

Fire extinguishing installations and equipment on premises —

Part 4: Specification for carbon dioxide systems

ICS 13.220.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee FSH/18, upon which the following bodies were represented:

- British Fire Protection Systems Association
- Chief and Assistant Chief Fire Officers Association
- Health and Safety Executive
- Home Office
- Institute of Fire Safety
- Institution of Fire Engineers
- London Fire and Civil Defence Authority
- Loss Prevention Council
- Maritime and Coastguard Agency
- Ministry of Defence
- Society of Motor Manufacturers and Traders
- Warrington Fire Research Centre

This British Standard, having been prepared under the direction of the Health and Environment Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 August 2001

© The British Standards Institution 2012
Published by BSI Standards Limited 2012

First published October 1979
Second edition March 1986
Third edition August 2001

The following BSI references relate to the work on this standard:

Committee reference FSH/18
Draft for comment 00/541249 DC;
11/30244843 DC

ISBN 978 0 580 75095 3

Amendments issued since publication

Amd. No.	Date	Comments
A1	April 2012	See Foreword for details

Contents

	Page
Foreword	iii
Introduction	1
1 Scope	1
2 Normative references	1
3 Terms and definitions	4
4 Characteristics and uses of carbon dioxide	5
5 Types of system	6
6 Planning	7
7 Specifications, plans and approvals	7
8 Commissioning and acceptance	8
9 Inspection, maintenance, testing and training	11
10 Total flooding systems	12
11 Local application systems	22
12 Manual hose systems	28
13 System components	29
14 System operation	30
15 Safety precautions	30
16 Carbon dioxide supply	36
17 Quantity of carbon dioxide	36
18 Storage containers	36
19 Pipework	38
20 Installation of pipework	42
21 Marking of pipework	45
Annex A (normative) Door fan test for determination of minimum hold time	46
Annex B (informative) Service schedule	52
Annex C (normative) Determination of carbon dioxide concentrations for flammable liquids and gases	53
Annex D (informative) Examples of calculation of carbon dioxide requirements	58
Annex E (informative) Determination of carbon dioxide pipe and orifice size	62
Bibliography	73
Figure 1 — Calculated CO ₂ loss rate based on an assumed 21 °C temperature within the enclosure and 21 °C ambient outside	15
Figure 1a — Discharge rates versus perimeter enclosed	26
Figure 2 — Aiming position for angled discharge nozzles	28
Figure 3 — Label to be displayed at manual control	34
Figure 4 — Label to be displayed at entrances to hazard	35
Figure C.1 — Cup burner apparatus	57
Figure D.1 — Example printer with a large enclosure	59
Figure D.2 — Example paint spray booth, open front and open top	60
Figure D.3 — Example paint spray booth, open front, one open side and open top	61
Figure E.1 — Pressure drop in pipeline for 20.7 bar storage pressure	66
Figure E.2 — Pressure drop in pipeline for 51.7 bar storage pressure	67
Table 0 — Physical properties of carbon dioxide	6
Table 1 — Volume factors	17
Table 2 — Minimum carbon dioxide concentration for extinction	18
Table 3 — Design concentrations and flooding factors for specific hazards	19

	Page
Table 4 — Extended discharge gas quantities for enclosed recirculation: rotating electrical machines	21
Table 5 — Aiming factors for nozzles installed at an angle (based on 150 mm freeboard)	27
Table 6 — Safety precautions for total flooding systems	31
Table 7 — Carbon dioxide requirements	36
Table 8 — Monitoring facilities	37
Table 9 — Closed sections of pipework	39
Table 10 — Open-ended pipework	40
Table 11 — Pipe fittings for closed and open ended pipework section — High pressure systems	41
Table 12 — Pipe fittings for closed and open ended pipework section — Low pressure systems	41
Table 13 — Maximum pipework spans	43
Table 14 — Safety clearances to enable operation, inspection, cleaning, repairs, painting and maintenance work to be carried out	45
Table E.1 — Values of Y and Z	63
Table E.2 — Values of Y and Z for 51.7 bar storage	64
Table E.3 — Discharge rate of equivalent orifice area for low pressure storage (20.7 bar)	69
Table E.4 — Equivalent length of threaded pipe fittings	69
Table E.5 — Equivalent length of welded pipe fittings	70
Table E.6 — Elevation correction factors for low pressure systems	70
Table E.7 — Elevation correction factors for high pressure systems	70
Table E.8 — Discharge rate of equivalent orifice area for high pressure storage (51.7 bar)	71
Table E.9 — Equivalent orifice sizes	72

Foreword

This part of BS 5306 is published by BSI Standards Limited, under licence from The British Standards Institution. It has been prepared by Technical Committee FSH/18. Amendment No.1:2012 has been prepared by Subcommittee FSH/18/6, under the direction of FSH/18. A list of organizations represented on this subcommittee can be obtained on request to its secretary. BS 5306-4:2001+A1:2012 supersedes BS 5306-4:2001, which is withdrawn.

The other parts of BS 5306 are as follows:

- *Part 0: Guide for the selection of installed systems and other fire equipment;*
- *Part 1: Hose reels and foam inlets;*
- *Part 2 (obsolescent): Specification for sprinkler systems;*
- *Part 3: Commissioning and maintenance of portable fire extinguishers — Code of practice;*
- *Part 5: Halon systems*
 - *Section 5.1: Specification for halon 1301 total flooding systems;*
 - *Section 5.2: Halon 1211 total flooding systems;*
- *Part 7: Specification for powder systems;*
- *Part 8: Selection and installation of portable fire extinguishers — Code of practice.*

As several different methods of piping supplies of carbon dioxide and applying the gas at the required points of discharge for fire extinction have been developed in recent years, there is a need for dissemination of information on established systems and methods. This standard has been prepared to meet this need. Its requirements and recommendations are made in the light of the best technical data known to the committee at the time of writing, but since a wide field is covered it has been impracticable to consider every possible factor or circumstance that might affect implementation of the requirements and recommendations.

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

The start and finish of text introduced or altered by Amendment No. 1:2012 is indicated in the text by tags **[A1]** **[A1]**. Minor editorial changes are not tagged.

Annex A and Annex C are normative. Annex B, Annex D and Annex E are informative.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 73, and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Introduction

It is important that the fire protection of a building or plant is considered as a whole. Carbon dioxide (CO₂) 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.

Carbon dioxide has for many years been a recognized effective medium for the extinction of flammable liquid fires and fires in the presence of electrical and ordinary class A hazards, but it should not be forgotten, in the planning of comprehensive schemes, that there may be hazards for which these mediums are not suitable, or that in certain circumstances or situations there may be dangers in their use, requiring special precautions.

A1 At concentrations used in fire fighting applications, carbon dioxide is immediately life-threatening and it is essential to prevent human exposure to it. **A1**

Advice on these matters can be obtained from the appropriate fire authority, the Health and Safety Executive or other enforcing authority under the Health and Safety at Work etc. Act 1974 [1], and insurers.

A1 Text deleted. **A1**

It is essential that fire extinguishing equipment is 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 part of BS 5306 specifies requirements and gives recommendations for the provision of carbon dioxide fire extinguishing systems in buildings or industrial plant. These systems are designed to convey carbon dioxide from a central source on the premises as and when required for the extinction of fire or the protection of particular plant or parts of the premises against possible fire risk.

This part of BS 5306 does not apply to carbon dioxide portable fire extinguishers or to wheeled appliances for conveying carbon dioxide in containers.

NOTE 1 Requirements and recommendations for carbon dioxide portable fire extinguishers (together with portable fire extinguishers of other types) are given in **A1** BS EN 3, BS 5306-3 and BS 5306-8 **A1**.

This standard gives requirements and characteristic data for carbon dioxide, the types of fires for which it is a recommended extinguishing medium, and requirements and recommendations for three established types of piped system embodying different concepts and employing different methods for the application of carbon dioxide, i.e.:

- a) the total flooding system;
- b) the local application system; and
- c) the manual hose reel system.

Two methods of operation, i.e. manual and automatic, are also specified. Requirements and recommendations are given on the selection of a system, on operational methods, **A1** on safe use of the systems, **A1** and on the design, maintenance and efficient operation of installations. Reference is also made to the part that carbon dioxide systems plays in general schemes of fire protection of premises **A1** (text deleted) **A1**.

NOTE 2 Unless otherwise stated in the text all pressures are in bar gauge.

$$1 \text{ bar} = 10^5 \text{ N/m}^2 = 100 \text{ kPa.}$$

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 21, *Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).*

BS 381C:1996, *Specification for colours for identification, coding and special purposes.*

BS 476-4, *Fire tests on building materials and structures — Part 4: Non-combustibility test for materials.*

BS 476-20, *Fire tests on building materials and structures — Part 20: Method for determination of the fire resistance of elements of construction (general principles).*

BS 476-21, *Fire tests on building materials and structures — Part 21: Methods for determination of the fire resistance of loadbearing elements of construction.*

BS 476-22, *Fire tests on building materials and structures — Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction.*

BS 476-23, *Fire tests on building materials and structures — Part 23: Methods for determination of the contribution of components to the fire resistance of a structure.*

 Reference deleted. 

BS 1640-3:1968, *Specification for steel butt-welding pipe fittings for the petroleum industry — Part 3: Wrought carbon and ferritic alloy steel fittings — Metric units.*

BS 1710, *Specification for identification of pipelines and services.*

BS 1821, *Specification for class I oxy-acetylene welding of ferritic steel pipework for carrying fluids.*

BS 2051-1, *Tube and pipe fittings for engineering purposes — Part 1: Copper and copper alloys capillary and compression tube fittings for engineering purposes.*

BS 2051-2, *Tube and pipe fittings for engineering purposes — Part 2: Specification for olive type copper alloy compression tube fittings.*

BS 2633, *Specification for Class I arc welding of ferritic steel pipework for carrying fluids.*

 Reference deleted. 

BS 3410, *Specification for metal washers for general engineering purposes.*

 References deleted. 

BS 3799:1974, *Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry.*

BS 4320, *Specification for metal washers for general engineering purposes — Metric series.*

BS 4368-1, *Compression couplings for tubes — Part 1: Split collet compression fittings.*

BS 4422-4, *Glossary of terms associated with fire — Part 4: Fire extinguishing equipment.*

BS 4677, *Specification for arc welding of austenitic stainless steel pipework for carrying fluids.*

 References deleted. 

BS 5839-1, *Fire detection and alarm systems for buildings — Part 1: Code of practice for system design, installation and servicing.*

BS 6266, *Fire protection for electronic equipment installations — Code of practice.*

BS 7273-1, *Code of practice for the operation of fire protection measures — Part 1: Electrical actuation of gaseous total flooding extinguishing systems.*

BS 7273-2, *Code of practice for the operation of fire protection measures — Part 2: Mechanical actuation of gaseous total flooding and local application extinguishing systems.*

 BS 7430, *Code of practice for earthing.* 

BS 7671, *Requirements for electrical installations — IET Wiring Regulations — Seventeenth edition.*

BS EN 856, *Rubber hoses and hose assemblies — Rubber-covered spiral wire reinforced hydraulic type — Specification.*

BS EN 1057, *Copper and copper alloys — Seamless, round copper tubes for water and gas in sanitary and heating applications.*

BS EN 1515-1, *Flanges and their joints — Bolting — Part 1: Selection of bolting.*

BS EN 1435, *Non-destructive examination of welds — Radiographic examination of welded joints.*

 BS EN 1759-1:2004, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, class-designated — Part 1: Steel flanges, NPS 1/2 to 24.* 

BS EN 1964-1, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres — Part 1: Cylinders made of seamless steel with an R_m value of less than 1 100 MPa.*

BS EN 1964-3, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres — Part 3: Cylinders made of seamless stainless steel with an R_m value of less than 1 100 MPa.*

A1 BS EN 1968, *Transportable gas cylinders — Periodic inspection and testing of seamless steel gas cylinders.*

BS EN 10216-1, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 1: Non-alloy steel tubes with specified room temperature properties.*

BS EN 10216-2, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties.*

BS EN 10217-7, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 7: Stainless steel tubes.*

BS EN 10226-1, *Pipe threads where pressure tight joints are made on the threads — Part 1: Taper external threads and parallel internal threads — Dimensions, tolerances and designation.*

BS EN 10226-2, *Pipe threads where pressure tight joints are made on the threads — Part 2: Taper external threads and taper internal threads — Dimensions, tolerances and designation.* **A1**

BS EN 10241:2000, *Steel threaded pipe fittings.*

BS EN 10242:1995, *Threaded pipe fittings in malleable cast iron.*

A1 BS EN 10255, *Non-alloy steel tubes suitable for welding and threading — Technical delivery conditions.* **A1**

BS EN 12094 (all parts), *Fixed firefighting systems — Components for gas extinguishing systems.*

A1 Reference deleted. **A1**

BS EN 12449, *Copper and copper alloys — Seamless, round tubes for general purposes.*

A1 BS EN 13096, *Transportable gas cylinders — Conditions for filling gases into receptacles — Single component gases.* **A1**

BS EN 25923, *Fire extinguishing media — Carbon dioxide (ISO 5923).*

A1 BS EN ISO 4126-2, *Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices.* **A1**

PD 5500, *Specification for unfired fusion welded pressure vessels.*

PD 6550 (all parts), *Explanatory supplement to BS 5500:1988 — Specification for unfired fusion welded pressure vessels — Section three — Design.*

ANSI B16.5:1996, *Steel pipe flanges and flanged fittings.*

ANSI B16.9:1993, *Factory-made wrought steel butt welding fittings.*

ANSI B16.11:1997, *Forged steel fittings, socket-welding and threaded.*

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

API 5L, *Specification for line pipe.*

ASTM A105M, *Specification for carbon steel forgings for piping applications.*

A1 ASTM A106 **A1**, *Specification for seamless carbon steel pipe for high temperature service.*

ASTM A234/A234M, *Specification for piping fittings of wrought carbon steel and alloy steel for moderate and high temperature service.*

3 Terms and definitions

For the purposes of this part of BS 5306, the terms and definitions given in BS 4422-4 and the following apply.

3.1

authority

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

3.2

automatic operation

method of operation in which a fire extinguishing system, under specified conditions, functions without intervention by a human operator

3.3

automatic/manual to manual only changeover switch

means of converting a fire extinguishing system from automatic/manual to manual only actuation or vice versa

NOTE This may be in the form of a manual switch on the control panel or other units, or a personnel door interlock.

3.4

closed section of pipework

section between two valves which may be intentionally or unintentionally closed, or between valves and carbon dioxide storage containers including filling and gas balance lines

3.5

competent person

person capable of carrying out the inspection and maintenance procedures of clause 9, by reason of experience and access to the requisite information, training, tools and equipment

3.6

deep-seated fire

fire involving solids subject to smouldering

3.7

filling density

mass of extinguishant per unit volume of container

3.8

high pressure storage

storage of carbon dioxide at ambient temperature, nominally 58 bar at 20 °C

3.9

local application system

automatic or manual fire extinguishing system in which a fixed supply of carbon dioxide is permanently connected to fixed piping with nozzles arranged to discharge the carbon dioxide directly to a fire occurring in a defined area that has no enclosure surrounding it, or is only partially enclosed, and that does not produce an extinguishing concentration throughout the entire volume containing the protected hazard

3.10

low pressure storage

storage of carbon dioxide in pressure containers at a controlled low temperature of –18 °C

NOTE The pressure in this type of storage is approximately 21 bar.

3.11

manual operation

method of operation in which a fire extinguishing system, under specified conditions, functions by means of intervention of a human operator

3.12**manual hose reel system**

manual fire extinguishing system consisting of a hose, stowed on a reel or a rack, with a manually operated discharge nozzle assembly, all connected by a fixed pipe to a supply of carbon dioxide

3.13**material conversion factor (MCF)**

numerical factor used when the minimum design concentration of carbon dioxide for the material at risk exceeds 34 %, to increase the basic quantity of carbon dioxide [as obtained by application of the volume factor (see 3.19)] required for protection against surface fires

3.14**open-ended pipework**

pipework between a valve (including a relief valve) and open nozzles which cannot be under a continuous pressure

3.15**pilot container**

container whose contents are only used for system actuation and whose contents do not form part of the quantity of extinguishant required

3.16**surface fire**

fire involving flammable liquids, gases or solids not subject to smouldering

3.17**total flooding system**

automatic or manual fire extinguishing system in which a fixed supply of carbon dioxide is permanently connected to fixed piping with nozzles arranged to discharge the carbon dioxide into an enclosed space in order to produce a concentration sufficient to extinguish fire throughout the entire volume of the enclosed space

3.18**user**

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

3.19**volume factor**

numerical factor that, when applied to the volume of an enclosure, indicates the basic quantity of carbon dioxide (subject to a minimum appropriate to the volume of the enclosure) required for protection against surface fires

4 Characteristics and uses of carbon dioxide**4.1 General**

Carbon dioxide for use in fire extinguishing systems shall conform to BS EN 25923.

COMMENTARY AND RECOMMENDATIONS ON 4.1. *Carbon dioxide at atmospheric pressure is a colourless, odourless and electrically non-conducting inert gas which is almost 1.5 times as dense as air. It is stored as a liquid under pressure, and 1 kg of liquid carbon dioxide expanded to atmospheric pressure will produce about 0.52 m³ of free gas at a temperature of 10 °C.*

Carbon dioxide extinguishes fire by reducing the oxygen content of the atmosphere to a point where it will not support combustion. Reducing the oxygen content from the normal 21 % in air to 15 % will extinguish most surface fires, though for some materials a greater reduction is necessary. In some applications the cooling effect of carbon dioxide will assist extinction.

Carbon dioxide may be used to fight fires of classes A and B as defined in BS EN 2. Class C fires may also be extinguished by carbon dioxide but in these cases the risk of explosion after extinction should be carefully considered.

Carbon dioxide may be ineffective on fires involving material such as metal hydrides, reactive metals such as sodium, potassium, magnesium, titanium, zirconium, A1 lithium A1 , and chemicals containing oxygen available for combustion, such as cellulose nitrate.

Carbon dioxide is suitable for use on fires involving live electrical apparatus.

A1 Information on the physical properties of carbon dioxide is given in Table 0.

Table 0 — Physical properties of carbon dioxide

Property	Unit	Value
Molecular mass	g/mol	44.01
Boiling point at 1.013 bar (absolute) ^a	°C	−56.6
Freezing point	°C	−78.5
Critical temperature	°C	28.25
Critical pressure	bar	72.8
Critical volume	cm ³ /mol	94
Critical density	kg/m ³	469
Vapour pressure 20 °C	bar abs	58.5
Liquid density −20 °C and 19.7 bar	kg/m ³	1 032 kg/m ³
Vapour density at 0 °C and 1.013 bar	kg/m ³	1.978
Specific volume of vapour (<i>S</i>) at 1.013 bar and 20 °C ^b	m ³ /kg	0.543 7
Chemical formula		CO ₂
Chemical name		Carbon dioxide
^a 1 bar = 0,1 MPa = 10 ⁵ Pa; 1 MPa = 1 N/mm ² ^b $S = k_1 + (k_2 \times t)$ $k_1 = 0.505\,875$, $k_2 = 0.001\,889$ t = temperature, in degrees Centigrade (°C)		

A1

4.2 Electrostatic discharge

A1 **WARNING.** Care should be taken when discharging carbon dioxide into potentially explosive atmospheres.

Where applying CO₂ in potentially explosive atmospheres, pipework shall be bonded and earthed in accordance with BS 7430 and BS 7671. (See also **20.10.**)

COMMENTARY AND RECOMMENDATIONS ON 4.2. *When applying CO₂ into potentially explosive atmospheres, in particular those containing explosive vapours and gases, the following should be taken into account:*

— *Electrostatic charging of steel piping not bonded to earth may occur during the discharge of carbon dioxide. This may discharge to other objects with sufficient energy to initiate a spark.*

— *The discharge of carbon dioxide is known to generate an electrostatic charge in the hazard. Under certain conditions, impingement of the CO₂ on isolated conducting surfaces over time can lead to a build-up of charge which could generate a spark. A1*

5 Types of system

CO₂ systems shall conform to the requirements of one of the following types:

- total flooding system;
- local application system;
- manual hose reel system.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 5. *In the selection of the type of carbon dioxide extinguishing system account should be taken of:*

- a) *the degree of hazard to personnel arising from the CO₂ discharge ^{A1}, discussed in clause 15 ^{A1};*
- b) *the nature of the hazard;*
- c) *the location and degree of enclosure of the hazard;*
- d) *operating requirements dictating either manual or automatic operation;*
- e) *other factors discussed in clauses 10, 11 and 12.*

6 Planning

Where a fixed carbon dioxide extinguishing system is being considered for new or existing buildings the appropriate authority shall be consulted.

Where a fire detection and control system is used in conjunction with a CO₂ system it shall conform to the requirements of BS 5839-1, BS 6266 and BS 7273-1 and -2 where appropriate.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 6. *The appropriate authority should be informed as early as possible of the type of carbon dioxide system to be installed and the system design engineers should be fully informed of the protection required in any area, whether total flooding, local application or hose reel. There may be other requirements of the authority which should be incorporated into the planning stages of the contract.*

7 ^{A1} Specifications, plans and approvals ^{A1}

7.1 General

Working documents shall be prepared only by persons fully experienced in the design of fire extinguishing systems.

Deviation from working documents shall require the permission of the appropriate authority.

^{A1} 7.2 Specifications

The specifications shall include all pertinent items necessary for the proper design of the system such as the designation of the authority, variances from the standard to be permitted by the authority, design criteria, system sequence of operations, the type and extent of the acceptance testing to be performed after installation of the system and owner training requirements.

7.3 Working documents

Layout and system proposal documents shall be submitted for approval to the authority before installation or modification begins. Working documents shall include the following items:

- a) drawings, to an indicated scale of carbon dioxide distribution system, including containers, location of containers, piping and nozzles, valves and pressure-reducing devices and pipe hanger spacing;
- b) name of owner and occupant;
- c) location of building in which hazard is located;
- d) location and construction of protected enclosure walls and partitions;
- e) enclosure cross-section, full height or schematic diagram, including raised access floor and suspended ceiling;
- f) that carbon dioxide is being used;
- g) extinguishing concentration, design concentration and maximum concentration;
- h) description of occupancies and hazards to be protected against;
- i) specification of containers used, including capacity, storage pressure and mass including carbon dioxide;
- j) description of nozzle(s) used, including inlet size, orifice port configuration, and orifice size/code;
- k) description of pipes, valves and fittings used, including material specifications, grade and pressure rating;
- l) equipment schedule or bill of materials for each piece of equipment or device, showing device name, manufacturer, model or part number, quantity and description;

- m) isometric view of carbon dioxide distribution system, showing the length and diameter of each pipe segment and node reference numbers relating to the flow calculations;
- n) enclosure pressurization and venting calculations;
- o) description of fire detection, actuation and control systems. 

8 Commissioning and acceptance

8.1 Tests

8.1.1 General

The completed CO₂ system shall be reviewed and tested by qualified personnel to meet the approval of the appropriate authority. To determine that the system has been properly installed and will function as specified, the tests specified in this clause (8.1.2, 8.1.3, 8.1.4, 8.1.5, 8.1.6, 8.1.7, 8.1.8, 8.1.9 and 8.1.10) shall be performed.

8.1.2 Enclosure check

It shall be determined that the hazard is in conformance with the drawings.

8.1.3 Review of mechanical components

8.1.3.1 The piping distribution system shall be inspected to determine that it conforms to the design and installation documents.

8.1.3.2 Nozzles and pipe size shall be in accordance with system drawings.

8.1.3.3 Piping joints, discharge nozzles, and piping supports shall be securely fastened to prevent unacceptable vertical or lateral movement during discharge. Discharge nozzles shall be installed so that piping cannot become detached during discharge.

8.1.3.4 During assembly, the piping distribution system shall be inspected internally to detect the possibility of any oil or particulate matter liable to soil the hazard area or affect the extinguishant distribution due to a reduction in the effective nozzle orifice area.

8.1.3.5 The discharge nozzles shall be oriented so that optimum extinguishant dispersal can be effected.

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

8.1.3.7 The discharge nozzles, piping, and mounting brackets shall be installed so that they will not potentially cause injury to personnel. Extinguishant shall not directly impinge on areas where personnel may be found in the normal work area, or on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

8.1.3.8 All carbon dioxide storage containers shall be properly located in accordance with an approved set of system drawings.

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

8.1.3.10 Although a full carbon dioxide discharge test is not required for compliance with this standard, if a discharge test is to be conducted, the mass of extinguishant shall be determined by weighing or other approved methods.

COMMENTARY AND RECOMMENDATIONS ON CLAUSE 8.1.3.10. *For total flooding systems discharge test concentration measurements should be made at a minimum of three points, one at the highest hazard level.*

For local application systems a check shall be made that carbon dioxide effectively covers the hazard for the full period of time required by the design.

NOTE For total flooding systems other assessment methods can normally be used to reduce unnecessary discharges into the environment, for example, the door fan pressurization test specified in Annex A. However, a discharge test may be conducted if required by the authority.

8.1.3.11 An adequate quantity of carbon dioxide to satisfy the design requirement shall be provided. For total flooding systems the actual enclosure volumes shall be checked against those indicated on the system drawings to ensure the proper quantity of extinguishant. Fan rundown and damper closure time shall be taken into consideration.

8.1.3.12 Unless the total piping contains no more than one change in direction fitting between the storage container and the discharge nozzle, and where all piping is physically checked for tightness, the following tests shall be carried out **11** (see also **20.12**) **11**.

a) All open ended piping shall be pneumatically tested in a closed circuit for a period of 10 min at 3 bar. At the end of 10 min, the pressure drop shall not exceed 20 % of the test pressure.

NOTE 1 Pressure testing is not required where the piping has been physically checked for tightness and there is no more than one change in direction between the container and the nozzle.

b) All closed sections of pipework shall be hydrostatically tested to a minimum of 190 bar for high pressure systems and 36 bar for low pressure systems. At the end of 2 min there shall be no leakage. On completion of the test, the tested sections shall be purged to remove moisture.

NOTE 2 It is recommended that hydrostatic testing is carried out at the manufacturer's works.

NOTE 3 Pressure testing is not required where the piping between the manifold and a valve has been physically checked for tightness and there is no more than one change in direction between the manifold and the valve.

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

8.1.3.13 A test using nitrogen, or suitable alternative, shall be performed on the piping network to verify that flow is continuous and that the piping and nozzles are unobstructed.

8.1.3.14 Fusible link systems shall be tested to ensure that control cable lines are free and that operating control weights develop sufficient energy to operate container and/or direction valve control mechanisms.

8.1.3.15 Pneumatic detection systems shall be tested with a manometer to ensure correct breathing rate and leak free capillary lines.

8.1.3.16 Nameplates and instruction plates shall be checked to ensure they are correctly worded.

8.1.3.17 Detectors shall be activated in accordance with the manufacturer's instructions to ensure correct operation and subsequent activation of control mechanisms.

8.1.4 Review of enclosure integrity

All total flooding systems shall have the enclosure checked to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified extinguishant concentration level for the specified holding period (see also **10.4.1** and **10.5**). Unless otherwise required by the appropriate authority, the test specified in Annex A shall be used.

8.1.5 Review of electrical components

8.1.5.1 All wiring systems shall be properly installed in accordance with BS 7671 (IEE Wiring Regulations) and the system drawings. A.c. and d.c. wiring shall not be combined in a common conduit unless properly shielded and grounded.

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

8.1.5.3 Adequate and reliable primary standby sources of energy, which conform to the requirements of **8.1.9**, shall be used to provide for operation of the detection, signalling, control and actuation requirements of the system.

8.1.5.4 All auxiliary functions such as alarm sounding or displaying devices, remote annunciators, air handling shutdown, power shutdown, etc., shall be checked for proper operation in accordance with system requirements and design specifications.

Alarm devices shall be installed so that they are audible and visible under normal operating and environmental conditions.

NOTE Where possible, all air-handling and power cut-off controls should be of the type that once interrupted require manual restart to restore power.

8.1.5.5 Where alarm silencing is provided it shall not affect other auxiliary functions such as air handling or power cut-off, if required in the design specification.

8.1.5.6 The detection devices shall be checked to ensure that the types and locations are as specified in the system drawings and are in accordance with the manufacturer's requirements.

8.1.5.7 Manual release devices shall be checked to ensure that they are properly installed, and are readily accessible, accurately identified, and properly protected to prevent damage.

8.1.5.8 All manual release devices used to release extinguishants shall be checked to ensure that they require two separate and distinct actions for operation. All manual release devices shall be properly identified. Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated. Manual release devices in this instance shall be clearly identified as to which hazard enclosure they protect.

8.1.5.9 For systems with a main/reserve capability, the main/reserve switch shall be checked to ensure that it is properly installed, readily accessible, and clearly identified.

8.1.5.10 For systems using hold switches, the switches shall be checked to ensure that they are of the deadman type requiring constant manual pressure, are properly installed, readily accessible within the hazard area, and clearly identified.

8.1.5.11 The control panel shall be checked to ensure that it is properly installed and readily accessible.

8.1.6 Preliminary functional tests

8.1.6.1 Where a system is connected to a remote central alarm station, the station shall be notified that the fire system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not required. All personnel concerned at the end-user's facility shall be notified that a test is to be conducted and instructed as to the sequence of operation.

8.1.6.2 Each extinguishant storage container release mechanism and selector valves, where fitted, shall be disabled or removed so that activation of the release circuit will not release extinguishant. The release circuit shall be reconnected with a functional device in lieu of each extinguishant storage container release mechanism.

NOTE Functional devices may include suitable lamps, flash bulbs, or circuit breakers. Pneumatically actuated functional devices may include pressure gauges. The manufacturer's recommendations should be referred to in all cases.

8.1.6.3 Each resettable detector shall be checked for proper response.

8.1.6.4 Polarized alarm devices and auxiliary relays shall be checked for polarity.

8.1.6.5 End-of-line devices, where required, shall be installed across all circuits.

8.1.6.6 Monitored circuits shall be checked for correct fault response.

8.1.7 System functional operational test

8.1.7.1 Detection initiating circuit(s) shall be operated. All alarm functions shall occur according to the design specification.

8.1.7.2 The necessary circuits to initiate a second alarm shall be operated. Second alarm functions shall be verified as occurring in accordance with design specifications.

8.1.7.3 Manual release devices shall be operated. Manual release functions shall be verified as occurring in accordance with design specifications.

8.1.7.4 Hold switches, where installed, shall be operated. Functions shall be verified as occurring in accordance with design specifications. Visual and audible supervisory signals shall be confirmed as occurring at the control panel.

8.1.7.5 Resettable valves and activators shall be function tested, unless testing the valves will release extinguishant.

NOTE "One-shot" valves, such as those incorporating frangible discs, should not be tested.

8.1.7.6 Pneumatic equipment shall be checked for integrity to ensure proper operation.

8.1.8 Remote monitoring operations (if applicable)

8.1.8.1 Primary power supply shall be disconnected and one of each type of input device operated while on standby power. Receipt of an alarm signal shall be received at the remote panel after the device is operated. The primary power supply shall be reconnected.

8.1.8.2 Each type of alarm condition shall be operated. Receipt of fault conditions at the remote station shall be verified.

8.1.9 Control panel primary power source

8.1.9.1 Connection of the control panel to a properly labelled dedicated unswitched circuit shall be verified. This panel shall be readily accessible only to authorized personnel.

8.1.9.2 A primary power failure shall be simulated and the system fully operated on standby power.

8.1.10 On completion of functional tests

When all functional tests are complete, each storage container shall be reconnected so that activation of the release circuit will release the extinguishant. The system shall be returned to its fully operational design condition. The central alarm station and all concerned personnel at the end-user's facility shall be notified that the fire system test is complete and that the system has been returned to full service condition by following the procedures specified in the manufacturers' specifications.

8.2 Completion certificate and documentation

The user shall obtain from the installer a completion certificate, a complete set of instructions, calculations and drawings showing the system as installed, and a statement that the system conforms to all the appropriate requirements of this standard. This documentation shall also give details of any departure from appropriate recommendations. The certificate shall give the design concentrations and if carried out, the report of the door fan test.

9 Inspection, maintenance, testing and training

9.1 Inspection

9.1.1 General

9.1.1.1 At least every six months, or more frequently if required by the authority, the mechanical parts of the system shall be thoroughly inspected and tested for proper operation by competent personnel.

NOTE Discharge tests are not required.

COMMENTARY AND RECOMMENDATIONS ON 9.1.1.1. *Any electrical detection systems should be tested in accordance with the requirements of BS 5839-1.*

9.1.1.2 The inspection report with recommendations shall be filed with the user.

9.1.1.3 At least every six months, the container contents shall be checked. If a container shows a loss of mass of 10 % or greater, it shall be refilled or replaced.

9.1.1.4 The date of inspection and the person performing the inspection shall be recorded on a tag attached to the container.

9.1.2 Container assemblies

 Container assemblies shall be subjected to periodical tests as required by BS EN 1968. 

9.1.3 Hose

All system hoses shall be examined annually for damage. If visual examination shows any deficiency, the hose shall be replaced  or pressure tested .

 Text deleted. 

9.1.4 Enclosure

At least every 12 months it shall be determined if penetrations or other changes to the protected enclosure have occurred that could affect leakage and carbon dioxide performance. If this is not possible, it shall be positively established that no changes to the enclosure have occurred. This shall be evaluated by repeating the test for enclosure integrity in accordance with Annex A.

Where the integrity test reveals increased leakage that would result in an inability to retain the carbon dioxide for the required period, remedial action shall be carried out.

Where it is established that changes to the volume of the enclosure or to the type of hazard within the enclosure, or both, have occurred, the system shall be redesigned to provide the **A1** correct **A1** degree of protection.

9.2 Maintenance

9.2.1 General

The user shall carry out a programme of inspection, arrange a service schedule and keep records of inspections and servicing.

NOTE The continued capability for effective performance of a fire fighting system depends on fully adequate service procedures.
A1 Text deleted. **A1**

9.2.2 User's programme of inspection

The user shall obtain from the installer an inspection programme for the system and its components. The programme shall include instructions on the action to be taken in respect of faults.

NOTE 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 the 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 any pressure gauges for correct reading and take the appropriate action specified in the user's manual.
- 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.

9.2.3 Service schedule

A service schedule shall include requirements for periodic inspection and test for the complete, installed system and for pressurized containers as specified in **A1** BS EN 1968. **A1**

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.

During servicing every care and precaution shall be taken to avoid release of extinguishant.

NOTE A suitable service schedule is provided in Annex B.

9.3 Training

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

Personnel working in an enclosure protected by a gaseous extinguishant shall receive training in the operation and use of the system, and on **A1** the specific hazards of carbon dioxide and other safety issues, such as noise, discharge turbulence etc. **A1**.

10 Total flooding systems

10.1 Uses

Total flooding systems shall conform to clause 6, clause 7, clause 8 and clause 9, unless otherwise specified in this clause, and may be used to extinguish or control the following fires:

- a) surface fires involving flammable liquids, gases and solids;
- b) deep-seated fires involving solids subject to smouldering.

10.2 General design

10.2.1 The quantity of carbon dioxide, which will vary according to the hazard and permitted openings, shall be sufficient to reduce the oxygen content of the atmosphere within the enclosure to a point where combustion can no longer be sustained. The rate of application and the time necessary to maintain the extinguishing concentration shall be determined according to the hazard, and as specified in 10.4, 10.5, and 10.6.

The distribution of the carbon dioxide shall be arranged so that it is evenly and thoroughly mixed with the existing atmosphere.

COMMENTARY AND RECOMMENDATIONS ON 10.2.1. A1 Enclosed pressure A1 venting may be required to avoid excessive pressure build-up resulting from the volume of carbon dioxide discharged into the hazard area (see 10.3.3).

10.2.2 The system shall be designed for either:

- a) automatic and manual operation;
- b) manual operation only.

NOTE This may be dependent upon the requirements of the appropriate authority.

10.3 Enclosure

10.3.1 General

The protected volume of an enclosure shall be enclosed by elements of construction having a fire resistance of not less than 30 min when tested in accordance with BS 476-20, -21, -22 and -23, whichever is appropriate, and classified as non-combustible when tested in accordance with BS 476-4. Where openings can be closed, they shall be arranged to close before or at the start of gas discharge. Where carbon dioxide can flow freely between two or more interconnected volumes, the quantity of carbon dioxide shall be the sum of quantities calculated for each volume using the respective volume and material conversion factors. If one volume requires higher than normal concentration, the higher concentration shall be used in all interconnected volumes. The volume of the enclosure shall be the gross volume. The only permitted reductions shall be permanent, impermeable building elements within the enclosure.

All total flooding systems shall have the enclosure checked to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified extinguishant concentration level for the specified holding period (see also 10.4.1 and 10.5). Unless otherwise required by the relevant authority, the test specified in Annex A shall be used.

COMMENTARY AND RECOMMENDATIONS ON 10.3.1. A well enclosed space is required to maintain the extinguishing concentration of carbon dioxide.

NOTE A1 Rooms with cable/floor voids are not considered as interconnected volumes. Where enclosures have voids and are supplied with re-circulating air handling equipment that is not shut down prior to carbon dioxide discharge, then the complete enclosure should be treated as interconnected. A1

10.3.2 Unclosable openings

10.3.2.1 General

For total flooding systems a reasonably well-enclosed space is assumed in order to minimize the loss of CO_2 .

A1 Text deleted. A1 Any unclosable openings shall be compensated for by additional CO_2 as specified in 10.3.2.2. If the quantity of CO_2 required for compensation exceeds the basic quantity of CO_2 required for flooding without leakage, the system shall be designed for local application in accordance with clause 11.

10.3.2.2 Rate of application

The minimum rates of application established are considered adequate for surface fires or deep-seated fires. However, where a hazard contains material that will produce both surface and deep-seated fires, the rate of application shall be at least the minimum required for surface fires. Having selected a rate suitable to the hazard, the tables and information shall be used or such special engineering as is required shall be carried out to obtain the proper combination of container releases, supply piping, and orifice sizes that will produce this desired rate.

As the leakage rate through unclosable openings in the absence of forced ventilation depends mainly on the difference in density between the atmosphere within the enclosure and the air surrounding the enclosure the following equation shall be used to calculate the rate of CO_2 loss, assuming that there is sufficient leakage in the upper part of the enclosure to allow free ingress of air:

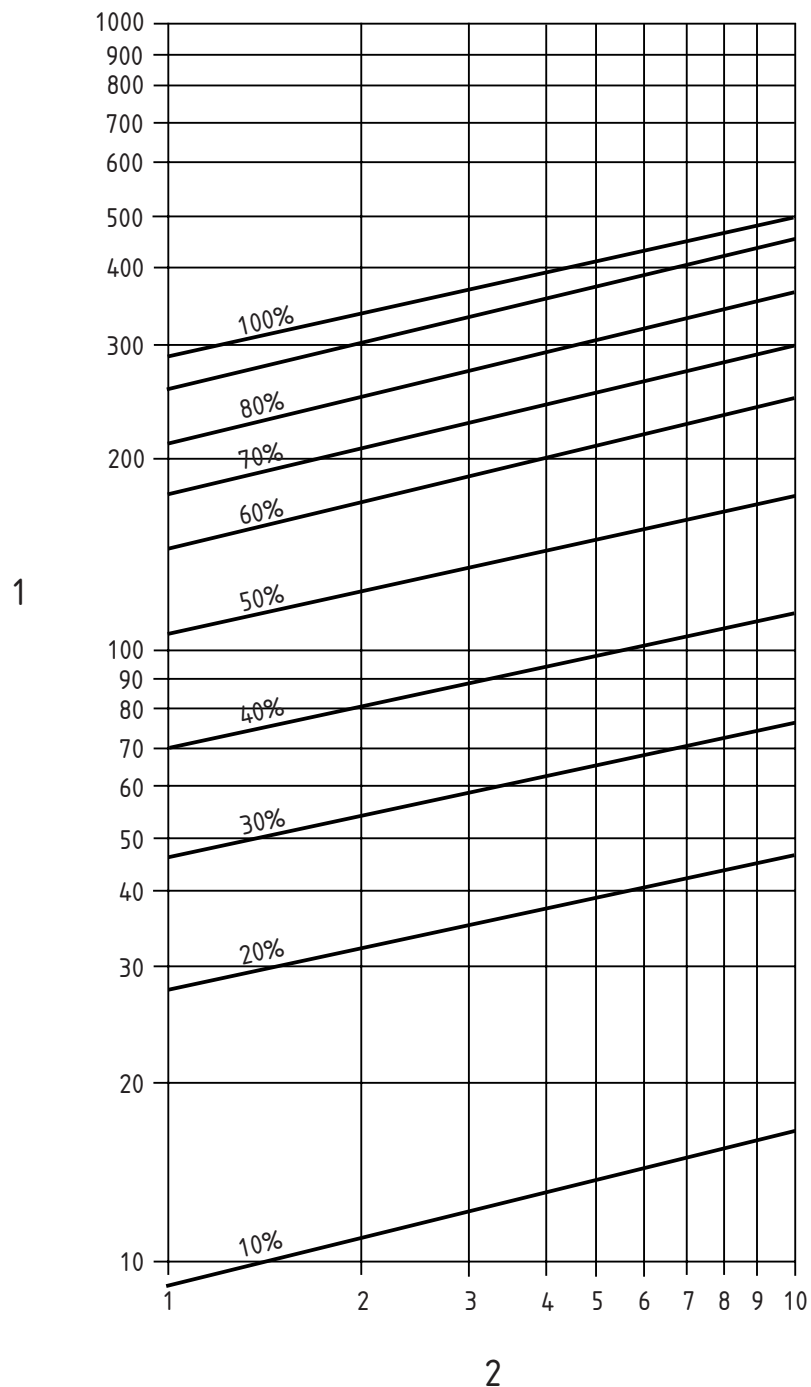
$$R_M = 60 C \rho_M A_M \sqrt{\frac{2 g_M (\rho_{M1} - \rho_{M2}) h_M}{\rho_{M1}}}$$

where

- R_M is the rate of loss of CO₂ in kilograms per minute (kg/min);
 C is the CO₂ concentration fraction;
 ρ_M is the density of CO₂ vapour in kilograms per cubic metre (kg/m³);
 A_M is the area of opening in square metres (m²) (flow coefficient included);
 g_M is the gravitational constant 9.81 m/s²;
 ρ_{M1} is the density of atmosphere in kilograms per cubic metre (kg/m³);
 ρ_{M2} is the density of surrounding air in kilograms per cubic metre (kg/m³);
 h_M is the static head between opening and top of enclosure in metres (m).

NOTE Figure 1 may be used as a guide in estimating discharge rates for extended discharge systems.

 Text deleted. 

**Key**

1 Leakage rate in kilograms of CO₂/min/m²

2 Height in metres of atmosphere above centre line of opening

$\overline{A_1}$ The percentage (%) relates to design concentration. $\overline{A_1}$

Figure 1 — Calculated CO₂ loss rate based on an assumed 21 °C temperature within the enclosure and 21 °C ambient outside

10.3.3 Area of opening required for venting

The protected enclosure shall have sufficient structural strength and integrity to contain the CO₂ discharge. Venting shall be provided to prevent excessive over-pressurization of the enclosure.

Determine the area of venting A , required to prevent over-pressurization of a protected enclosure during the discharge of a total flooding CO₂ system, as follows:

$$\boxed{A_1} \quad A = \frac{M_{\text{CO}_2} \times S_{\text{CO}_2}}{\sqrt{\Delta P \times S_{\text{HOM}}}} \quad \boxed{A_1}$$

where

A is the required vent area in square metres (m²);

M_{CO_2} is the mass flow rate of CO₂ in kilograms per second (kg/s);

$\boxed{A_1} S_{\text{CO}_2} \boxed{A_1}$ is the specific volume of CO₂ = 1/ ρ_{CO_2} at 0 °C = $\boxed{A_1} 0.506 \text{ m}^3/\text{kg} \boxed{A_1}$;

$\boxed{A_1} S_{\text{HOM}} \boxed{A_1}$ is the specific volume of the CO₂/air mixture at 0 °C (m³/kg)
 $= 1 / (x_{\text{air}} \times \rho_{\text{air}} + x_{\text{CO}_2} \times \rho_{\text{CO}_2})$;

x is the volume fraction (≤ 1);

ρ_{air} is the density of air at 0 °C = 1.29 kg/m³;

ρ_{CO_2} is the density of CO₂ at 0 °C = 1.98 kg/m³;

ΔP is the maximum allowable pressure increase in the enclosure in pascals (Pa).

EXAMPLE

A total flooding system discharges 300 kg CO₂ into the protected enclosure within a discharge time of 60 s. The CO₂ quantity was calculated for an extinguishing concentration of 34 % by volume. The enclosure is of lightweight construction with glazing, and can be exposed to a maximum over pressure of $\boxed{A_1} 250 \text{ Pa} \boxed{A_1}$.

$$\boxed{A_1} \quad A = \frac{M_{\text{CO}_2} \times S_{\text{CO}_2}}{\sqrt{\Delta P \times S_{\text{HOM}}}} \quad \boxed{A_1}$$

$$M_{\text{CO}_2} = 300/60 = 5 \text{ kg/s}$$

$$\boxed{A_1} \quad S_{\text{HOM}} = \frac{1}{\left\{ (0.66 \times 1.29) + (0.34 \times 1.98) \right\}} = 0.6833 \text{ m}^3/\text{kg} \quad \boxed{A_1}$$

$$\Delta P = \boxed{A_1} 250 \text{ Pa} \boxed{A_1}$$

$$\boxed{A_1} \quad A = \frac{5 \times 0.506}{\sqrt{(250 \times 0.6833)}} = 0.194 \text{ m}^2 \quad \boxed{A_1}$$

$\boxed{A_1}$ NOTE 1 In some instances, openings in the enclosure that are necessary as part of the processes carried out may be sufficient to provide adequate venting.

NOTE 2 Some or all of the required vent area (as determined by the room integrity test), may also be provided by the inherent natural leakage of the enclosure. However, by the time in a project at which an integrity test can be carried out to determine the equivalent leakage area, it may be too late to introduce venting without incurring avoidable extra delay. When the integrity test is conducted with doors held open in adjacent rooms to the room under test, there could be less natural leakage available than may have been assumed from the ELA value. In such cases, if natural leakage is to be used for pressure relief, the protected enclosure needs to be assessed and judgement applied in deciding what proportion of the ELA is used as a contribution to the total vent area.

NOTE 3 Further guidance is given in the FIA publication *Guidance on the pressure relief and post-discharge venting of enclosures protected by gaseous fire-fighting systems — FIA guidance for the fire protection industry* [4]. $\boxed{A_1}$

10.4 Carbon dioxide for surface fires

10.4.1 Volume factor

The volume factor used to determine the basic quantity of carbon dioxide to protect an enclosure containing a material requiring a design concentration up to 34 % shall be in accordance with Table 1. For materials requiring a design concentration over 34 %, the basic quantity of carbon dioxide calculated from the volume factor given in Table 1 shall be increased by multiplying this quantity by the appropriate conversion factor given in Table 2. ~~[A1] Text deleted. [A1]~~

Where forced air ventilating systems are involved, they shall, if possible, be shut down and/or closed automatically before, or simultaneously with, the start of the carbon dioxide discharge. Where ventilation systems cannot be shut down and/or closed, the design shall allow for additional carbon dioxide to be supplied to achieve and maintain the design concentration. Services within the enclosure that are likely to contribute to the fire hazard, e.g. heating, fuel supply and paint spraying, shall be arranged to be shut down automatically prior to, or simultaneously with, the discharge of carbon dioxide.

For materials not given in Table 2, the minimum carbon dioxide design concentration shall be obtained from a recognized source or determined from the test method described in Annex C.

NOTE Examples illustrating the application of carbon dioxide requirements for surface fires are given in Annex D.

Table 1 — Volume factors

Volume of space m ³	Volume factor (mass of CO ₂ per unit volume of enclosed space) kg/m ³
≤ 4	1.15
>4 ≤ 14	1.07
>14 ≤ 45	1.01
>45 ≤ 126	0.90
>126 ≤ 1 400	0.80
>1 400	0.74

Table 2 — Minimum carbon dioxide concentration for extinction

Material	Minimum design CO ₂ concentration %	Material conversion factor
Acetylene	66	2.5
Acetone	31	1.0
Benzol, benzene	37	1.1
Butane	34	1.0
Buta-1,3-diene	41	1.3
Carbon disulphide	72	3.0
Carbon monoxide	64	2.4
Coal gas or natural gas	37	1.1
Cyclopropane	37	1.1
Diethyl ether	46	1.5
Dowtherm	46	1.5
Ethane	40	1.2
Ethanol	43	1.3
Ethylene	49	1.6
Ethylene dichloride	25	1.0
Ethylene oxide	53	1.75
Hexane	35	1.1
Hydrogen	75	3.3
Isobutane	36	1.1
Kerosene	34	1.0
Methane	30	1.0
Methanol	40	1.2
Pentane	35	1.1
Petroleum spirit	34	1.0
Propane	36	1.1
Propene	36	1.1
Quenching, lubricating oils	34	1.0

10.4.2 Compensation for abnormal temperatures

Where there are abnormal temperatures, additional quantities of gas shall be provided as follows.

- Where the normal temperature of the enclosure is above 100 °C, 2 % carbon dioxide shall be added for each additional 5 °C over 100 °C. The additional quantity of carbon dioxide shall not be discharged within the design discharge period (see 10.6.1).
- Where the normal temperature of the enclosure is below –20 °C, 2 % carbon dioxide shall be added for each 1 °C below –20 °C. The additional quantity of carbon dioxide shall be discharged within the design discharge period, to compensate for the lower expansion rate at a reduced temperature.

10.4.3 Calculation process

The following steps shall be carried out to determine agent quantity.

- Enclosure volume × volume factor × MCF = basic carbon dioxide quantity.
- Provide additional carbon dioxide for unclosable openings.
- Adjust for temperature compensation on total of items a) and b) above.