	16 711	16 619	16 526	16 432	16 338	16 243	16 148	16 052	15 956	0.511
20	17 690	17 604	17 518	17 430	17 342	17 254	17 165	17 075	16 985	16 894	0.576
19	18 520	18 439	18 359	18 277	18 195	18 112	18 029	17 945	17 861	17 776	0.646
18	19 290	19 216	19 141	19 065	18 989	18 912	18 835	18 757	18 679	18 599	0.723
17	20 002	19 933	19 864	19 794	19 724	19 653	19 582	19 510	19 437	19 364	0.807
16	20 654	20 591	20 528	20 464	20 400	20 335	20 270	20 203	20 137	20 069	0.897
15	21 247	21 191	21 133	21 075	21 017	20 958	20 898	20 838	20 777	20 716	0.996
14	21 783	21 732	21 680	21 628	21 576	21 522	21 468	21 414	21 359	21 303	1.103
13	22 262	22 217	22 171	22 124	22 077	22 030	21 981	21 933	21 883	21 833	1.219
12	22 687	22 647	22 606	22 565	22 524	22 481	22 439	22 395	22 352	22 307	1.345
11	23 060	23 025	22 989	22 953	22 917	22 880	22 842	22 804	22 766	22 727	1.481
10	23 383	23 353	23 322	23 291	23 259	23 227	23 195	23 162	23 128	23 094	1.629
9	23 659	23 634	23 608	23 581	23 554	23 527	23 499	23 470	23 442	23 412	1.791
8	23 893	23 872	23 850	23 827	23 805	23 781	23 758	23 734	23 709	23 685	1.969
7	24 087	24 069	24 051	24 033	24 014	23 995	23 975	23 955	23 935	23 914	2.165
6	24 245	24 231	24 216	24 201	24 186	24 171	24 155	24 138	24 122	24 105	2.383
5	24 371	24 360	24 348	24 336	24 324	24 312	24 299	24 286	24 273	24 259	2.629

^a Example. The Y factor for a pressure of 34.4 bar is 81 (kg·bar)/m³

Table 17 — Y and Z factors for 25 bar systems at a filling density of 1 000 kg/m³ to 1 121 kg/m³

Y factor, in (kg·bar)/m ³											Z factor
Pressure ^a	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
19	972	821	668	514	360	204	46	0	0	0	0.046
18	2 422	2 283	2 142	2 000	1 856	1 712	1 566	1 419	1 271	1 122	0.127
17	3 752	3 624	3 496	3 366	3 235	3 103	2 969	2 834	2 698	2 561	0.220
16	4 955	4 840	4 725	4 608	4 489	4 369	4 249	4 126	4 003	3 878	0.327
15	6 028	5 926	5 824	5 720	5 614	5 508	5 400	5 291	5 180	5 068	0.449
14	6 970	6 882	6 792	6 701	6 609	6 515	6 420	6 324	6 227	6 128	0.587
13	7 785	7 709	7 632	7 554	7 474	7 393	7 311	7 228	7 143	7 057	0.740
12	8 481	8 416	8 351	8 284	8 216	8 147	8 077	8 006	7 934	7 860	0.907
11	9 065	9 011	8 956	8 901	8 844	8 786	8 727	8 667	8 606	8 554	1.086
10	9 550	9 506	9 461	9 414	9 367	9 319	9 270	9 220	9 170	9 118	1.278
9	9 949	9 912	9 875	9 838	9 799	9 760	9 719	9 678	9 637	9 594	1.482
8	10 272	10 242	10 212	10 182	10 151	10 119	10 086	10 053	10 019	9 984	1.698
7	10 530	10 506	10 483	10 458	10 434	10 408	10 382	10 355	10 328	10 300	1.931
6	10 733	10 714	10 696	10 677	10 657	10 637	10 617	10 596	10 574	10 552	2.183
5	10 889	10 875	10 861	10 846	10 831	10 816	10 800	10 784	10 767	10 750	2.460

^a Example. The Y factor for a pressure of 19.5 bar is 204 (kg·bar)/m³**Table 18 — Y and Z factors for 25 bar systems at a filling density of 850 kg/m³ to 999 kg/m³**

Y factor in (kg·bar)/m ³											Z factor
Pressure ^a	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
20	604	450	294	138	0	0	0	0	0	0	0.025
19	2 088	1 945	1 800	1 654	1 508	1 360	1 211	1 061	909	757	0.097
18	3 463	3 331	3 197	3 063	2 927	2 790	2 652	2 513	2 372	2 231	0.179
17	4 723	4 602	4 481	4 358	4 233	4 108	3 981	3 854	3 725	3 595	0.273
16	5 863	5 754	5 645	5 534	5 421	5 308	5 194	5 078	4 961	4 842	0.380
15	6 879	6 783	6 686	6 587	6 487	6 386	6 284	6 181	6 076	5 970	0.502
14	7 774	7 690	7 604	7 518	7 430	7 342	7 252	7 160	7 068	6 974	0.637
13	8 549	8 477	8 403	8 328	8 253	8 176	8 098	8 018	7 938	7 856	0.787
12	9 212	9 151	9 088	9 024	8 960	8 894	8 827	8 759	8 690	8 620	0.950
11	9 722	9 720	9 668	9 614	9 560	9 504	9 448	9 391	9 332	9 273	1.126
10	10 239	10 196	10 153	10 108	10 063	10 017	9 969	9 921	9 873	7 823	1.314
9	10 624	10 589	10 553	10 517	10 469	10 441	10 402	10 363	10 322	10 281	1.514
8	10 937	10 909	10 880	10 850	10 820	10 789	10 757	10 725	10 692	10 658	1.727
7	11 188	11 166	11 143	11 119	11 095	11 070	11 045	11 019	10 992	10 965	1.957
6	11 386	11 368	11 350	11 332	11 313	11 293	11 273	11 253	11 232	11 210	2.206
5	11 538	11 525	11 511	11 497	11 482	11 467	11 452	11 436	11 420	11 403	2.480

^a Example. The Y factor for a pressure of 20.3 bar is 138 (kg·bar)/m³

Table 19 — Y and Z factors for 25 bar systems at a filling density of 700 kg/m³ to 849 kg/m³

Y factor, in (kg·bar)/m ³											Z factor
Pressure ^a	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
21	229	72	0	0	0	0	0	0	0	0	0.008
20	1 739	1 592	1 445	1 296	1 146	996	844	692	538	384	0.072
19	3 149	3 013	2 875	2 737	2 597	2 457	2 315	2 172	2 029	1 884	0.145
18	4 455	4 329	4 202	4 074	3 945	3 815	3 684	3 552	3 419	3 284	0.228
17	5 650	5 536	5 420	5 303	5 185	5 066	4 946	4 825	4 703	4 579	0.322
16	6 731	6 629	6 524	6 419	6 313	6 205	6 096	5 987	5 876	5 763	0.428
15	7 697	7 606	7 513	7 420	7 325	7 229	7 132	7 033	6 934	6 833	0.548
14	8 548	8 468	8 387	8 305	8 221	8 137	8 051	7 964	7 876	7 787	0.681
13	9 288	9 219	9 149	9 077	9 005	8 932	8 857	8 782	8 705	8 627	0.828
12	9 923	9 864	9 804	9 743	9 681	9 618	9 554	9 489	9 423	9 356	0.988
11	10 461	10 412	10 361	10 309	10 257	10 204	10 149	10 094	10 038	9 981	1.160
10	10 912	10 870	10 828	10 785	10 742	10 697	10 651	10 605	10 558	10 510	1.344
9	11 284	11 250	11 216	11 180	11 144	11 107	11 070	11 031	10 992	10 952	1.540
8	11 589	11 561	11 533	11 504	11 475	11 445	11 414	11 382	11 350	11 318	1.750
7	11 833	11 811	11 789	11 766	11 742	11 718	11 693	11 668	11 642	11 616	1.976
6	12 026	12 009	11 992	11 973	11 955	11 936	11 916	11 896	11 876	11 855	2.223
5	12 175	12 162	12 149	12 135	12 121	12 106	12 091	12 075	12 059	12 043	2.497

^a Example. The Y factor for a pressure of 21.1 bar is 72 (kg·bar)/m³**Table 20 — Y and Z factors for 25 bar systems at a filling density of 600 kg/m³ to 699 kg/m³**

Y factor, in (kg·bar)/m ³											Z factor
Pressure ^a	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
bar	(kg·bar)/m ³										
21	1 382	1 232	1 082	932	780	627	473	319	164	7	0.051
20	2 822	2 682	2 541	2 400	2 257	2 113	1 969	1 823	1 677	1 530	0.116
19	4 167	4 037	3 906	3 774	3 641	3 507	3 372	3 236	3 099	2 961	0.190
18	5 411	5 291	5 170	5 048	4 926	4 802	4 677	4 551	4 424	4 296	0.273
17	6 549	6 440	6 330	6 219	6 107	5 993	5 879	5 763	5 647	5 529	0.367
16	7 579	7 481	7 382	7 281	7 180	7 078	6 974	6 869	6 764	6 657	0.473
15	8 499	8 412	8 324	8 234	8 144	8 053	7 960	7 866	7 772	7 676	0.592
14	9 312	9 235	9 158	9 079	8 999	8 919	8 837	8 754	8 670	8 585	0.723
13	10 020	9 953	9 886	9 818	9 749	9 678	9 607	9 535	9 461	9 387	0.867
12	10 629	10 573	10 515	10 456	10 397	10 336	10 275	10 213	10 149	10 085	1.024
11	11 148	11 100	11 051	11 001	10 951	10 900	10 847	10 794	10 740	10 685	1.192
10	11 583	11 543	11 502	11 461	11 419	11 375	11 331	11 287	11 241	11 195	1.372
9	11 944	11 911	11 878	11 843	11 808	11 773	11 736	11 699	11 661	11 623	1.565
8	12 240	12 213	12 186	12 158	12 129	12 100	12 070	12 040	12 009	11 977	1.772
7	12 479	12 457	12 435	12 413	12 390	12 366	12 342	12 317	12 292	12 267	1.995
6	12 668	12 651	12 634	12 616	12 598	12 579	12 560	12 541	12 520	12 500	2.239
5	12 815	12 802	12 789	12 775	12 761	12 747	12 732	12 716	12 701	12 685	2.507

^a Example. The Y factor for a pressure of 21.5 bar is 627 (kg·bar)/m³

21 Safety

21.1 Exits

Adequate means of egress from the protected enclosure shall be provided. Doors at exits shall open outwards and shall be self-closing. All exit doors shall open readily from the inside and any that have to be secured shall be fitted with panic bolts or latches.

COMMENTARY AND RECOMMENDATIONS ON 21.1. *Attention is drawn to the Fire Precautions Act 1971.*

The means of egress from the protected enclosure should be kept clear at all times. In addition to the various precautions specified or recommended elsewhere in this standard, provision should be made for the prompt discovery and rescue of any persons rendered unconscious, and to safeguard persons who may be in the protected enclosure during or immediately after the discharge, either planned or accidental, of the system.

21.2 System isolation

21.2.1 General

To enable system inspection and maintenance to be carried out in safety, a means shall be provided to prevent the discharge of the storage container(s).

COMMENTARY AND RECOMMENDATIONS ON 21.2.1. *Attention is drawn to the possibility, with systems employing detonators, of induced currents from nearby electrical cables providing sufficient electrical energy to actuate the detonator.*

21.2.2 Modular systems

For modular systems with manual operation the means to prevent discharge shall prevent manual actuation. For modular systems using electrical actuation the means to prevent discharge shall isolate the electrical actuation circuit from the power source.

21.3 Audible and visual alarms

Alarms shall be provided within the protected area to indicate, where applicable:

- a) operation of the fire detection system indicated by audible and visual alarm; and
- b) commencement of time-delay period indicated by audible alarm.

COMMENTARY AND RECOMMENDATIONS ON 21.3. *The alarms should be easily distinguishable from the house fire alarms. Additional alarms, and signs may be appropriate where there is a high level of background noise. 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 halon 1301.*

21.4 Warning signs

21.4.1 Manual control points

The sign illustrated in Figure 14 shall be prominently displayed at each manual control point.

21.4.2 Entrances

21.4.2.1 The sign illustrated in Figure 15(a) shall be prominently displayed at each entrance to an area protected by a halon 1301 system which:

- a) will give an achieved concentration not greater than 6 %; or
- b) will give an achieved concentration greater than 6 %, but less than 10 %, and where arrangements have been made for the system to be on manual control only during periods of entry (see 15.3.2.2).

21.4.2.2 The sign illustrated in Figure 15(b) shall be prominently displayed at each entrance to an area protected by a halon 1301 which:

- a) will give an achieved concentration greater than 6 %, but not greater than 10 %, and where arrangements have not been made for the system to be on manual control only during periods of entry (see 15.3.2.2); or
- b) will give an achieved concentration greater than 10 %.

21.5 Ventilation after discharge

The protected enclosure shall be provided with a normally closed means of ventilation, with extraction arrangements at low level in the enclosure, which will discharge directly to the open air.

COMMENTARY AND RECOMMENDATIONS ON 21.5. *This requirement allows for ventilation of halon and the post-fire atmosphere in the enclosure, away from other parts of the building.*

Any mechanical ventilation provided should not form part of the normal ventilation system.

Any electric switches for the ventilation system should be outside the protected enclosure, preferably at the system central control panel, and should be provided with a notice bearing the wording "Fire brigade halon extraction switch".

21.6 Electrical hazards

Where exposed electrical conductors are present, clearances no smaller than those given in Table 21 shall be provided, where practicable, between the electrical conductors and all parts of the halon system that may be approached during maintenance. Where these clearance distances cannot be achieved, warning notices shall be provided and a safe system of maintenance work shall be adopted.

COMMENTARY AND RECOMMENDATIONS ON 21.6. *The system should be so arranged that all normal operations can be carried out with safety to the operator.*

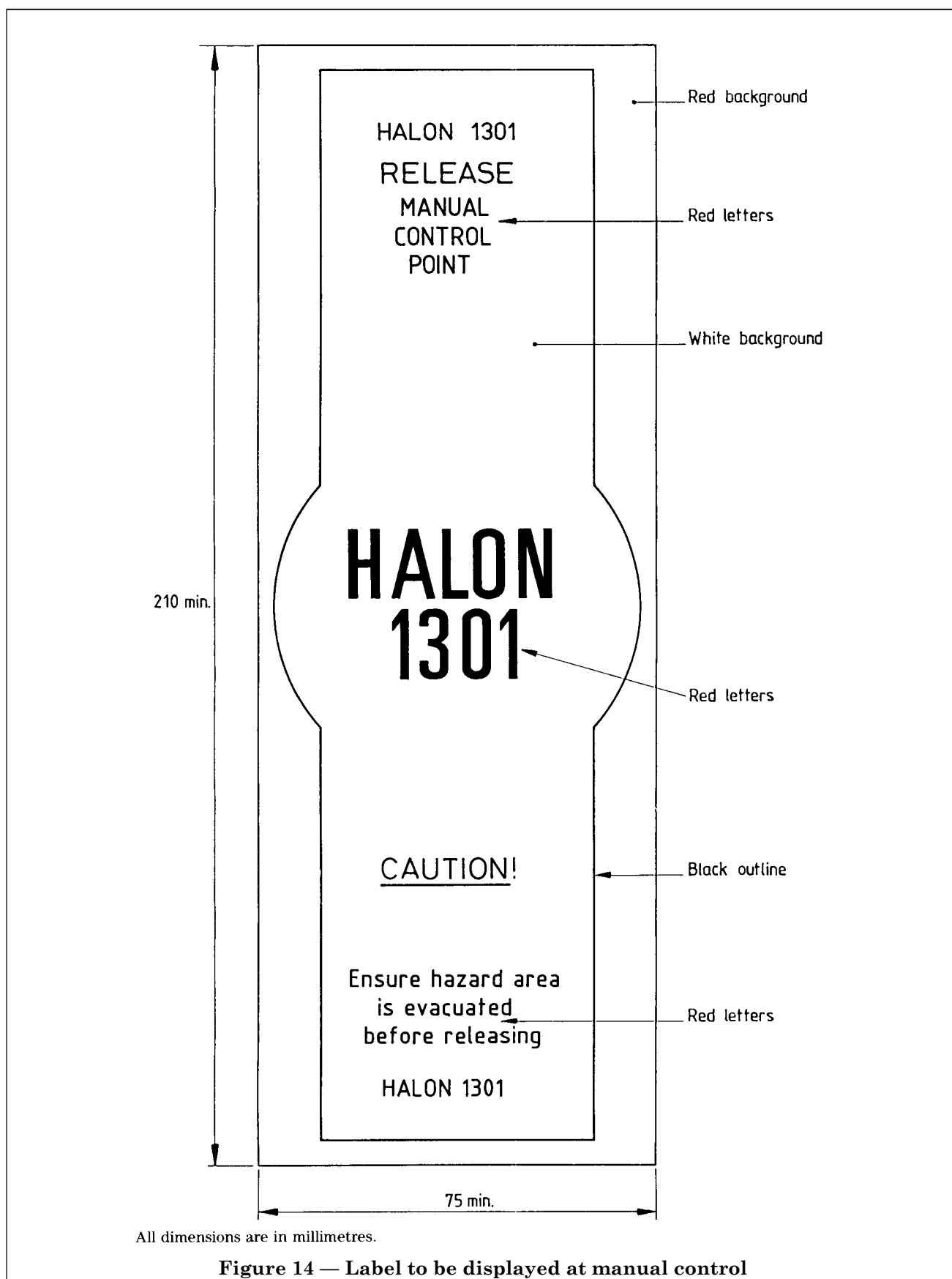
21.7 Electrical earthing

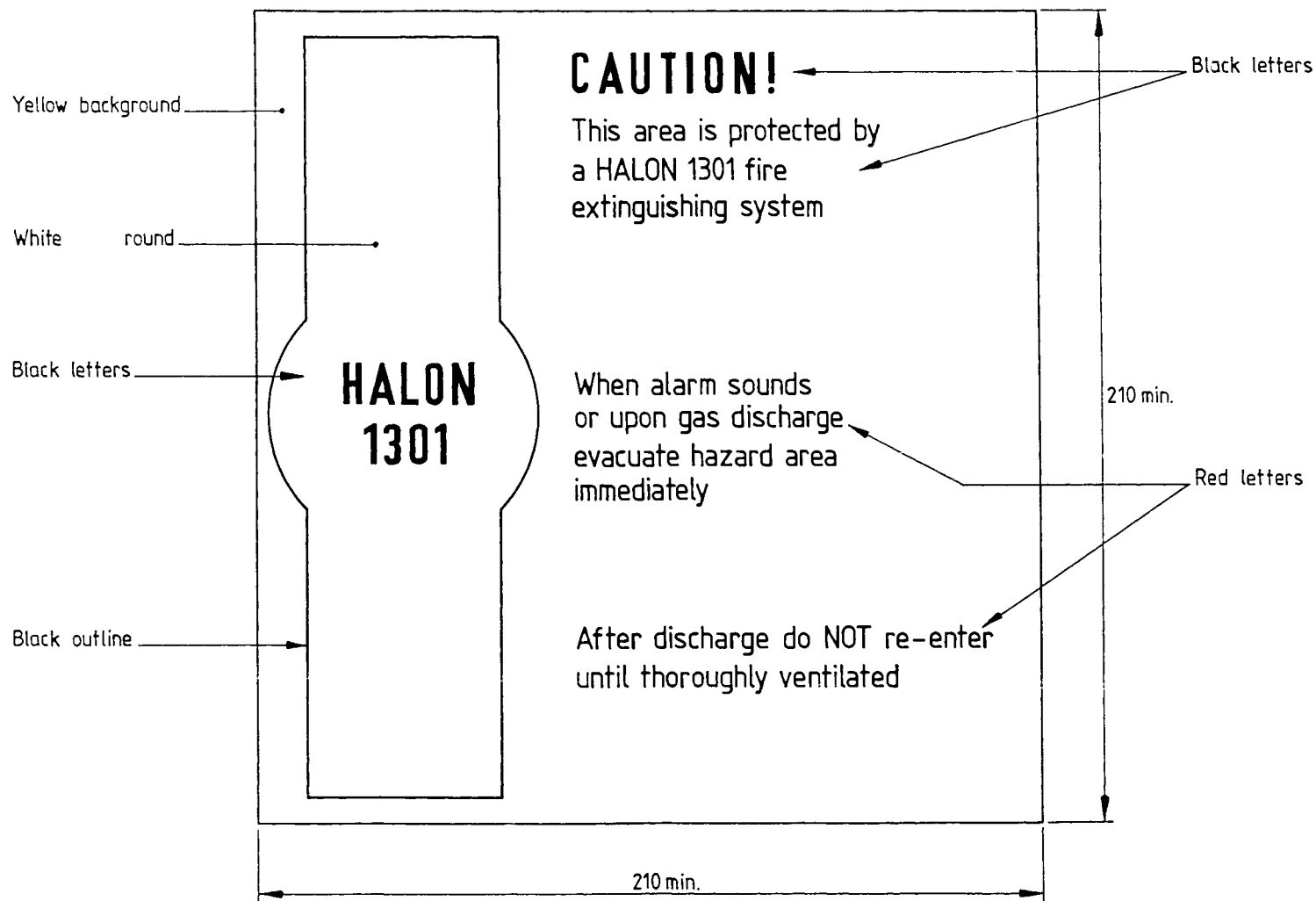
All exposed metalwork in systems that are housed within electrical substations or switchrooms shall be efficiently earthed to prevent the metalwork becoming electrically charged.

COMMENTARY AND RECOMMENDATIONS ON 21.7. *The halon system metalwork should be efficiently connected to the main earthing terminal of the electrical installation, where this is required by the Regulations for Electrical Installations (Wiring Regulations) (15th edition).*

Adequate earthing of systems, wherever located, will minimize the risk of electrostatic discharge.

BS 5958-1 gives basic information on earthing practice.

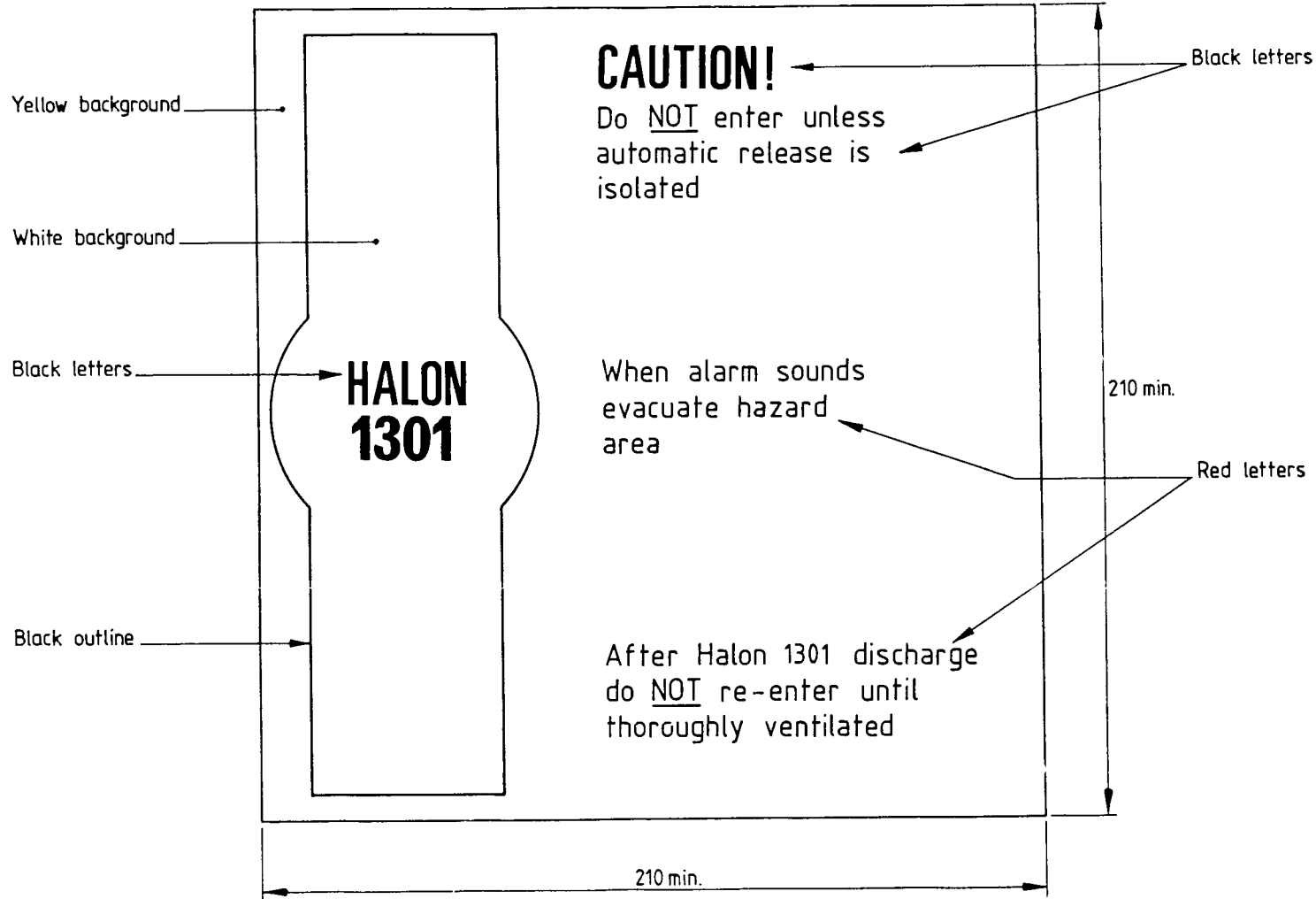




(a) For systems giving achieved concentrations not greater than 6 % or greater than 6 % but not greater than 10 % with manual control only (see 21.4.2.1)

All dimensions are in millimetres.

Figure 15 — Labels to be displayed at entrances to hazards



(b) For systems giving achieved concentrations greater than 10 % or greater than 6 % but not greater than 10 % with automatic control (see 21.4.2.2)

All dimensions are in millimetres.

Figure 15 — Labels to be displayed at entrances to hazards (concluded)

Table 21 — Safety clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out

Maximum rated voltage	Minimum clearance from any point on or about the permanent equipment where a person may be required to stand (measure 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 (see note 2) supporting a live conductor (ground clearance)
kV	m	m
15	2.59	2.44
33	2.74	
44	2.89	
66	3.05	
88	3.20	
110	3.35	
132	3.50	
165	3.81	
220	4.27	
275	4.75	
NOTE 1 This table is derived from Table 10 of BS 162:1961, which has been withdrawn.		
NOTE 2 The term insulator includes all forms of insulating supports, such as pedestal and suspension insulators, bushings, cable sealing ends and the insulating supports of certain types of circuit breaker.		

Appendix A Fan test for determination of predicted minimum hold time of an enclosure

NOTE See clause 12.

A.1 Principle

A fan is temporarily located within an access opening to pressurize and depressurize the enclosure. A series of pressure and air flow measurements is made from which the leakage characteristics of the enclosure are established.

The predicted hold time is calculated using these leakage characteristics on the following assumptions:

- a) that leakage occurs under the worst conditions, i.e. when one half of the effective leakage area is at the maximum enclosure height and represents the inward leakage of air, and the other half (the lower leakage area) of the effective leakage area is at the lowest point in the enclosure and represents the outward leakage of halon/air; and
- b) that all leak flow is one-dimensional, i.e. ignoring stream functions; and
- c) that flow through any particular leak area is either into or out of the enclosure and respectively either from or into an infinitely large space; and
- d) that the system is at sea-level, at a temperature of 20 °C, and atmospheric pressure is 1.013 bar absolute.

A.2 Apparatus

A.2.1 Fan unit, consisting of a frame which will fit into and seal an access opening in the enclosure, and one or more variable speed fans, with low flow facilities, capable of giving a differential pressure of not less than 25 Pa across the enclosure boundary.

A.2.2 Two pressure measuring devices, one to measure enclosure differential pressure and one to measure fan flow pressure.

A.2.3 Flexible tubing, for connecting the pressure measuring devices.

A.2.4 Chemical smoke pencils and/or smoke generator.

A.2.5 Two thermometers, to measure ambient temperatures.

A.2.6 Signs, reading “Do not open — pressure test in progress” and “Do not close — pressure test in progress”.

NOTE Additional apparatus, such as measuring tapes, torches, ladders, tools to remove floor and ceiling tiles, computer or other calculating device, may be necessary or convenient.

A.3 Calibration of apparatus

A.3.1 Fan unit

Calibrate the fan unit at the intervals and by the method recommended by the manufacturer. Keep records, and where appropriate calibration certificates. Use a flowmeter accurate to $\pm 5\%$ and a pressure measuring device accurate to ± 1 Pa. Present the data to give Q_f or

$$Q_f \left[\frac{P_c}{101.3} \times \frac{20 + 273}{T_c + 273} \right]^{1/2}$$

in terms of P_f .

A.3.2 Pressure measuring devices

Not more than 12 months before a test calibrate the pressure measuring devices. Keep records, and where appropriate calibration certificates.

If inclined manometers are used, change the fluid not more than 3 months before the test. Level and zero inclined manometers before each test.

A.4 Preliminary preparation

A.4.1 Obtain a description of air-handling equipment and halon extraction systems in the enclosure from the user.

A.4.2 Check for the following:

- a) raised platform floors and false ceiling spaces; and
- b) visually obvious leaks in the enclosure; and

- c) adequate return paths outside the enclosure between all leaks and the fan unit; and
- d) conflicting activities in and around the enclosure.

A.4.3 Provide the following information to the user:

- a) a description of the test; and
- b) the time required to complete the test; and
- c) what assistance will be needed from the user's staff; and
- d) information on any necessary disturbance to the building or its services during the test; for example, removal of floor or ceiling tiles, shutdown of air handling systems, holding doors open and/or shut.

A.5 Evaluation of enclosure

Obtain or prepare a sketch plan showing walls, the location of door and other openings through which air will flow during the test, and the location of any ducts penetrating the enclosure, and any dampers in the ducts. Show the status (i.e. whether open or closed when the halon system is discharged) of each door, hatch and damper, and which accesses opening(s) is (are) to be used for the fan unit.

Show the location of floor and sink drains.

A.6 Measurement of enclosure

Measure the protected enclosure volume as necessary and record the following:

- a) the overall height of the protected enclosure, H_o ;
- b) the height of the highest hazard in the enclosure, H ;
- c) the gross volume of the protected enclosure, V_g .

A.7 Test procedure

A.7.1 Preparation

Immediately before the test, make the following preparations.

- a) Advise supervisory personnel in the area of the test.
- b) Remove papers and objects likely to be disturbed by the turbulence from the fan.
- c) Block open sufficient doors outside the enclosure envelope to provide an adequate return path for air between the fan unit and the enclosure leaks while correcting any breach of any requirements of the facility, including requirements for security, fire protection, environmental boundaries.
- d) Using the sketch plan (see **A.5**) set all air-handling equipment and halon extraction systems to the state they would be in at the time of halon system discharge, except as follows:
 - 1) recirculating air-handling equipment without fresh air make-up which does not give a bias pressure across the enclosure boundary or otherwise preclude accurate testing, and which would be shutdown on halon discharge, may be left operating during the test if this is needed to avoid temperature build-up in equipment such as computers; and
 - 2) recirculating air-handling equipment which would continue to operate on halon discharge should be shutdown if it creates excessive bias pressure.
- e) Post the appropriate (**A.2.6**) signs on open doors.
- f) Open doors and remove floor or ceiling tiles within the halon protected portions of the enclosure envelope so that the halon protected volume is treated as one space. Do not remove false ceiling tiles if the volume above the false ceiling is not protected with halon.
- g) Close all doors and windows in the enclosure envelope.
- h) Check that liquid traps in the floor and sink drains are sealed with liquid.

A.7.2 Setting up door fan unit

A.7.2.1 Set up the fan unit in an access opening leading from the enclosure into the largest volume of building space which will complete the air-flow path from the fan, via the enclosure, leaks, and building space back to the fan.

A.7.2.2 Gently blow into or suck from the flexible tubing so that the readings of the pressure measuring devices traverse the full scale and hold the maximum reading for not less than 10 s.

Release the pressure and zero the devices.

A.7.2.3 Connect the enclosure differential pressure measuring device. Ensure that the open ends of the flexible tubing near the fan unit are away from its air stream path and any other air flows which might affect readings.

A.7.2.4 Use the fan(s) to raise or lower the pressure of the enclosure by approximately 15 Pa. Check all dampers with smoke and ensure that they are closing properly. Check doors and hatches and ensure correct closure. Inspect the wall perimeter (above and below any false floor) and the floor slab for any major leaks and note their size and location.

A.7.3 Measurement of bias pressure

Seal the fan unit inlet or outlet and without the fan(s) operating observe the enclosure differential pressure measuring device for at least 30 s.

If a bias pressure is indicated, use smoke to detect the consequent air flow and its direction. If the existence of a bias pressure is confirmed record the pressure measuring device reading as the bias pressure (P_b).

If the enclosure is large, or if the bias pressure is largely caused by wind or stack effects repeat the measurement at one or more different access openings. Record all the values measured and use the largest positive value (or if only negative values are recorded the value closest to zero) as the bias pressure.

NOTE A bias pressure as low as 0.5 Pa can affect the accuracy of the test result. If the bias pressure has a numerical value greater than 25 % of the halon/air column pressure, then the hold time is likely to be low and the enclosure may not hold the specified halon concentration. The source of the excessive bias pressure should be identified and if possible permanently reduced.

A.7.4 Measurement of leakage rate

A.7.4.1 Measure the air temperature inside the enclosure T_e , and measure the air temperature outside the enclosure T_o , at several points. If the location of leaks is not known, use the average value; otherwise, use the average value weighted according to the known location of the leaks.

A.7.4.2 Unseal the fan and connect the fan flow pressure measuring device.

A.7.4.3 Use the fan unit to depressurize the enclosure to the maximum extent, but by not more than 60 Pa. Allow the enclosure differential pressure measuring reading to stabilize (which may take up to 30 s) and record the value ($P_f + P_b$), which will be negative. Repeat at not less than four more fan unit flow rates to give five readings more or less evenly spaced over the range down to 10 Pa.

A.7.4.4 Use the fan unit to pressurize the enclosure and repeat the procedure of **A.7.4.3**. Again record values of ($P_f + P_b$), which will be positive.

A.8 Calculation

A.8.1 The symbols of the quantities, and their units, used in the calculation are as follows:

A_e	effective leakage area	(in m^2)
A_l	actual lower leakage area below height H	(in m^2)
A_t	actual total leakage area	(in m^2)
c	design concentration of halon in air for the enclosure	[in % (V/V)]
$c_{\min.}$	minimum concentration of halon in air for the enclosure	[in % (V/V)]
F	lower leakage fraction, effective area of lower leaks divided by effective area of all leaks	dimensionless
g_n	gravitational acceleration (= 9.81)	(in m/sec^2)
H	height of highest hazard	(in m)
H_o	overall height of enclosure	(in m)
k_0	actual leakage area discharge coefficient (= 0.61 to 1.0)	dimensionless
k_1	leakage characteristic [see equation (8)]	[in $\text{m}^3/(\text{s} \cdot \text{Pa}^n)$]
k_2	correlation constant [see equation (9)]	[in $\text{kg}^n \cdot \text{m}^{3(1-n)}/(\text{s} \cdot \text{Pa}^n)$]
k_3	simplifying constant [see equation (10)]	(in m/s^2)
k_4	simplifying constant [see equation (11)]	(in $\text{Pa} \cdot \text{m}^3/\text{kg}$)
n	leakage characteristic [see equation (7)]	dimensionless
P_c	atmospheric pressure during fan calibration	(in bar)
P_f	differential pressure produced by the fan	(in Pa)
P_m	halon/air column pressure	(in Pa)

P_b	bias pressure	(in Pa)
Q	air flow rate	(in m ³ /s)
Q_f	indicated, uncorrected, air flow through fan calibrated at T_c and P_c	(in m ³ /s)
Q_{lm}	mean value of Q_1 at $P_f = P_m$	(in m ³ /s)
$Q_{lm/2}$	mean value of Q_1 at $P_f = \frac{1}{2} P_m$	(in m ³ /s)
Q_1	calculated air flow through leaks at 20 °C, 1.013 bar atmospheric pressure	(in m ³ /s)
T_c	air temperature through fan during calibration	(in °C)
T_e	air temperature inside enclosure	(in °C)
T_o	air temperature outside enclosure	(in °C)
t	predicted minimum hold time	(in s)
V_g	enclosure gross volume	(in m ³)
ρ_a	air density (1.205 at 20 °C and 1.013 bar)	(in kg/m ³)
ρ_{mf}	halon/air mixture density at 80 % of the minimum design concentration, 20 °C and 1.013 bar	(in kg/m ³)
ρ_{mi}	halon/air mixture density at design concentration, 20 °C and 1.013 bar	(in kg/m ³)
ρ_m	halon/air mixture density	(in kg/m ³)

A.8.2 From the measured values of $(P_f + P_b)$ and P_b calculate the values of P_f and, using the fan calibration data (see **A.3.1**), the corresponding air flows Q_1 through the leaks corrected to the standard conditions of 20 °C and 1.013 bar atmospheric pressure using equations (1) and (2), as appropriate:

for depressurization

$$Q_1 = Q_f \left[\frac{P_c}{1.013} \times \frac{20 + 273}{T_c + 273} \right]^{1/2} \left[\frac{T_o + 273}{T_e + 273} \right]^{1/2} \quad (1)$$

for pressurization

$$Q_1 = Q_f \left[\frac{P_c}{1.013} \times \frac{20 + 273}{T_c + 273} \right]^{1/2} \left[\frac{T_e + 273}{T_o + 273} \right]^{1/2} \quad (2)$$

For each set of results (pressurization and depressurization) express the fan test results in the form:

$$|Q_1| = k_1 |P_f|^n \quad (3)$$

and check that the correlation coefficients of each set are not less than 0.99 using the method of least squares. The two sets will almost always have different values of k_1 and n .

A.8.3 Calculate the density of the halon/air mixture at 20 °C at the design concentration using the equation:

$$\rho_{mi} = \frac{6.283c}{100} + \frac{\rho_a(100 - c)}{100} \quad (4)$$

For enclosures with mixing, calculate the density of the halon/air mixture at 20° at 80 % of the minimum design concentration using the equation:

$$\rho_{mf} = \frac{6.283 \times 0.8 \times c_{min.}}{100} + \frac{\rho_a(100 - 0.8c_{min.})}{100} \quad (5)$$

Calculate the corresponding halon/air column pressure at the base of the enclosure using the following equation:

$$P_m = g_n H_o (\rho_{mi} - \rho_a) \quad (6)$$

A.8.4 Determine the average values of the leakage characteristics k_1 and n , as follows.

Calculate the average values (i.e. of the pressurization and depressurization data) of Q_1 for values of P_f equal to P_m , and for P_f equal to $\frac{1}{2}P_m$. These are Q_{1m} and $Q_{1m/2}$ respectively.

$$n = \frac{\ln Q_{1m} - \ln Q_{1m/2}}{\ln 2} \quad (7)$$

and

$$k_1 = \exp \left\{ \frac{(\ln Q_{1m/2})(\ln P_m) - (\ln Q_{1m})(\ln P_m - \ln 2)}{\ln 2} \right\} \quad (8)$$

A.8.5 Calculate the correlation constant k_2 using the equation:

$$k_2 = k_1 \left(\frac{\rho_a}{2} \right)^n \quad (9)$$

Calculate the simplifying constant k_3 using the equation:

$$k_3 = \frac{2g_n(\rho_{mi} - \rho_a)}{\rho_{mi} + \rho_a \left(\frac{F}{1-F} \right)^{1/n}} \quad (10)$$

Calculate the simplifying constant k_4 using the equation:

$$k_4 = \frac{2P_b}{\rho_{mi} + \rho_a \left(\frac{F}{1-F} \right)^{1/n}} \quad (11)$$

A.8.6 For enclosures without mixing, assume $F = 0.5$ and calculate the predicted minimum hold time t for the halon/air interface to fall to height H , using the equation:

$$t = \frac{V_g}{H_o} \times \frac{(k_3 H_o + k_4)^{(1-n)} - (k_3 H + k_4)^{(1-n)}}{(1-n) k_2 F k_3} \quad (12)$$

A.8.7 For enclosures with mixing, assume $F = 0.5$ and calculate the predicted minimum hold time t for the halon concentration in the enclosure to fall from the design concentration to 80 % of the minimum design concentration (see 11.2) using the equation:

$$t = \frac{V_g}{F k_2} \int_{\rho_{mf}}^{\rho_{mi}} \left[\frac{2g_n H_o (\rho_m - \rho_a)^{(n+1)/n} + 2P_b (\rho_m - \rho_a)^{1/n}}{\rho_m + \rho_a \left[\frac{F}{1-F} \right]^{1/n}} \right]^{-n} d\rho_m \quad (13)$$

Solve the equation by a method of approximation, for example by using Simpson's rule using an even number (not less than 20) of intervals.

A.9 Report

Prepare a written report containing the following information:

- the enclosure leak flow characteristics [i.e. the average values of k_1 , and n from equations (7) and (8)];
- the design concentration of halon 1301;
- the gross volume of the enclosure;

- d) the mass of halon 1301 provided;
- e) the height of the enclosure;
- f) the height of the highest hazard;
- g) the predicted minimum hold time and whether or not the value complies with the recommendation of clause 12, i.e. whether it is less than 10 min or the higher necessary value, as appropriate.
- h) the sketch plan used in the evaluation of the enclosure (see A.5);
- i) the current calibration data for the fan unit and the pressure measuring devices, and if available corresponding certificates;
- j) the test results, including a record of the test measurements and any appropriate computer printout.

Appendix B Treatment of enclosures with predicted minimum hold times less than the recommended value

NOTE See clause 12.

B.1 General

If the predicted minimum hold time, calculated in accordance with Appendix A, is less than as recommended in clause 12 then B.2, and B.3 should be implemented in sequence.

B.2 Estimation of leakage area

To illustrate the scale of the problem calculate the effective leakage area, A_e from the equation:

$$A_e = \frac{Q_1}{P_{fn}} \left(\frac{\rho_a}{2} \right)^n = k_1 \left(\frac{\rho_a}{2} \right)^n \quad (14)$$

At 20 °C and 1.013 bar, equation (14) reduces to:

$$A_e = k_1 (0.602)^n \quad (15)$$

The actual total leakage area, which consists of a variety of cracks, gaps and openings of different sizes and flow characteristics, is larger than the effective leakage area, and:

$$A_e = k_o \times A_t \quad (16)$$

A_t can neither be measured directly nor, since K_o is unknown, be calculated from A_e . For illustrative purposes the equivalent leakage area (ELA) may be calculated as:

$$ELA = A_e / 0.61 \quad (17)$$

It is the area of a circular sharp-edged orifice which has the same value of A_e as the actual leakage area A_t .

B.3 Improved sealing of the enclosure

Consideration should be given to improving the sealing of the enclosure. If the sealing is improved and the new predicted minimum hold time is not less than the minimum recommended value, no further action is necessary.

B.4 Quantification and location of leaks

B.4.1 General

The lower leaks are those through which the halon/air mixture will escape from the enclosure; conversely upper leaks are those through which air will flow into the enclosure. For the purposes of this assessment lower leaks are assumed to be those below the height of the highest hazard, H , and upper leaks those above.

The fan test does not show the location of the leaks or the value of the lower leakage fraction F . In Appendix A it is assumed that the value of F is 0.5, with all the lower leaks in the base of the enclosure and that all the upper leaks (equal in area to the lower leaks) are in the top of the enclosure. This is the worst case and gives the minimum value for hold time.

If some lower leaks are above the base of the enclosure or if some upper leaks are below the top of the enclosure, the hold time will also be underestimated but a simple mathematical treatment of this case is not possible.

The hold time will also be underestimated if F is not 0.5 and the effect of this can be calculated.

B.4.2 Second calculation of hold time

Make a second calculation of the hold time using equations (10), (11) and (12), or equation (13) as appropriate, assuming $F = 0.15$. If this value is more than the recommended minimum (see clause 12) then make an estimate of the actual value of F using one or both of the methods of B.4.3.

B.4.3 Methods of estimating F

B.4.3.1 First method

Temporarily seal known or suspected leaks, such as large dampers, or suspended ceilings or raised floors using for example plastics sheet and sealing tape, and carry out additional fan tests. Calculate the effective leakage area from equation (14) and compare with the original value (see B.2) and estimate F for the original condition.

B.4.3.2 Second method

Make a detailed inspection of the enclosure using chemical smoke to establish that there are no significant lower leaks and that there are substantial upper leaks, and estimate F .

B.5 Final calculation of hold time

Using the value of F estimated as in B.4.3, which should not be more than 0.5 or less than 0.15, recalculate the hold time using equations (10), (11) and (12), or equation (13) as appropriate.

Appendix C Example of fan test procedure, calculation and assessment in accordance with Appendix A and Appendix B

C.1 Preliminary preparation (see A.4)

The enclosure contained communications equipment. The enclosure had a recirculating air-conditioning unit situated in an adjacent plant corridor, with two subfloor supply ducts and two return air ducts through the wall of the enclosure. All ducts had dampers that would close immediately prior to the release of halon into the enclosure. There was a separate fresh air make-up supply duct at high level, also fitted with a damper. There were no drains.

The enclosure had a raised floor and a suspended ceiling.

The design concentration was 5.606 % and the quantity of halon 90 kg.

C.2 Evaluation of enclosure (see A.5)

The sketch plan was prepared (see Figure 16).

C.3 Measurement of enclosure (see A.6)

The following heights were measured:

ceiling void height	1.24 m
room height	3.17 m
floor void height	0.29 m
equipment cabinet height above floor	2.20 m

From which the following values were calculated:

$$H_o = 0.29 + 3.17 + 1.24 = 4.70 \text{ m};$$

$$H = 0.29 + 2.20 = 2.49 \text{ m};$$

$$V_g = 4.7(5.49 \times 9.64 - 0.69 \times 0.68 - 0.75 \times 0.68) - 3 \times 1 \times 0.99 = 241.18 \text{ m}^3.$$

C.4 Measurement of bias pressure (see A.7.3)

The bias pressure was measured with the enclosure air conditioning shut down, i.e. as for halon discharge into the enclosure; P_b was found to be -2 Pa. A second measurement with the air conditioning in the adjacent room shut down was made, giving P_b to be -0.5 Pa. For increased accuracy the test was continued under these latter conditions, but for the hold time calculation the bias pressure at the time of discharge, -2 Pa, was used.

C.5 Temperatures (see A.7.4.1)

The temperatures were measured to be:

$$T_e = 18\text{ }^{\circ}\text{C};$$

$$T_o = 20\text{ }^{\circ}\text{C}.$$

C.6 Fan flow readings (see A.7.4.3 and A.7.4.4)

Seven readings were taken in the depressurized mode (two more than the minimum specified) and seven in the pressurized mode.

C.7 Calculation of the average leakage characteristics (see A.8.3 and A.8.4)

The measured flow rates Q_f were corrected, using equation (1) for the depressurized mode and equation (2) for the pressurized mode. The corrected differential pressures were calculated for the depressurized mode by adding the bias pressure ($P_b = -0.5\text{ Pa}$) to the measured pressure differentials, i.e. by subtracting 0.5 from the measured values, and for the pressurized mode by subtracting the bias pressure from the measured pressure differentials, i.e. by adding 0.5 to the measured values.

The results were tabulated as in Table 22.

Using the method of least squares, these two sets of data were fitted to equation (3) to give:

$$Q_1 = 0.307 P_f^{0.489} \text{ (depressurization data)}$$

and

$$Q_1 = 0.245 P_f^{0.543} \text{ (pressurization data)}$$

In each case the correlation coefficient was found to be 0.999.

The halon/air mixture density was calculated from equation (4) using the known design concentration 5.61 %, and air density 1.205 kg/m^3 , as follows:

$$\begin{aligned} \rho_{\text{mi}} &= \frac{6.283 \times 5.61}{100} + \frac{1.205 \times 94.39}{100} \\ &= 1.490\text{ kg/m}^3 \end{aligned}$$

and the corresponding column pressure was calculated from equation (5) to be 13.13 Pa.

Two values for Q_1 were calculated at this value of P_f and the average calculated and similarly for two values of Q_1 at $0.5P_f$. These values were used in equations (7) and (8) to give average values of the leakage characteristics as follows:

$$n = 0.515$$

$$k_1 = 0.275$$

which when substituted in (3) give for the enclosure:

$$Q_1 = 0.275 P_f^{0.515}$$

C.8 Correlation and simplifying constants (see A.8.4, A.8.5 and A.8.6)

The constants were calculated from equations (9), (10) and (11), and found to be:

$$k_2 = 0.212$$

$$k_3 = 2.073$$

$$k_4 = -1.484$$

(on the assumption that $F = 0.5$ [see A.1]).

C.9 Calculation of hold time

Using equation (12), the hold time was calculated to be 435 s (7 min 15 s).

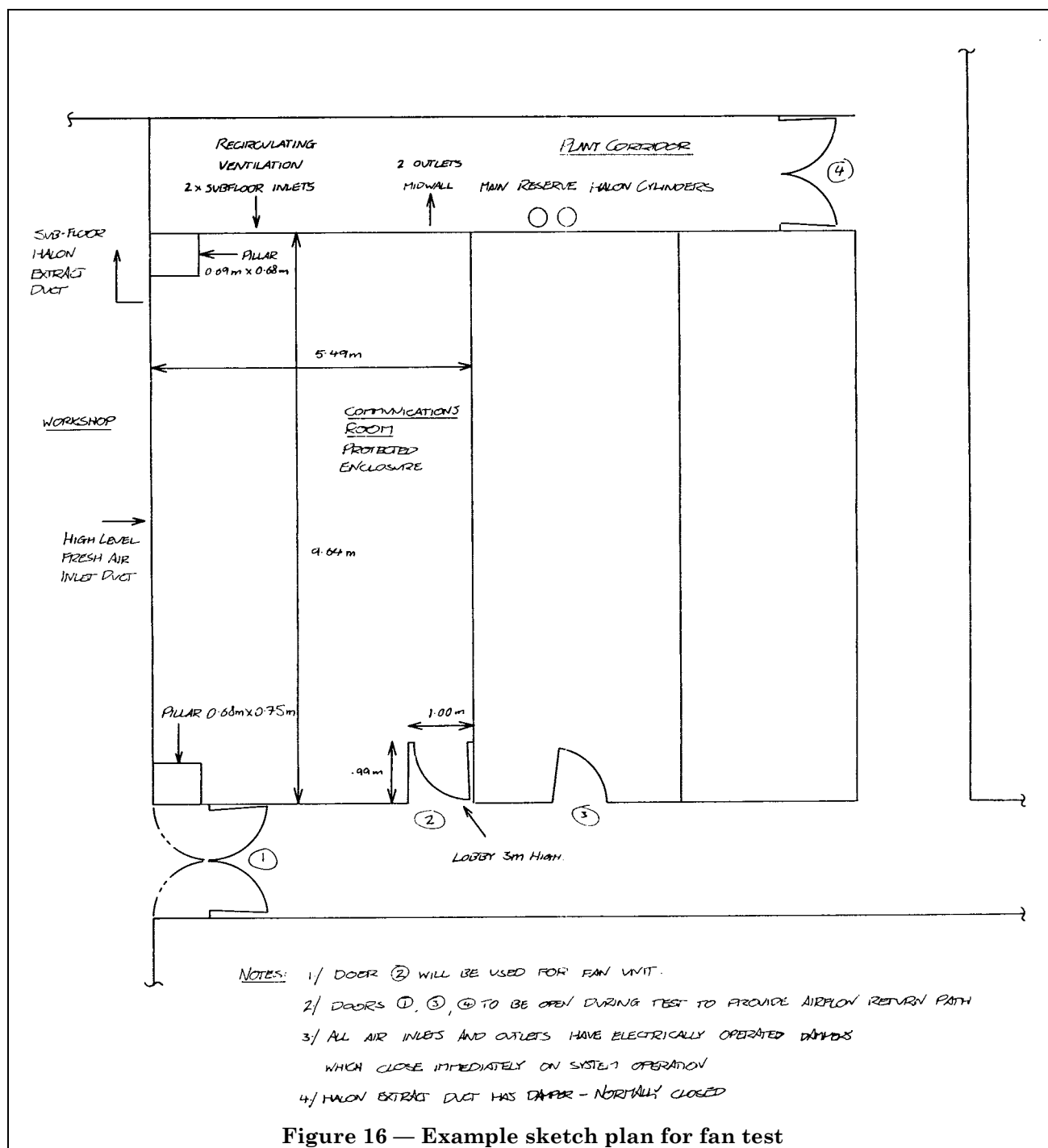


Figure 16 — Example sketch plan for fan test

Table 22 — Example results of average leakage characteristics

Mode	Measurement number	Measured differential pressure	Corrected differential pressure P_f	Measured flow Q_f	Corrected flow Q_l
Depressurized mode		Pa	Pa	m ³ /s	m ³ /s
	1	33	32.5	1.675	1.6807
	2	29	28.5	1.581	1.5864
	3	25	24.5	1.463	1.4680
	4	22	21.5	1.369	1.3737
	5	20	19.5	1.298	1.3025
	6	15	14.5	1.133	1.1369
	7	10	9.5	0.920	0.9232
Pressurized mode	8	35	35.5	1.699	1.6932
	9	31	31.5	1.605	1.5995
	10	29	29.5	1.534	1.5288
	11	25	25.5	1.439	1.4341
	12	20	20.5	1.274	1.2696
	13	16	16.5	1.133	1.1291
	14	11	11.5	0.920	0.9169

C.10 Evaluation (see B.1)

The calculated hold time was less than the 10 min minimum recommended in clause 12. Using the fan to depressurize the enclosure, a search was made with chemical smoke to locate and identify leaks. The following were identified:

- a) unsealed pipe, cable and conduit penetrations through the plasterboard above the suspended ceiling;
- b) unsealed joints and gaps in the plasterboard above the suspended ceiling;
- c) gaps between the plasterboard and the underside of the concrete roof slab around the perimeter of the enclosure;
- d) a large hole at high level between the protected enclosure and the adjacent workshop area;
- e) a hole through the partition wall above the entrance door where cables run to an illuminated sign;
- f) gaps around the frame of the return air damper at the rear of the enclosure;
- g) gaps around and beneath the air conditioning supply ducts beneath the false floor.

For comparison purposes the equivalent leakage area (ELA) was calculated using equations (15) and (17)

$$\begin{aligned}
 \text{ELA} &= A_e/0.61 \\
 &= \frac{k_1(0.602)^n}{0.61} \\
 &= \frac{0.275 \times (0.602)^{0.515}}{0.61} \\
 &= 0.347 \text{ m}^2
 \end{aligned}$$

C.11 Recalculation of hold time assuming $F = 0.25$

The calculation of hold time in C.9 was made assuming $F = 0.5$ (i.e. the worst case). The inspection for leaks disclosed that for this enclosure most leakage was at a high level and it was estimated that a realistic assumption was that $F = 0.25$, so a second calculation was made, assuming this value. The revised values for k_3 and k_4 , calculated using equations (10) and (11), respectively, were:

$$k_3 = 3.422$$

$$k_4 = -2.451$$

and the revised hold time, using equation (12), was:

$$t = 672 \text{ s (11 min 12 s)}$$

C.12 Recommendations to user

Although the revised hold time was more than the recommended minimum of 10 min, it was recommended to the user that remedial work to reduce leakage (in particular the low level leakage through which halon is most likely to leak from the enclosure) should be carried out, followed by a further fan test. It was also recommended that any future pipe, cable or conduit penetrations into the enclosure should be properly sealed (see 16.3) and that the enclosure integrity should be checked at 12 month intervals [see 9.3 c)].

C.13 Hold time with mixing

The system design required the recirculating air-conditioning system to be shut down on halon discharge. To prevent temperature build-up, consideration was given to allowing this to continue in operation. In this condition the enclosure has mixing and equation (13) applies. The hold time was calculated in this condition using Simpson's rule applied at 20 intervals and found to be 277 s (4 min 37 s).

Appendix D Determination of halon 1301 extinguishing and inerting concentrations

D.1 Extinguishing concentration

D.1.1 Principle

The cup burner apparatus is used to determine flame extinguishing and inerting concentrations for liquids and gases.

D.1.2 Apparatus

D.1.2.1 Cup burner, as shown in Figure 17 or as modified by D.1.4.1

D.1.3 Procedure for flammable liquids

D.1.3.1 Place a flammable liquid sample in the fuel reservoir.

D.1.3.2 Adjust the adjustable stand under the fuel reservoir to bring the fuel in the cup to within 1 mm of the top of the cup.

D.1.3.3 Adjust the electric control circuitry to the cup heating element to bring the fuel temperature to 25 °C or to 5 °C above the open cup flash point of the fuel, whichever is the higher.

D.1.3.4 Ignite the fuel by suitable means preferably electrical.

NOTE It is essential that the means of ignition should not contaminate the fuel under test.

D.1.3.5 Adjust the air flow rate to 40 l/min.

D.1.3.6 Start the flow of the halon 1301 and increase it slowly until the flame is extinguished. Record the halon 1301 flow.

D.1.3.7 Remove approximately 10 ml to 20 ml of fuel from the surface of the cup with a pipette.

D.1.3.8 Repeat the procedure given in D.1.3.4 to D.1.3.6 and average the results

D.1.3.9 Calculate the percentage flame extinguishing concentration c_{ext} from the following equation:

$$c_{\text{ext}} = \frac{Q_{\text{F}}}{40 + Q_{\text{f}}} \times 100$$

where

Q_{F} is the halon 1301 flow (in l/min).

D.1.3.10 Increase the fuel temperature to 5 °C below the boiling point of the fuel, or to 200 °C, whichever is the lower.

D.1.3.11 Repeat the procedure given in **D.1.3.2** and **D.1.3.4** to **A.1.3.9**.

D.1.3.12 Take the flame extinguishing concentration to be the higher of the two values obtained at the two fuel temperatures.

D.1.4 Procedure for flammable gases

D.1.4.1 Modify the apparatus by filling the cup with glass wool and inserting a rotameter calibrated for the fuel in place of the fuel reservoir of Figure 17. Connect the rotameter to a source of fuel through an appropriate pressure regulator.

D.1.4.2 Adjust the fuel flow to produce a linear velocity within the cup of 130 mm/s.

D.1.4.3 Follow the procedure given in **D.1.3.3** to **D.1.3.9**.

D.1.4.4 Increase the fuel temperature to 150 °C.

D.1.4.5 Repeat the procedure given in **D.1.3.4** to **D.1.3.9**.

D.1.4.6 Take the flame extinguishing concentration to be the higher of the two values obtained at the two fuel temperatures.

D.1.4.7 If the concentration requirement at the higher temperature exceeds that at the lower temperature, classify the fuel as “temperature-sensitive”. Determine the flame extinguishing concentration for temperature-sensitive fuels at the maximum ambient temperature existing in the specific protected area.

D.2 Inerting concentration

D.2.1 Principle

The behaviour of flames in different mixtures of air, fuel and halon 1301 is observed to determine whether or not they can propagate through the mixture.

D.2.2 Apparatus

D.2.2.1 *Glass tube*, (75 ± 25) mm diameter and (1.5 ± 0.3) m long.

D.2.2.2 *Ignition source*, close to the base of the glass tube.

D.2.2.3 *Gas mixing device*, to feed air, fuel and halon 1301 to the base of the tube.

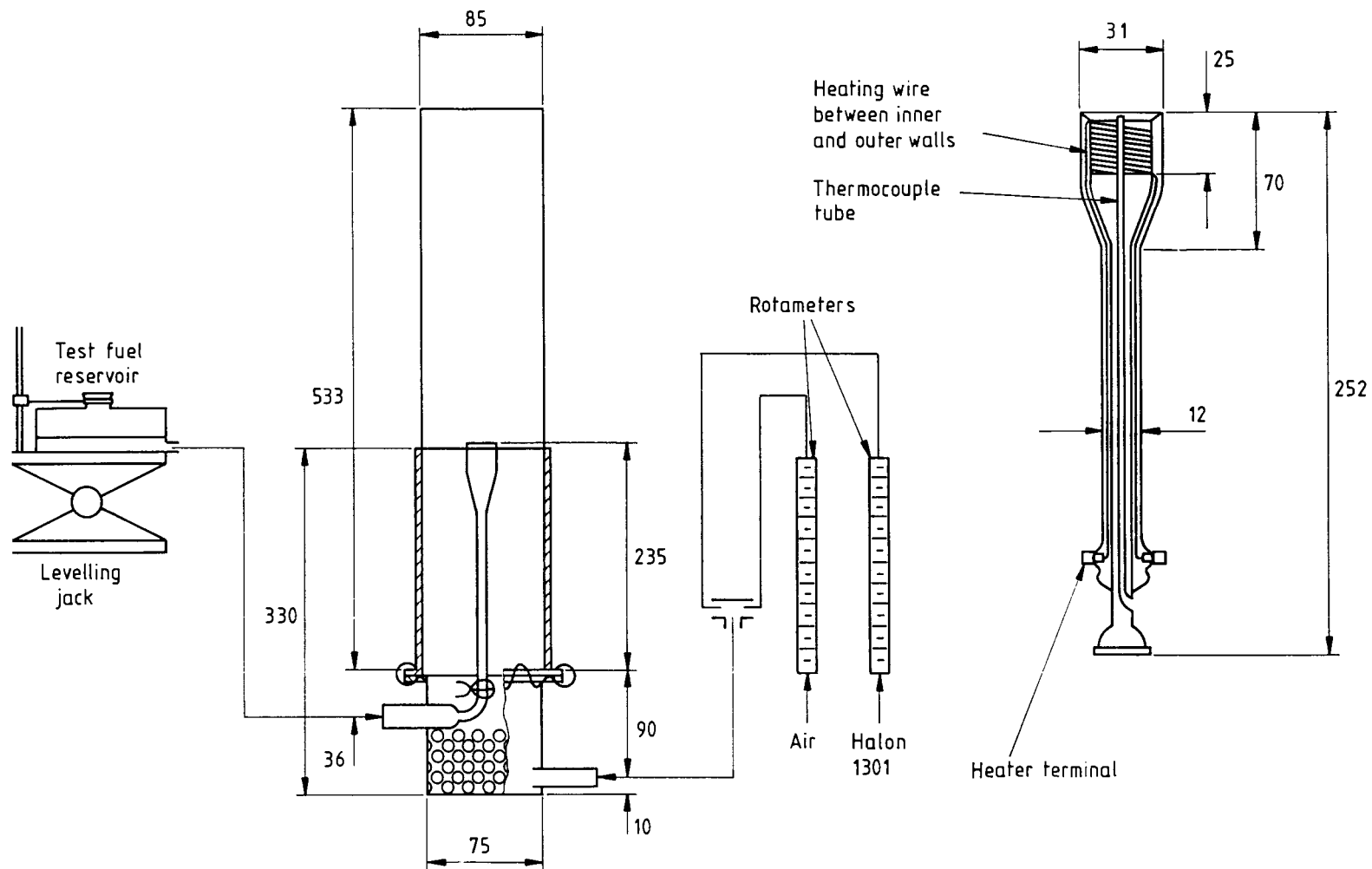
D.2.3 Procedure

D.2.3.1 Clean the glass tube if necessary and set it up vertically.

D.2.3.2 Adjust the gas mixing device to feed the desired mixture into the tube.

D.2.3.3 Operate the ignition source and observe any flame front passing up the tube. Report any mixture which allows a flame to propagate more than 0.6 m up the tube as not inerted.

D.2.3.4 Plot the results either on triangular coordinate paper or on linear paper, as fuel concentration against halon concentration, expressing the composition of the mixture as a percentage by volume to determine the concentration of halon which will prevent propagation through any mixture. This is the inerting concentration.



All dimensions are in millimetres.

NOTE The apparatus is shown set up for testing liquid fuel.

Figure 17 — Cup burner apparatus

Appendix E Marine applications

E.1 General

The information in this appendix is applicable to halon 1301 systems on vessels and mobile offshore units.

E.2 Regulations and consultation

The appropriate marine authority should be consulted (see clause 5) in the planning stages.

NOTE The use of halon 1301 systems on board vessels and mobile offshore units is regulated by The International Maritime Organization (IMO), 4 Albert Embankment, London SE1 7SR through the Safety of Life at Sea (SOLAS) 1974 Regulations and amendments, and in the United Kingdom by the Marine Directorate, Department of Transport, Sunley House, 90 High Holborn, London WC1V 6LP through the Merchant Shipping (Fire Protection) Regulations 1984 (SI 1218) and amendments.

E.3 Calculation methods

The marine authority may require verification of the calculation methods (including computer programs) used in the design of the system (see 20.2).

E.4 Minimum nozzle pressure

If the expected container storage temperature is outside the range 21 ± 5 °C, the marine authority may require that the calculated minimum nozzle pressure is not less than 13.5 bar at 21 °C.

E.5 Time delays

E.5.1 The marine authority may require that only time delays essential to the safe operation of the system are used and that they are fitted with a manually operated by-pass.

E.5.2 The marine authority may require that the time is sufficient to allow the following:

- a) all ventilation fans to be stopped (see 16.2); and
- b) inlet and exhaust ventilation dampers to close; and
- c) all machinery (including for example diesel engines) drawing from within the protected space to be brought to a standstill.

E.5.3 Where the shutdown of the machinery listed in E.5.2 cannot be checked visually or audibly by the operator at the discharge control point the marine authority may require that a visual indication that shut-down has been completed is to be provided at the control point of discharge.

E.6 Suitability for marine environment

The marine authority may require certification or other means of verification that equipment is suitable for use in a marine environment, with respect to corrosion, vibration, and shock resistance.

Publications referred to

- BS 21, *Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).*
- BS 143 & BS 1256, *Specification for malleable cast iron and cast copper alloy threaded pipe fittings.*
- BS 381C, *Specification for colours for identification, coding and special purposes.*
- BS 476, *Fire tests on building materials and structures.*
- BS 476-20, *Method for determination of the fire resistance of elements of construction (general principles).*
- BS 476-21, *Methods for determination of the fire resistance of loadbearing elements of construction.*
- BS 476-22, *Methods for determination of the fire resistance of non-loadbearing elements of construction.*
- BS 476-23, *Methods for determination of the contribution of components to the fire resistance of a structure.*
- BS 1387, *Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or screwing to BS 21 pipe threads.*
- BS 1560, *Circular flanges for pipes, valves and fittings (Class designated).*
- BS 1560-3.1, *Specification for steel flanges.*
- BS 1600, *Specification for dimensions of steel pipe for the petroleum industry.*
- BS 1600-2, *Metric units.*
- BS 1640, *Specification for steel butt-welding pipe fittings for the petroleum industry.*
- BS 1640-3, *Wrought carbon and ferritic alloy steel fittings. Metric units.*
- BS 1740, *Specification for wrought steel pipe fittings (screwed BS 21 R-series thread).*
- BS 1740-1, *Metric units.*
- BS 1821, *Specification for class I oxy-acetylene welding of ferritic steel pipework for carrying fluids.*
- BS 2051, *Tube and pipe fittings for engineering purposes.*
- BS 2051-1, *Copper and copper alloys capillary and compression tube fittings for engineering purposes.*
- BS 2633, *Specification for class I arc welding of ferritic steel pipework for carrying fluids.*
- BS 2871, *Specification for copper and copper alloys. Tubes.*
- BS 2871-2, *Tubes for general purposes.*
- BS 2915, *Specification for bursting discs and bursting disc devices.*
- BS 3410, *Specification for metal washers for general engineering purposes.*
- BS 3601, *Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes.*
- BS 3602, *Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specific elevated temperature properties.*
- BS 3602-1, *Specification for seamless and electric resistance welded including induction welded tubes.*
- BS 3605, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes.*
- BS 3799, *Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry.*
- BS 3974, *Specification for pipe supports.*
- BS 3974-1, *Pipe hangers, slider and roller type supports.*
- BS 4368, *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, *Specification for arc welding of austenitic stainless steel pipework for carrying fluids.*
- BS 4882, *Specification for bolting for flanges and pressure containing purposes.*

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