
**Gaseous fire-extinguishing systems —
Physical properties and system
design —**

**Part 1:
General requirements**

*Systèmes d'extinction d'incendie utilisant des agents gazeux —
Propriétés physiques et conception des systèmes —*

Partie 1: Exigences générales

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 8, *Gaseous media and firefighting systems using gas*.

This fourth edition cancels and replaces the third edition (ISO 14520-1:2015), which has been technically revised. It also cancels and replaces ISO/TR 23107:2021.

The main changes are as follows:

- the Scope has been extended to cover an additional agent, halocarbon blend 55;
- [subclause 5.2.1](#) has been amended to require upper limit threshold concentrations to be established for any impurity that could result in acute toxicity at concentrations below the cardiac sensitization NOAEL of the agent. [Subclause G.4.4](#) has also been added to provide further information on these requirements;
- a new subclause ([6.4.4.2](#)) has been added requiring that in the event of an electrical actuator being removed from a container valve or selector valve, an audible and visual alarm is to be provided at the control panel;
- [subclause 7.4.1](#) has been amended to draw attention to ISO 21805;
- a new subclause ([7.5](#)) has been added providing guidance regarding the effects of noise that can be caused by the alarm devices or the discharge of the agent;
- [subclause 7.6.1.3](#), (previously 7.5.1.3) has been amended to give several scenarios to explain the recommended selection of regular and high hazard design concentrations;
- Annex I has been added to reflect the content of the withdrawn document ISO/TR 12854;
- Annex J has been added to reflect the content of ISO/TR 23107 (to be withdrawn).

A list of all parts in the ISO 14520 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Firefighting systems covered in this document are designed to provide information on a supply of gaseous extinguishing medium for the extinction of fire.

Several different methods of supplying extinguishant to, and applying it at, the required point 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 document has been prepared to meet this need.

The requirements of this document are made in the light of the best technical data known to the working group at the time of writing but, since a wide field is covered, it has been impracticable to consider every possible factor or circumstance that can potentially affect the implementation of the recommendations.

It has been assumed in the preparation of this document 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 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 extinguishant.

Attention is drawn to the Montreal Protocol on substances that deplete the ozone layer and those that contribute towards climate change.

It is important to consider the fire protection of a building or plant as a whole. Gaseous extinguishant systems form only a part of the available facilities. It should not be assumed that their adoption removes the need to consider supplementary measures, for example, the provision of portable fire extinguishers or other mobile appliances for first aid, emergency use or for dealing with special hazards.

Gaseous extinguishants have been a recognized effective medium for the extinction of flammable liquid fires and fires in the presence of electrical and ordinary Class A hazards for many years. However, in the planning of comprehensive schemes, it should be remembered that these media are not suitable for all hazards. Additionally, in certain circumstances or situations there can be dangers relating to their use which require special precautions.

Advice on these matters can be obtained from the appropriate manufacturer of the extinguishant or the extinguishing system. Information may also be sought from the appropriate fire authority, the health and safety authorities and insurers. Also, reference should be made as necessary to other national standards and statutory regulations of the particular country.

It is essential that fire-fighting equipment be carefully maintained to ensure instant readiness when required. Routine maintenance is liable to be overlooked or given insufficient attention by the owner of the system. It is, however, neglected at peril to the lives of occupants of the premises and the risk of crippling financial loss. The importance of maintenance cannot be too highly emphasized. Installation and maintenance should only be done by qualified personnel.

Inspection, preferably by a third party, should include an evaluation that the extinguishing system continues to provide adequate protection for the risk (protected zones, as well as state of the art, can change over time).

Gaseous fire-extinguishing systems — Physical properties and system design —

Part 1: General requirements

1 Scope

This document specifies requirements and gives recommendations for the design, installation, testing, maintenance and safety of gaseous firefighting systems in buildings, plants or other structures, and the characteristics of the various extinguishants and types of fire for which they are a suitable extinguishing medium.

It covers total flooding systems primarily related to buildings, plants and other specific applications, utilizing electrically non-conducting gaseous fire extinguishants that do not leave a residue after discharge and for which there are sufficient data currently available to enable validation of performance and safety characteristics by an appropriate independent authority. This document does not apply to explosion suppression.

This document is not intended to indicate approval of the extinguishants listed therein by the appropriate authorities, as other extinguishants can be equally acceptable. CO₂ is not included as it is covered by other International Standards.

This document applies to the extinguishants listed in [Table 1](#). It is essential that it be used in conjunction with the separate parts of the ISO 14520 series for specific extinguishants, as cited in [Table 1](#).

Table 1 — Listed extinguishant

Extinguishant	Chemical	Formula	CAS No.	International Standard
FK-5-1-12	Dodecafluoro-2-methylpentan-3-one	CF ₃ CF ₂ C(O)CF(CF ₃) ₂	756-13-8	ISO 14520-5
HCFC-123	Dichlorotrifluoroethane	CHCl ₂ CF ₃	306-83-2	
HCFC-22	Chlorodifluoromethane	CHClF ₂	75-45-6	ISO 14520-6
HCFC-124	Chlorotetrafluoroethane	CFC ₂ ClCF ₃	2837-89-0	
	Isopropenyl-1-methylcyclohexene	C ₁₀ H ₁₆	5989-27-5	
HFC 125	Pentafluoroethane	CHF ₂ CF ₃	354-33-6	ISO 14520-8
HFC 227ea	Heptafluoropropane	CF ₃ CHFCF ₃	2252-84-8	ISO 14520-9
HFC 23	Trifluoromethane	CHF ₃	75-46-7	ISO 14520-10
IG-01	Argon	Ar	74040-37-1	ISO 14520-12
IG-100	Nitrogen	N ₂	7727-37-9	ISO 14520-13
IG-55	Nitrogen (50 %)	N ₂	7727-37-9	ISO 14520-14
	Argon (50 %)	Ar	74040-37-1	
IG-541	Nitrogen (52 %)	N ₂	7727-37-9	ISO 14520-15
	Argon (40 %)	Ar	74040-37-1	
	Carbon dioxide (8 %)	CO ₂	124-38-9	
Halocarbon Blend 55	E-1-chloro-3,3,3-trifluoropropene (50 % by mass)	CF ₃ CHCHCl	102687-65-0	ISO 14520-17
	Dodecafluoro-2-methylpentan-3-one (50% by mass)	CF ₃ CF ₂ C(O)CF(CF ₃) ₂	756-13-8	

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14520-5:2019, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 5: FK-5-1-12 extinguishant*

ISO 14520-8:2019, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 8: HFC 125 extinguishant*

ISO 14520-9:2019, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 9: HFC 227ea extinguishant*

ISO 14520-10:2019, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 10: HFC 23 extinguishant*

ISO 14520-12:2015, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 12: IG-01 extinguishant*

ISO 14520-13:2015, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 13: IG-100 extinguishant*

ISO 14520-14:2015, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 14: IG-55 extinguishant*

ISO 14520-15:2015, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 15: IG-541 extinguishant*

ISO 14520-17:2022, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 17: Halocarbon Blend 55*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

NOTE For the purposes of this document, the term “bar”¹⁾ is taken as “gauge”, unless otherwise indicated. Concentrations or quantities expressed in percentages (%) are taken as by volume unless otherwise indicated.

3.1 approved

acceptable to a relevant *authority* (3.2)

Note 1 to entry: In determining the acceptability of installations or procedures, equipment, or materials, the authority can base acceptance on conformance with the appropriate International Standards.

3.2 authority

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

3.3 automatic/manual switch

means of converting the system from automatic to manual actuation

Note 1 to entry: This can be in the form of a manual switch on the control panel or other units, or a personnel door interlock. In all cases, this changes the actuation mode of the system from automatic and manual to manual only or vice versa.

3.4 extinguishant

electrically non-conducting gaseous fire extinguishing agent that, upon evaporation, does not leave a residue

Note 1 to entry: See [Table 1](#).

Note 2 to entry: The terms “extinguishant” and “agent” are used interchangeably throughout this document.

3.5 clearance

air gap between equipment, including piping and nozzles and unenclosed or uninsulated live electrical components at other than the ground potential

3.6 Terms relating to concentration

3.6.1 design concentration

concentration of extinguishant, including a safety factor, required for system design purposes

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1N/mm²

3.6.2

maximum concentration

concentration achieved from the actual extinguishant quantity at the maximum ambient temperature in the protected area

3.6.3

extinguishing concentration

minimum concentration of extinguishant required to extinguish a fire involving a particular fuel under defined experimental conditions excluding any safety factor

3.7

engineered system

system in which the supply of extinguishant stored centrally is discharged through a system of pipes and nozzles in which the size of each section of pipe and nozzle orifice has been calculated in accordance with a specific method

Note 1 to entry: The specific method used for calculating the size of each section of pipe and nozzle orifice is provided in [Annex H](#).

3.8

fill density

mass of extinguishant per unit volume of the container

3.9

flooding quantity

mass or volume of extinguishant required to achieve the design concentration within the protected volume

3.10

net volume

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

3.11

hold time

period of time during which a concentration of extinguishant, not less than 85 % of the design concentration, surrounds the hazard

3.12

inspection

visual check to give reasonable assurance that the extinguishing system is fully charged and operable

Note 1 to entry: This is done by seeing that the system is in place, that it has not been activated or tampered with, and that there is no obvious physical damage or condition to prevent operation.

3.13

liquefied gas

gas or gas mixture (normally a halocarbon), which is liquid at the container pressurization level at room temperature (20 °C)

3.14

lock-off device

manual shut-off valve installed in the discharge piping downstream of the agent containers or another type of device that mechanically prevents agent container actuation

Note 1 to entry: The actuation of this device indicates system isolation.

Note 2 to entry: The intent is to prevent the discharge of the agent into the hazard area when the lock-off device is activated.

3.15**lowest observed adverse effect level****LOAEL**

lowest concentration at which an adverse toxicological or physiological effect has been observed

3.16**maintenance**

thorough check, comprising a thorough examination and any necessary repair or replacement of system component, to give maximum assurance that the extinguishing system will operate as intended

3.17**maximum working pressure**

equilibrium pressure within a container at the maximum working temperature

Note 1 to entry: For liquefied gases, this is at the maximum fill density and can include superpressurization.

3.18**no observed adverse effect level****NOAEL**

highest concentration at which no adverse toxicological or physiological effect has been observed

3.19**non-liquefied gas**

gas or gas mixture (normally an inert gas), which, under normal service pressure and permissible service temperature conditions, is always present in the gaseous form

3.20**normally occupied area**

area intended for occupancy

3.21**normally unoccupied area**

area not normally occupied by people, but which can be entered occasionally for brief periods

3.22**pre-engineered systems**

system consisting of a supply of extinguishant of specified capacity coupled to pipework with a balanced nozzle arrangement up to a maximum permitted design

Note 1 to entry: No deviation is permitted from the limits specified by the manufacturer or authority.

3.23**regulated system**

non-liquefied gas system where the pressure downstream of a pressure regulation device is limited to some maximum pressure under both flow and no-flow conditions

3.24**safety factor**

multiplier of the agent extinguishing concentration to determine the agent minimum design concentration

3.25**sea-level equivalent of the agent**

agent concentration (volume percent) at sea level for which the partial pressure of agent matches the ambient partial pressure of agent at a given altitude

3.26**sea-level equivalent of oxygen**

oxygen concentration (volume percent) at sea level for which the partial pressure of oxygen matches the ambient partial pressure of oxygen at a given altitude

3.27

selector valve

valve installed in the discharge piping downstream of the agent containers, to direct the agent to the appropriate hazard enclosure

Note 1 to entry: This is used where one or more agent containers are arranged to selectively discharge agent to any of several separate hazard enclosures.

3.28

superpressurization

addition of gas to the extinguishant container, where necessary, to achieve the required pressure for proper system operation

3.29

total flooding system

system arranged to discharge extinguishant into an enclosed space to achieve the appropriate design concentration

3.30

unoccupiable area

area that cannot be occupied due to dimensional or other physical constraints

EXAMPLE Shallow voids and cabinets.

4 Use and limitations

4.1 General

The design, installation, service and maintenance of gaseous fire-extinguishing systems shall be performed by those competent in fire extinguishing system technology. Maintenance and installation shall only be performed by qualified personnel and companies.

The hazards against which these systems offer protection, and any limitations on their use, shall be contained in the system supplier's design manual.

Total flooding fire-extinguishing systems are used primarily for protection against hazards that are in enclosures or equipment that, in itself, includes an enclosure to contain the extinguishant. The following are typical of such hazards, but the list is not exhaustive:

- a) electrical and electronic hazards;
- b) telecommunications facilities;
- c) flammable and combustible liquids and gases;
- d) other high-value assets.

4.2 Extinguishants

4.2.1 General

Any agent that is to be recognized by this document or proposed for inclusion in this document shall first be evaluated in accordance with [Annex J](#). This is equivalent to the process used by the U.S. Environmental Protection Agency's (EPA) SNAP Program or other internationally recognized extinguishing agent approval institutions.

The extinguishants referred to in this document are electrically non-conductive media.

The extinguishants and specialized system parameters are each covered individually in the relevant parts of the ISO 14520 series for specific extinguishants. These parts of the ISO 14520 series (see [Table 1](#)), shall be used in conjunction with this document.

Unless relevant testing has been carried out to the satisfaction of the authority, the extinguishants referred to in the relevant parts of the ISO 14520 series shall not be used on fires involving the following:

- a) chemicals containing their supply of oxygen, such as cellulose nitrate;
- b) mixtures containing oxidizing materials, such as sodium chlorate or sodium nitrate;
- c) chemicals capable of undergoing autothermal decomposition, such as some organic peroxides;
- d) reactive metals (such as sodium, potassium, magnesium, titanium and zirconium), reactive hydrides, or metal amides, some of which can react violently with some gaseous extinguishants;
- e) environments where significant surface areas exist at temperatures greater than the breakdown temperature of the extinguishing agent and are heated by means other than the fire.

4.2.2 Environmental properties

Global warming potential (GWP) and ozone depletion potential (ODP) values applicable to the gaseous extinguishing agents are detailed in ISO 14520-2 to ISO 14520-17.

NOTE GWP is a measure of how much a given mass of gas is estimated to contribute to global warming. The scale is a relative comparison on a mass basis where a clean agent is compared to carbon dioxide, which has a GWP equal to 1. ODP provides a relative comparison of the ability to react with ozone at altitudes within the stratosphere. ODP values are reported relative to the same mass of CFC-11, which has an ODP equal to 1. The intergovernmental panel on climate change (IPCC) and the Parties to the Montreal Protocol provide up to date environmental information on clean agent alternatives. Users of this document are encouraged to review the information provided by those organizations to understand the significance of the environmental properties of the agents in this document.

4.3 Electrostatic discharge

Care shall be taken when discharging extinguishant into potentially explosive atmospheres. Electrostatic charging of conductors not bonded to earth can occur during the discharge of extinguishant. These conductors can discharge to other objects with sufficient energy to initiate an explosion. Where the system is used for inerting, pipework shall be adequately bonded and earthed.

4.4 Compatibility with other extinguishants

Mixing of extinguishants in the same container shall be permitted only if the system is approved for use with such a mixture.

Systems using the simultaneous discharge of different extinguishants to protect the same enclosed space shall not be permitted.

4.5 Temperature limitations

All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation. Devices shall normally be designed to function properly from $-20\text{ }^{\circ}\text{C}$ to $+50\text{ }^{\circ}\text{C}$, or marked to indicate temperature limitations, or in accordance with manufacturers' specifications which shall be marked on the name-plate, or (where there is no name-plate) in the manufacturer's instruction manual.

5 Safety

5.1 Hazard to personnel

Any hazard to personnel created by the discharge of gaseous extinguishants shall be considered in the design of the system, in particular regarding the hazards associated with particular extinguishants in the supplementary parts of the ISO 14520 series. Unnecessary exposure to all gaseous extinguishants shall be avoided.

Adherence to the ISO 14520 series does not remove the user's statutory responsibility to comply with the appropriate safety regulations.

The decomposition products generated by the clean agent breaking down in the presence of very high degrees of heat can be hazardous. All of the present halocarbon agents contain fluorine. In the presence of available hydrogen (from water vapour, or the combustion process itself), the main decomposition product is hydrogen fluoride (HF).

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

The amount of agent that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the particular clean agent, the concentration of the agent, and the length of time the agent is in contact with the flame or heated surface. If there is a very rapid build-up of concentration to the critical value, then the fire will be extinguished quickly, and the decomposition will be limited to the minimum possible with that agent. Should that agent's specific composition be such that it could generate large quantities of decomposition products, and the time to achieve the critical value is lengthy, then the number of decomposition products can be quite great. The actual concentration of the decomposition products then depends on the volume of the room in which the fire was burning and on the degree of mixing and ventilation.

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

Non-liquefied agents do not decompose measurably in extinguishing a fire. As such, toxic or corrosive decomposition products are not found. However, breakdown products of the fire itself can still be substantial and can make the area untenable for human occupancy.

5.2 Safety precautions

5.2.1 General

As acceptable alternatives to the requirements of [5.2](#) and [5.3](#), either the requirements of [Annex G](#) for safe personnel exposure guidelines or those requirements specified by appropriate national standards shall be followed.

The safety precautions required by this document do not address toxicological or physiological effects associated with the products of combustion caused by fire. The maximum exposure time assumed by the safety precautions in this document is 5 min. Exposure times longer than 5 min can involve physiological or toxicological effects not addressed by this document.

Upper limit threshold concentrations shall be established for any impurity that could result in acute toxicity at concentrations below the cardiac sensitization NOAEL.

5.2.2 For normally occupied areas

The minimum safety precautions taken shall be in accordance with [Table 2](#). The intent of this table is to avoid unnecessary exposure of occupants to the discharged extinguishant. Factors such as the time for egress and the risk to the occupants, by the fire, should be considered when determining the system discharge time delay. Where national standards require other precautions, these should be implemented.

Table 2 — Minimum safety precautions

Maximum concentration	Time delay device	Automatic/manual switch	Lock-off device
Up to and including the NOAEL	Required	Not required	Not required
Above the NOAEL and up to the LOAEL	Required	Required	Not required
LOAEL and above	Required	Required	Required

When using inert gas agents, the NOAEL and LOAEL are the agent concentrations that result in low-limit partial pressures of oxygen of 12,1 kPa (91,0 mm Hg) and 10,2 kPa (76,6 mm Hg), respectively. These agent concentrations depend on the barometric pressure at the altitude at which the hazard is located. The relationship of altitude to average atmospheric pressure is as expressed in [Formula \(1\)](#):

$$P_{ATM} = 101,325(1 - 0,000\ 022\ 557\ 7h)^{5,255\ 88} \quad (1)$$

where

h is the altitude, m;

P_{ATM} is the atmospheric pressure, Pa.

The maximum inert gas agent concentration, C_{MAX} , that reduces the oxygen partial pressure to the low-limit value, $P_{O2,L-L}$ can be calculated using [Formula \(2\)](#):

$$C_{MAX} = 476,2 \times (0,21P_{ATM} - P_{O2,L-L}) / P_{ATM} \quad (2)$$

where

C_{MAX} is the maximum allowable agent concentration, vol. %;

P_{ATM} is the local atmospheric pressure, Pa;

$P_{O2,L-L}$ is the minimum allowed oxygen concentration in the agent-air mixture, Pa.

The effect of applying these formulae on C_{MAX} as a function of altitude is shown in [Table 3](#).

Table 3 — Maximum inert gas agent concentration at the NOAEL and LOAEL limits as a function of altitude

			NOAEL	LOAEL
$P_{O2,L-L}$, kPa →			12,1	10,2
h	P_{ATM}	$P_{O2,ATM}$	C_{MAX}	C_{MAX}
m	kPa	kPa	vol. %	vol. %
0	101,325	21,28	43,1	52,1
250	98,358	20,66	41,4	50,6
500	95,461	20,05	39,6	49,1
750	92,634	19,45	37,8	47,6

Table 3 (continued)

			NOAEL	LOAEL
$P_{O_2,L-L}$, kPa →			12,1	10,2
h	P_{ATM}	$P_{O_2,ATM}$	C_{MAX}	C_{MAX}
m	kPa	kPa	vol. %	vol. %
1 000	89,875	18,87	35,9	46,0
1 250	87,182	18,31	33,9	44,3
1 500	84,556	17,76	31,9	42,6
1 750	81,994	17,22	29,7	40,8
2 000	79,495	16,69	27,5	38,9
2 250	77,058	16,18	25,2	37,0
2 500	74,683	15,68	22,8	35,0
2 750	72,366	15,20	20,4	32,9
3 000	70,109	14,72	17,8	30,7

5.2.3 For normally unoccupied areas

The maximum concentration shall not exceed the LOAEL for the extinguishant used unless a lock-off device is fitted.

It is recommended that systems where the NOAEL is expected to be exceeded be placed in non-automatic mode whilst the room is occupied.

WARNING — Any change to the enclosure volume, or addition or removal of fixed contents that were not covered in the original design will affect the concentration of extinguishant. In such instances, the system shall be recalculated to ensure that the required design concentration is achieved, and the maximum concentration is consistent with [Table 2](#).

5.2.4 For unoccupiable areas

The maximum concentration may exceed the LOAEL for the extinguishant used, without the need for a lock-off device to be fitted.

5.3 Occupiable areas

In areas that are protected by total flooding systems and that are capable of being occupied, the following shall be provided.

- a) Time delay devices:
 - 1) For applications where a discharge delay does not significantly increase the threat to life or property, from fire, extinguishing systems shall incorporate a pre-discharge alarm with a time delay sufficient to allow personnel evacuation before discharge.
 - 2) Time delay devices shall be used only for personnel evacuation or to prepare the hazard area for discharge.
- b) Automatic/manual switch and lock-off devices where required in accordance with [5.2](#).

NOTE Although lock-off devices are not always required, they are essential in some situations, particularly for some specific maintenance functions.

- c) Exit routes, which shall be kept clear at all times, and emergency lighting and adequate direction signs to minimize travel distances.

- d) Outward-swinging self-closing doors that can be opened from the inside, including when locked from the outside.
- e) Continuous visual and audible alarms at entrances and designated exits inside the protected area and continuous visual alarms outside the protected area, which operate until the protected area has been made safe.
- f) Appropriate warning and instructions signs.
- g) Where required, pre-discharge alarms within such areas, which are distinctive from all other alarm signals, and which, upon detection of the fire, will operate immediately on commencement of time delay.
- h) Means for prompt natural or forced-draft ventilation of such areas after any discharge of extinguishant. Forced-draft ventilation will often be necessary. Care shall be taken to completely dissipate hazardous atmospheres and not just move them to other locations, as most extinguishants are heavier than air.
- i) Instructions and drills of all personnel within or in the vicinity of protected areas, including maintenance or construction personnel who can be brought into the area, to ensure their correct actions when the system operates.

In addition to the above requirements, the following are recommended.

- 1) Personnel should not enter the enclosure until it has been verified as being safe to do so.
- 2) Self-contained breathing apparatus should be supplied, and personnel trained in its use.

5.4 Electrical hazards

Where exposed electrical conductors are present, clearances no smaller than those given in [Table 4](#) shall be provided, where practicable, between the electrical conductors and all parts of the system that can 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.

The system should be so arranged that all normal operations can be carried out with safety to the operator.

Table 4 — Safety clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out

Maximum rated voltage kV	Minimum clearance from any point on or about the permanent equipment where a person can be required to stand ^a	
	To the nearest unscreened live conductor in the air (section clearance) m	To the nearest part not at earth potential of an insulator ^b supporting a live conductor (ground clearance) m
15	2,6	2,5
33	2,75	
44	2,90	
66	3,10	
88	3,20	
110	3,35	
132	3,50	

^a Measured from the position of the feet.

^b 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 a circuit breaker.

Table 4 (continued)

Maximum rated voltage kV	Minimum clearance from any point on or about the permanent equipment where a person can be required to stand ^a	
	To the nearest unscreened live conductor in the air (section clearance) m	To the nearest part not at earth potential of an insulator ^b supporting a live conductor (ground clearance) m
165	3,80	
220	4,30	
275	4,60	

^a Measured from the position of the feet.

^b 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 a circuit breaker.

5.5 Electrical earthing

Systems within electrical substations or switch rooms shall be efficiently bonded and earthed to prevent the metalwork from becoming electrically charged.

5.6 Electrostatic discharge

The system shall be adequately bonded and earthed to minimize the risk of electrostatic discharge.

6 System design

6.1 General

This clause sets out the requirements for the design of the extinguishing system.

All ancillary systems and components are required to conform to the relevant national or International Standards.

6.2 Extinguishant supply

6.2.1 Quantity

6.2.1.1 The amount of extinguishant in the system shall be at least sufficient for the largest single hazard or group of hazards that are to be protected simultaneously.

6.2.1.2 Where required, the reserve quantity shall be as many multiples of the main supply as the authority considers necessary.

6.2.1.3 Where uninterrupted protection is required, both the main and reserve supply shall be permanently connected to the distribution piping and arranged for easy changeover.

6.2.2 Quality

The extinguishant shall conform to the relevant part of the ISO 14520 series.

6.2.3 Container arrangement

6.2.3.1 Arrangements shall be made for container and valve assemblies and accessories to be accessible for inspection, testing and other maintenance when required.

6.2.3.2 Containers shall be adequately mounted and suitably supported according to the systems installation manual to provide for convenient individual servicing of the container and its contents.

6.2.3.3 Containers shall be located as near as is practical to the enclosure they protect, preferably outside the enclosure. Containers can be located within the enclosure only if sited to minimize the risk of exposure to fire and explosion.

6.2.3.4 Storage containers shall not be located where they will be subjected to severe weather conditions or potential damage due to mechanical, chemical, or other causes. Where potentially damaging exposure or unauthorized interference is likely, suitable enclosures or guards shall be provided.

NOTE Direct or indirect sunlight has the potential to increase the container temperature above that of the surrounding atmospheric temperature.

6.2.4 Storage containers

6.2.4.1 General

Containers shall be designed to hold the specific extinguishant. Containers shall not be charged to a fill density greater than specified in the relevant part of the ISO 14520 series relating to the specific extinguishant.

The containers used in these systems shall be designed to meet the requirements of relevant national standards and as a minimum shall be suitable for the maximum pressure developed at 50 °C.

Where required, the container and valve assembly should be fitted with a pressure relief device conforming to the appropriate national standard.

6.2.4.2 Contents indication

Means shall be provided to indicate that each container is correctly charged.

6.2.4.3 Marking

Each halocarbon container shall have a permanent nameplate or other permanent marking specifying the extinguishant, tare and gross mass, and the superpressurization level (where applicable) of the container. Each inert gas container shall have a permanent marking specifying the extinguishant, pressurization level of the container and nominal volume.

6.2.4.4 Manifoldd containers

When two or more containers are connected to the same manifold, automatic means (such as check valves) shall be provided to prevent extinguishant loss from the manifold if the system is operated when any containers are removed for maintenance.

Containers connected to a common manifold in a system shall be:

- a) of the same nominal form and capacity,
- b) filled with the same nominal mass of extinguishant, and
- c) pressurized to the same nominal working pressure.

Different sized storage containers connected to a common manifold may be used for non-liquefied gas containers, provided they are all pressurized to the same nominal working pressure.

6.2.4.5 Operating temperatures

Unless otherwise approved, in-service container operating temperatures for total flooding systems shall not exceed 50 °C nor be less than -20 °C (see also [7.3.1](#)).

External heating or cooling should be used to keep the temperature of the storage container within the specified range unless the system is designed for proper operation with operating temperatures outside this range.

6.3 Distribution

6.3.1 General

6.3.1.1 Pipework and fittings shall conform to the appropriate national standards, shall be non-combustible and able to withstand the expected pressures and temperatures without damage.

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

A dirt-trap consisting of a tee with a capped nipple, at least 50 mm long, shall be installed at the end of each pipe run. Drain traps protected against interference by unauthorized personnel should be fitted at the lowest points in the pipework system if there is any possibility of a build-up of water.

6.3.1.3 In systems where valve arrangements introduce sections of closed piping, such sections shall be equipped with the following:

- a) indication of extinguishant trapped in the piping;
- b) means for safe manual venting (see [6.3.1.4](#));
- c) automatic relief of overpressures.

Over-pressure relief devices shall be designed to operate pressure:

- 1) greater than the maximum working pressure of the system, and
- 2) less than the test pressure of the pipework, or as required by the appropriate national standard.

6.3.1.4 Pressure relief devices, which can include the selector valve, shall be fitted so that the discharge, in the event of operation, will not injure or endanger personnel and, if necessary, so that the discharge is piped to an area where it will not become a hazard to personnel.

6.3.1.5 In systems using pressure-operated container valves, automatic means shall be provided to vent any container leakage that could build up pressure in the pilot system and cause an unwanted opening of the container valve. The means of pressure venting shall not prevent the operation of the container valve.

6.3.1.6 All closed-section pipework and pipework upstream of pressure-reducing devices shall be hydrostatically tested to a minimum of $1,5 \times$ the maximum working pressure or the maximum pressure obtained with a regulated system for 2 min during which there shall be no leakage. On completion of the test, the pipework shall be purged to remove moisture.

6.3.1.7 Adequate protection shall be given to pipes, fittings or support brackets and steelwork that are likely to be affected by corrosion. Special corrosion-resistant materials or coatings shall be used in highly corrosive atmospheres.

6.3.2 Piping

6.3.2.1 Piping shall be of non-combustible material having physical and chemical characteristics, such that its integrity under stress can be predicted with reliability. The thickness of the pipe wall shall be calculated in accordance with the relevant national standard. The pressure for this calculation shall be the developed pressure at a maximum storage temperature of not less than 50 °C. If higher operating temperatures are approved for a given system, the design pressure shall be adjusted to the developed pressure at maximum temperature.

In performing these calculations, all joint factors and threading, grooving or welding allowances shall be taken into account.

Where a static pressure-reducing device is used in a non-liquefied gas system, the maximum working pressure in the distribution pipework downstream of the device shall be used in the calculation of the downstream pipe wall thickness.

6.3.2.2 Cast iron and non-metallic pipes shall not be used except when approved for the rated operating pressure.

6.3.2.3 Flexible tubing or hoses (including connections) shall be of approved materials and shall be suitable for service at the anticipated extinguishant pressure and maximum and minimum temperatures.

6.3.3 Fittings

6.3.3.1 Fittings shall have a minimum rated working pressure equal to or greater than the maximum pressure in the container at 50 °C, or the temperature specified in the national standard when filled to the maximum permissible fill density for the extinguishant being used. For systems that use a pressure-reducing device in the distribution piping, the fittings downstream of the device shall have a minimum rated working pressure equal to or greater than the maximum anticipated pressure in the downstream piping.

Cast iron fittings, other than ductile or malleable cast iron, shall not be used.

NOTE In some countries it is not permitted to use any type of cast iron.

6.3.3.2 Welding and brazing alloys shall have a melting point above 500 °C.

6.3.3.3 Welding shall be performed in accordance with relevant national standards.

6.3.3.4 Where copper, stainless steel or other suitable tubing is joined with compression fittings, the manufacturer's pressure/temperature ratings of the fitting shall not be exceeded, and care shall be taken to ensure the integrity of the assembly.

6.3.4 Pipe and valve supports

Pipe and valve supports shall be of non-combustible material, shall be suitable for the expected temperature and shall be able to withstand the dynamic and static forces involved. Due allowance shall be made for the stresses induced in the pipework by temperature variations. Adequate environmental protection shall be given to supports and associated steelwork. The distance between pipe supports shall be as specified in [Table 5](#).

Adequate support shall be provided for nozzles and their reactive forces such that in no case shall the distance from the last support be greater than as follows:

a) ≤ 25 mm pipe: ≤ 100 mm;

b) > 25 mm pipe: ≤ 250 mm.

Movement of pipework, caused by temperature fluctuations arising from the environment or the discharge of extinguishant, can be substantial, particularly over long lengths and should be taken into account when deciding on support fixing methods.

Table 5 — Maximum pipework spans

Nominal diameter of the pipe DN	Maximum pipework span m
6	0,5
10	1,0
15	1,5
20	1,8
25	2,1
32	2,4
40	2,7
50	3,4
65	3,5
80	3,7
100	4,3
125	4,8
150	5,2
200	5,8

6.3.5 Valves

6.3.5.1 All valves, gaskets, O-rings, sealants and other valve components shall be constructed of materials that are compatible with the extinguishant and shall be suitable for the envisaged pressures and temperatures.

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

6.3.5.3 Special corrosion-resistant materials or coatings shall be used in severely corrosive atmospheres.

6.3.6 Nozzles

6.3.6.1 Nozzle choice and location

Nozzles, including nozzles directly attached to containers, shall be approved and shall be located with the geometry of the enclosure taken into consideration.

The type number and placement of nozzles shall be such that:

- a) the design concentration is achieved in all parts of the enclosure (see also [Annex C](#));
- b) the discharge does not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion or otherwise adversely affect the occupants; and
- c) the velocity of discharge does not adversely affect the enclosure or its contents.

Where clogging by foreign materials is possible, the discharge nozzles shall be provided with frangible discs or blow-out caps. These devices shall provide an unobstructed opening upon system operation and shall be designed and arranged so they will not injure personnel.

Nozzles shall be suitable for the intended use and shall be approved for discharge characteristics, including area coverage and height limitations (see also [Annex C](#)), or shall be approved under the procedure described in national or international nozzle standards.

Nozzles shall be of adequate strength for use with the expected working pressures, they shall be able to resist nominal mechanical abuse and shall be constructed to withstand expected temperatures without deformation.

Nozzle discharge orifice inserts shall be of corrosion-resistant material.

6.3.6.2 Nozzles in ceiling tiles

To minimize the possibility of lifting or displacement of lightweight ceiling tiles, precautions shall be taken to securely anchor tiles for a minimum distance of 1,5 m from each discharge nozzle.

NOTE The discharge velocities created by the design of nozzles can be a factor in the displacement of ceiling tiles.

6.3.6.3 Marking

Discharge nozzles shall be permanently marked to identify the manufacturer and size of the orifice.

6.3.6.4 Filters

The inlet of any nozzle assembly or pressure-reducing assembly, which contains an orifice of area less than 7 mm², shall be provided with an internal filter capable of preventing obstruction of the orifice.

6.3.7 Pressure reducing orifice assembly

Pressure reducing orifice assemblies shall be permanently marked to identify the size of the orifice. This marking shall be readily visible after the assembly is installed.

6.4 Detection, actuation and control systems

6.4.1 General

Detection, actuation and control systems can be either automatic or manual. Where they are automatic, the provision shall also be made for manual operation.

Detection, actuation, alarm and control systems shall be installed, tested and maintained in accordance with appropriate national standards.

Unless otherwise specified in a relevant national standard, 24 h minimum standby sources of energy shall be used to provide for the operation of the detection, signalling, control and actuation requirements of the system.

6.4.2 Automatic detection

Automatic detection shall be by any method or device acceptable to the authority and shall be capable of early detection and an indication of heat, flame, smoke, combustible vapours or any abnormal condition in the hazard that is likely to produce fire.

NOTE Detectors installed at the maximum approved spacing for fire alarm use can result in an excessive delay in extinguishant release, especially where more than one detection device is required to be in alarm before automatic actuation results.

6.4.3 Operating devices

6.4.3.1 Automatic operation

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 conform to the appropriate national standard. The electric power supply shall be independent of the supply for the hazard area and shall include an emergency secondary power supply with an automatic changeover in case the primary supply fails.

When two or more detectors are used, such as those for detecting smoke or flame, it is preferable for the system to operate only after signals from two detectors have been received.

6.4.3.2 Manual operation

Provision shall be made for manual operation of the firefighting system using a control situated outside the protected space or adjacent to the main exit from the space.

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.
- b) A manual device for providing direct mechanical actuation of the system or an electrical manual release system in which the control equipment monitors for abnormal conditions in the power supply and provides a signal when the power source is inadequate.

Manual operation shall cause simultaneous operation of the appropriate automatically operated valves for extinguishant release and distribution.

NOTE 1 National standards can not require a manual release or can require the release to operate via the pre-discharge alarms and time delay.

The manual operation device 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.

NOTE 2 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.

6.4.4 Control equipment

6.4.4.1 Electric control equipment

Electric control equipment shall be used to supervise the detecting circuits, manual and automatic releasing circuits, signalling circuits, electrical actuating devices and associated wiring and, when required, cause actuation. The control equipment shall be capable of operation with the number and type of actuating devices utilized.

6.4.4.2 Electrical actuators

Removal of an electrical actuator from the agent storage container valve or selector valve that it controls shall result in an audible and visual alarm of system impairment at the control panel.

6.4.4.3 Pneumatic control equipment

Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of

integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity occurs.

6.4.5 Operating alarms and indicators

6.4.5.1 Alarms or indicators, or both, shall be used to indicate the operation of the system, hazards to personnel or failure of any supervised device. The type (audible, visual or olfactory), number and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment, or both, shall be approved.

6.4.5.2 Audible and visual pre-discharge alarms shall be provided within the protected area to give a positive warning of impending discharge. The operation of the warning devices shall be continued after extinguishant discharge until positive action has been taken to acknowledge the alarm and proceed with the appropriate action.

6.4.5.3 Alarms indicating failure of supervised devices or equipment shall give a prompt and positive indication of any failure and shall be distinct from alarms indicating operation or hazardous conditions.

6.4.6 Hold switches

Hold switches, where provided, shall be located within the protected area and shall be located near the means of egress for the area. The hold switch shall be a type that requires constant manual force to inhibit system operation. Operation of the hold function shall result in both audible and distinct visual indication of system impairment. Operation of the hold switch when the system is in the quiescent state shall result in a fault indication at the control unit. The hold switch shall be clearly recognizable for the purpose intended.

7 Extinguishant system design

7.1 General

This clause sets out the requirements for the specifications, system flow calculations and extinguishant concentrations. It shall be read in conjunction with the appropriate part of the ISO 14520 series for the specific agent.

7.2 Specifications, plans and approvals

7.2.1 Specifications

Specifications for gaseous fire-extinguishing systems shall be prepared under the supervision of a person fully experienced in the design of gaseous extinguishing systems and, where appropriate, with the advice of the authority. 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. Extinguishant specifications are included in the relevant parts of the ISO 14520 series for the specific agent.

7.2.2 Working documents

Layout and system proposal documents shall be submitted for approval to the authority before installation or modification begins. The type of documentation required is specified in [Annex A](#).

7.3 System flow calculations

7.3.1 General

System flow calculations shall be carried out at a nominal extinguishant storage temperature of 20 °C, shall have been validated by an accredited approval authority by appropriate tests, such as those described in this document, and shall be properly identified. The system design shall be within the manufacturer's specified limitations. [Annex H](#) provides guidance on how to carry out a flow calculation.

NOTE 1 Variations from the nominal 20 °C storage temperature affect flow conditions used in calculations.

NOTE 2 Pre-engineered systems do not require a flow calculation when used within approved limitations.

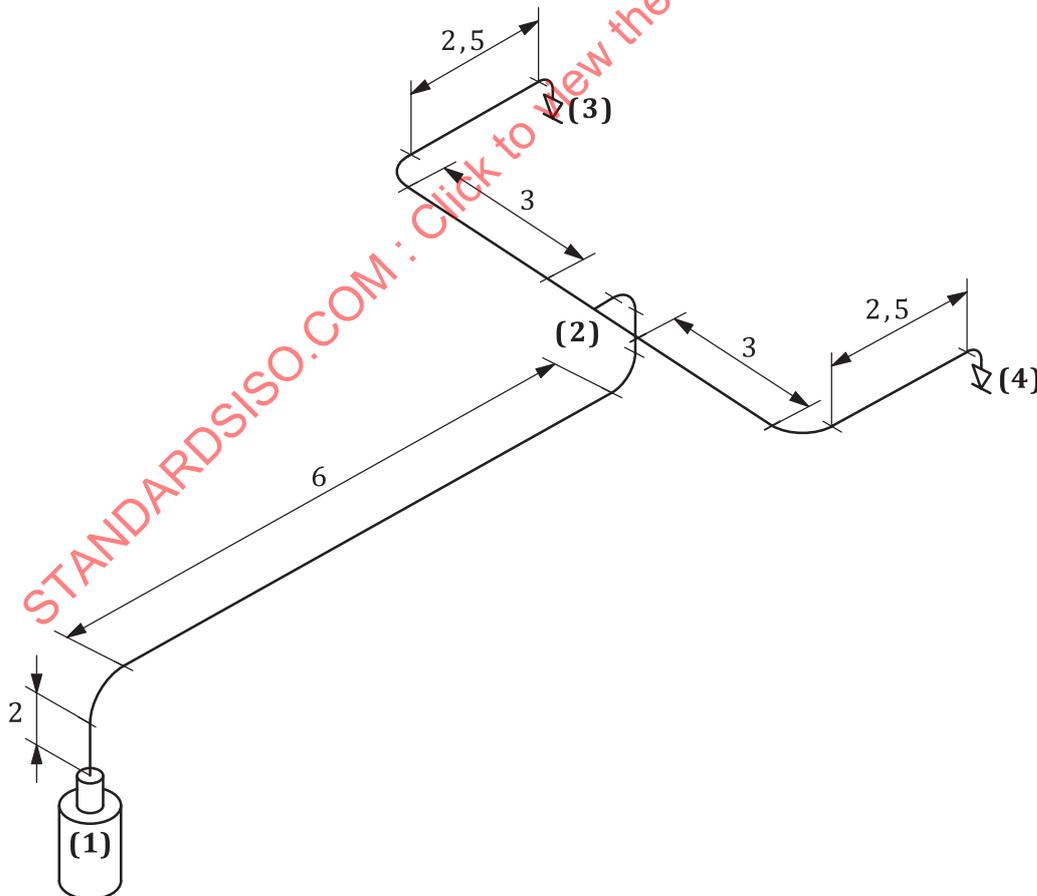
7.3.2 A balanced and unbalanced system

7.3.2.1 A balanced system shall be one of the following:

- a) actual or equivalent pipe lengths from the container to each nozzle are all within 10 % of each other;
- b) the discharge rate of each nozzle is the same (see [Figure 1](#)).

7.3.2.2 Any system that does not meet these criteria shall be considered to be an unbalanced system (see [Figure 2](#)).

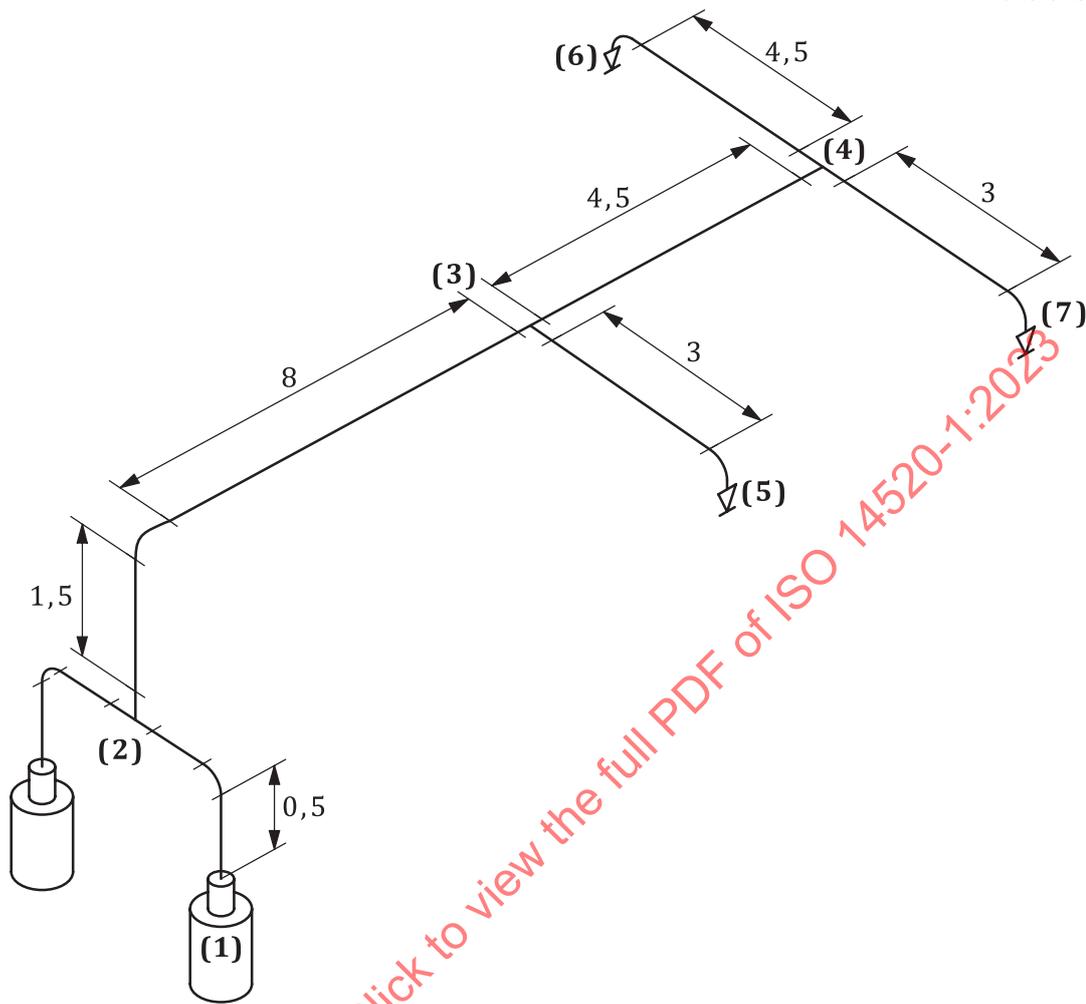
Dimensions in metres



NOTE Figures in bold in parentheses denote design nodes for calculations.

Figure 1 — Typical balanced system

Dimensions in metres



NOTE Figures in bold in parentheses denote design nodes for calculations.

Figure 2 — Typical unbalanced system

7.3.3 Friction losses

An allowance shall be made for the friction losses in pipes and in container valves, dip tubes, flexible connectors, selector valves, time delay devices and other equipment (e.g. pressure-reducing devices) within the flow line.

NOTE The flow of liquefied gas has been demonstrated to be a two-phase phenomenon, the fluid consisting of a mixture of liquid and vapour the proportions of which are dependent on pressure and temperature. The pressure drop is non-linear, with an increasing rate of pressure loss as the line pressure reduced by pipe friction.

7.3.4 Pressure drop

The pressure drop shall be calculated using two-phase flow equations for liquefied gases and single-phase flow equations for non-liquefied gases.

NOTE These equations use friction factors and constants dependent on pressure and density obtained empirically. As the formulae cannot be solved directly, a computer program is usually used to assist with a large number of iterative calculations in which pipe and nozzle sizes and, if appropriate, size of pressure reducing devices are selected within prescribed pressure losses.

7.3.5 Elevation changes

Pressure changes due to changes in pipe elevation shall be calculated.

7.3.6 Valves and fittings

Valves, fittings and check valves shall be rated for resistance coefficient or equivalent length in terms of pipe, or tubing sizes with which they will be used. The equivalent length of the container valves shall be listed and shall include syphon tube (where fitted), valve, discharge head, flexible connector and check valve.

7.3.7 Piping length

The piping length and nozzle and fitting orientation shall be in accordance with the manufacturer's approved manual to ensure proper system performance.

7.3.8 Drawings

If the final installation varies from the prepared drawings and calculations, new as-installed drawings and calculations shall be prepared.

7.3.9 Liquefied gases — Specific requirements

The minimum discharge rate for liquefied extinguishants shall be sufficient to maintain the velocity required for turbulent flow to prevent separation.

NOTE If the turbulent flow is not maintained, separation of the liquid and gaseous phases will occur, which can lead to unpredictable flow characteristics.

7.4 Enclosures

7.4.1 The protected enclosure shall have sufficient structural strength and integrity to contain the extinguishant discharge. Venting shall be provided to prevent excessive over or under pressurization of the enclosure. Guidance on gaseous system venting can be found in ISO 21805.

7.4.2 To prevent loss of extinguishant through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures. Where reasonable confinement of extinguishants is not practicable, protection shall be extended to include the adjacent connected hazards or work areas.

7.4.3 Forced-air ventilating systems shall be shut down or closed automatically where their continued operation would adversely affect the performance of the fire-extinguishing system or result in the propagation of the fire. Ventilation systems necessary to ensure safety are not required to be shut down upon system activation. An extended extinguishant discharge shall be provided to maintain the design concentration for the required duration of protection. The volumes of both ventilated air and the ventilation system ductwork shall be considered as part of the total hazard volume when determining extinguishant quantities.

All services within the protected enclosure (e.g. fuel and power supplies, heating appliances, paint spraying) that are likely to impair the performance of the extinguishing system should be shut down prior to, or simultaneously with, the discharge of the extinguishant.

7.5 Effects of noise

Extinguishing systems have two major sources of noise: the alarm devices used to warn personnel to leave the area before the agent is released and the discharge of the agent itself. The noise output from alarm devices is normally available from manufacturers, but noise from the discharge of the system

can vary according to the type of system used. It should be determined whether it is necessary to take measures designed to reduce the noise reaching sensitive equipment, such as certain hard disk drives, by selection and location of system components and the enclosure design. This could include installing the sensitive equipment in soundproof enclosures, changing the nozzle spacings, and /or using nozzles and alarms that have been developed to reduce the sound output.

7.6 Extinguishant concentration requirements

7.6.1 Flame extinguishment

7.6.1.1 For fire classifications, see ISO 3941.

7.6.1.2 The minimum Class B design concentration for each extinguishant shall be a demonstrated extinguishing concentration for each Class B fuel plus a safety factor of 1,3. The extinguishing concentration used shall be that demonstrated by the cup burner test, carried out in accordance with the method set out in [Annex B](#), that has been verified with the heptane pan tests detailed in [C.6.2](#). For hazards involving multiple fuels, the value for the fuel requiring the greatest design concentration shall be used. The extinguishing concentration shall be taken as the cup burner value or the heptane pan test value (see [Annex C](#)), whichever is greater. Where the heptane pan test value is not available, refer to [Annex I](#).

7.6.1.3 The extinguishing concentration for Class A surface fires shall be the greater of the values determined by the wood crib and polymeric sheet fire tests described in [Annex C](#). The minimum design concentration for Class A fires shall be the extinguishing concentration increased by a safety factor of 1,3. For non-cellulosic Class A fuels, higher design concentrations can be required.

If polymeric sheet fire test data are not available, an extinguishing concentration of 95 % of that determined from the heptane fire test shall be used.

The safety factor of 1,3 relates to the increase of 30 % from the extinguishing concentration to the design concentration, which results in an additional quantity of the agent. Circumstances that are not adequately covered by this factor (although in some cases they are covered by other requirements in this document) and which need allowance for additional extinguishant (i.e. more than 30 %) include but are not limited to the following.

- a) Where leakage occurs from a non-tight enclosure. This is covered in this document by the requirement for a room integrity test and sealing of the enclosure to achieve a defined hold time.
- b) Where leakage occurs due to doors being opened during or immediately after discharge. This should be covered by operational protocols for individual risks.
- c) Where it is important to minimize the quantities of toxic or corrosive products of combustion from the fire.
- d) Where it is important to minimize the toxic or corrosive breakdown products from the extinguishant itself.
- e) Where excessive leakage occurs from an enclosure due to expansion of the extinguishant.
- f) Where hot surfaces, heated by fire or other means, can cause degradation of the extinguishing agent and hence reduce the efficiency of the agent.
- g) Where metal surfaces, heated by the fire, can act as an ignition source if not adequately cooled during agent discharge and hold time.

In practice, the application of this document is likely to result in higher safety factors (e.g. by the application of gross volumes rather than net volumes and design of systems for minimum anticipated temperatures) than those that apply in real conditions.

WARNING — Under certain conditions, it can be dangerous to extinguish a burning gas jet. As a first measure, shut off the gas supply.

CAUTION — It is recognized that the wood crib and polymeric sheet Class A fire tests do not always adequately indicate extinguishing concentrations suitable for the protection of certain plastic fuel hazards (e.g. electrical and electronic type hazards involving grouped power or data cables such as computer and control room under-floor voids, telecommunication facilities, etc.). An extinguishing concentration not less than that determined in accordance with [7.6.1.3](#), or not less than 95 % of that determined from the heptane fire tests described in [B.7](#) and [C.6.2](#), whichever is the greater, should be used under certain conditions. These high hazard Class A conditions can include the following:

- a) cable bundles greater than 100 mm in diameter;
- b) cable trays with a fill density greater than 20 % of the tray cross-section;
- c) horizontal or vertical stacks of cable trays (closer than 250 mm);
- d) equipment energized during the extinguishment period where the collective power consumption exceeds 5 kW.

Several scenarios could exist in certain enclosures, which shall be considered when selecting either the regular Class A hazard or the high hazards Class A concentration.

Scenario 1 – Enclosure with both regular and high hazards elements, such as a room with ceiling and floor voids, but without re-circulating air handling equipment running during the discharge and hold time.

In enclosures with a room and ceiling void space containing regular Class A hazards and a floor void meeting the high hazard criteria, as a minimum, the floor void shall be classified as a higher hazard. The room and ceiling voids are considered to contain regular hazards that do not need to be provided with higher hazard concentrations if the re-circulating air handling equipment is shut down prior to agent discharge.

Scenario 2 – Enclosure with both regular and high hazard elements, such as a room with ceiling and floor voids, and with re-circulating air handling equipment running during the discharge and hold time.

In enclosures with a room and ceiling void space containing regular Class A hazards and a floor void meeting the high hazard criteria, which are supplied with re-circulating air handling equipment, that is not shut down prior to agent discharge, the complete enclosure should be provided with a higher hazard concentration.

Scenario 3 – Enclosures without floor voids/high hazards

In enclosures with a room not having a high hazard and not having floor voids or where it is definitively established that the floor void does not have sufficient fire load to require a higher hazard concentration, then a regular hazard concentration may be used throughout the enclosure.

For any enclosure where it cannot be determined that only a regular hazard exists, the whole enclosure should be treated as a higher hazard throughout and the higher hazard concentrations applied.

7.6.2 Inerting

Inerting concentrations shall be used where conditions for subsequent reflash or explosion could exist. These conditions exist when both:

- a) the quantity of fuel permitted in the enclosure is sufficient to develop a concentration equal to or greater than one half of the lower flammable limit throughout the enclosure, and
- b) the volatility of the fuel before the fire is sufficient to reach the lower flammable limit in the air (maximum ambient temperature or fuel temperature exceeds the closed cup flash point)

temperature) or the system response is not rapid enough to detect and extinguish the fire before the volatility of the fuel is increased to a dangerous level as a result of the fire.

The minimum design concentrations used to inert atmospheres involving flammable liquids and gases are determined by the test in [Annex D](#), plus a safety factor of 10 %.

7.7 Total flooding quantity

7.7.1 General

The amount of extinguishant required to achieve the design concentration shall be calculated from [Formulae \(3\)](#) or [\(4\)](#) as appropriate, or from the data in [Tables 3](#) and 4 of ISO 14520-5:2019, ISO 14520-8:2019, ISO 14520-9:2019, ISO 14520-10:2019, ISO 14520-12:2015, ISO 14520-13:2015, ISO 14520-14:2015 or ISO 14520-15:2015, as appropriate.

In addition to these calculated concentration requirements, additional quantities of extinguishant can be required by national standards to compensate for any special conditions that would adversely affect the extinguishing efficiency (see [7.6.1](#)), or if required by the physical characteristics of the extinguishant (see [7.10.1.2](#)).

7.7.2 Liquefied gases

For liquefied gases, [Formula \(3\)](#) is used to calculate the amount of extinguishant required.

$$m = \left(\frac{C}{100 - C} \right) \frac{V}{v} \quad (3)$$

7.7.3 Non-liquefied gas

For non-liquefied gases, [Formula \(4\)](#) is used to calculate the amount of extinguishant required.

$$m = \frac{V}{v} \ln \left(\frac{100}{100 - C} \right) \quad (4)$$

where

m is the total flooding quantity, in kilograms;

C is the design concentration in percent by volume;

V is the net volume of the hazard, in cubic metres (i.e. enclosed volume minus fixed structures impervious to extinguishant);

v is the specific volume, in cubic metres per kilogram: $v = k_1 + k_2 \times T$

k_1, k_2 are constants specific to the extinguishant being used, supplied by the extinguishant manufacturer;

T is the minimum anticipated ambient temperature of the protected volume, in degrees centigrade.

For some purposes (e.g. filling of containers), it is convenient to express the flooding quantity as the volume at given reference (standard) conditions. For those cases, the total flooding quantity is calculated using [Formula \(5\)](#):

$$Q_R = m \times v_R \quad (5)$$

where

- Q_R is the total flooding quantity, in cubic metres, expressed at ambient pressure [1,013 bar absolute (1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm²)] and T_R ;
- m is the total flooding quantity, in kilograms;
- v_R is the specific volume at the reference temperature, in cubic metres per kilogram: $v_R = k_1 + k_2 \times T_R$
- k_1, k_2 are constants specific to the extinguishant being used, supplied by the extinguishment manufacturer;
- T_R is the reference temperature, in degrees centigrade.

7.8 Altitude adjustment

The design quantity of the extinguishant shall be adjusted to compensate only for ambient pressures that vary more than 11 % (equivalent to approximately 1 000 m of elevation change) from standard sea level pressure (1,013 bar² absolute). The ambient pressure is affected by changes in altitude, pressurization or depressurization of the protected enclosure, and weather-related barometric pressure changes. The extinguishant quantity is determined by multiplying the quantity determined in 7.6 by the ratio of the average ambient enclosure pressure to the standard sea level pressure. Correction factors for gaseous agents are shown in [Table 6](#).

Table 6 — Correction factors

Equivalent altitude m	Correction factor
-1 000	1,130
0	1,000
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

7.9 Duration of protection

7.9.1 It is important that an effective extinguishant concentration be not only achieved but also maintained for a sufficient period of time to allow effective emergency action. This is equally important in all classes of fires since a persistent ignition source (e.g. an arc, heat source, oxyacetylene torch, or “deep-seated” fire) can lead to a resurgence of the initial event once the extinguishant has dissipated.

7.9.2 It is essential to determine the likely period during which the extinguishing concentration will be maintained within the protected enclosure. This is known as the hold time. The hold time shall be predicted by the door fan test specified in [Annex E](#) or determined by a full discharge test based on the following criteria.

- a) The start of the hold time is when the concentration throughout the enclosure shall be the minimum design concentration.

2) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm².

- b) At the end of the hold time, the extinguishant concentration at the elevation of the protected hazard shall be not less than 85 % of the design concentration.
- c) The hold time shall be not less than 10 min unless otherwise specified by the authority.

7.10 System performance

7.10.1 Discharge time

7.10.1.1 Liquefied extinguishant

The liquefied extinguishant discharge shall be completed as quickly as possible to suppress the fire and limit the formation of decomposition products. In no case shall the discharge time required to achieve 95 % of the design concentration exceed 10 s at 20 °C, or as otherwise required by the authority.

The discharge time period is defined as the time required to discharge from the nozzles 95 % of the extinguishant mass required to achieve the design concentration at 20 °C. For liquefied extinguishants, this can be approximated as the interval between the first appearance of liquid at the nozzle and the time when the discharge becomes predominantly gaseous. Flow calculations performed in accordance with 7.3 or with the approved pre-engineered systems instruction manuals shall be used to demonstrate conformance to this.

7.10.1.2 Non-liquefied extinguishant

For inert gas agents, the discharge time is the time required to discharge from the nozzles 95 % of the extinguishant required to achieve the minimum design concentration for flame extinguishing at 20 °C and shall not exceed 60 s for Class B fuel hazards, 120 s for both regular and high hazard Class A applications. Flow calculations performed in accordance with 7.3 or with the approved pre-engineered systems instruction manuals shall be used to demonstrate conformance to this.

7.10.2 Extended discharge

When an extended discharge is necessary, the rate shall be sufficient to maintain the desired concentration for the required hold time.

8 Commissioning and acceptance

8.1 General

This clause sets out the minimum requirements for the commissioning and acceptance of the gaseous extinguishing system.

8.2 Tests

8.2.1 General

The completed system shall be reviewed and tested by a competent person to meet the approval of the authority. Only equipment and devices designed to national standards shall be used in the systems. To determine that the system has been properly installed and will function as specified, the tests specified in 8.2.2 to 8.2.9 shall be performed.

8.2.2 Enclosure check

Determine that the protected enclosure is in general conformance with the plans.

8.2.3 Review of mechanical components

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

8.2.3.2 Nozzles and pipe size and, if appropriate, pressure-reducing devices shall be in accordance with system drawings. The means for pipe size reduction and attitudes of tees shall be checked for conformance to the design.

8.2.3.3 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 in such a manner that piping cannot become detached during discharge.

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

8.2.3.5 The discharge nozzles shall be oriented in such a manner that optimum extinguishant dispersal can be effected.

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

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

8.2.3.8 All extinguishant storage containers shall be properly located in accordance with the "approved for construction" set of system drawings, as specified in [7.3.8](#).

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

8.2.3.10 A discharge test for extinguishants is generally not recommended. However, if a discharge test is to be conducted, the mass of the extinguishant shall be determined by weighing or other approved methods. Concentration measurements should be made at a minimum of three points, one at the highest hazard level.

However, a discharge test may be conducted if acceptable to the authority.

8.2.3.11 An adequate quantity of extinguishant to produce the desired specified concentration shall be provided. 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.

8.2.3.12 Unless the total piping contains not more than one change in direction fitting between the storage container and the discharge nozzle, and unless all piping has been physically checked for tightness, the following tests shall be carried out.

- a) All open-ended piping shall be pneumatically tested in a closed circuit for 10 min at 3 bar³⁾. At the end of 10 min, the pressure drop shall not exceed 20 % of the test pressure.

3) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1N/mm²

- b) All closed-section pipework and pipework upstream of pressure-reducing devices shall be hydrostatically tested to a minimum of 1,5 times the maximum working pressure for 2 min during which there shall be no leakage. On completion of the test, the pipework shall be purged to remove moisture.

It is recommended that hydrostatic testing be carried out at the manufacturer's works where practicable.

WARNING — Pneumatic pressure testing creates a potential risk of injury to personnel in the area, as a result of airborne projectiles if a 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.

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

8.2.4 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 [7.4.1](#)). Unless otherwise required by the authority (see [3.2](#)), the test specified in [Annex E](#) shall be used.

8.2.5 Review of electrical components

8.2.5.1 All wiring systems shall be properly installed in accordance with the appropriate national standard and the system drawings (see [7.3.8](#)). The a.c. and d.c. wiring shall not be combined in a common conduit unless properly shielded and earthed.

8.2.5.2 All field circuitry shall be tested for earthing faults and short circuit condition. When testing field circuitry, all electronic components (such as smoke and flame 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. Replace components after testing the circuits.

8.2.5.3 Adequate and reliable primary standby sources of energy, which conform to [6.4](#) shall be used to provide for the operation of the detection, signalling, control and actuation requirements of the system.

8.2.5.4 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.

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

8.2.5.5 Check that for systems using alarm silencing, this function does not affect other auxiliary functions, such as air handling or power cut-off where they are required in the design specification.

8.2.5.6 Check the detection devices to ensure that the types and locations are as specified in the system drawings and are in accordance with the manufacturer's requirements.

8.2.5.7 Check that manual release devices are properly installed and are readily accessible, accurately identified and properly protected to prevent damage.

8.2.5.8 Check that all manual release devices used to release extinguishants require two separate and distinct actions for operation. They shall be properly identified. Particular care shall be taken where manual release devices for more than one system are nearby and could be confused or the wrong system actuated. For manual release devices in this instance, it shall be clearly identified which hazard enclosure they protect.

8.2.5.9 Check that for systems with a main/reserve capability, the main/reserve switch is properly installed, readily accessible and clearly identified.

8.2.5.10 Check that for systems using hold switches requiring constant manual force, these are properly installed, readily accessible within the hazard area and clearly identified.

8.2.5.11 Check that the control panel is properly installed and readily accessible.

8.2.6 Preliminary functional tests

8.2.6.1 Where a system is connected to a remote central alarm station, notify the station 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. Notify all concerned personnel at the end-user's facility that a test is to be conducted and instruct them as to the sequence of operation.

8.2.6.2 Disable or remove each extinguishant storage container release mechanism and selector valve where fitted so that activation of the release circuit will not release extinguishant. Reconnect the release circuit with a functional device in place of each extinguishant storage container release mechanism.

For electrically actuated release mechanisms, these devices include suitable lamps, flashbulbs, or circuit breakers. Pneumatically actuated release mechanisms include pressure gauges. Refer to the manufacturer's recommendations in all cases.

8.2.6.3 Check each resettable detector for proper response.

8.2.6.4 Check that polarity has been observed on all polarized alarm devices and auxiliary relays.

8.2.6.5 Check that all required end-of-line devices have been installed.

8.2.6.6 Check all supervised circuits for correct fault response.

8.2.7 System functional operational test

8.2.7.1 Operate the detection initiating circuit(s). All alarm functions shall occur according to the design specification.

8.2.7.2 Operate the necessary circuit to initiate a second alarm circuit if present. Verify that all second alarm functions occur according to design specifications.

8.2.7.3 Operate the manual release device. Verify that manual release functions occur according to design specifications.

8.2.7.4 Where appropriate, operate the hold switch. Verify that functions occur according to the design specifications. Confirm that visual and audible supervisory signals are received at the control panel.

8.2.7.5 Check the function of all resettable valves and actuators, unless testing the valve will release the extinguishant.

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

8.2.7.6 Check pneumatic equipment, where fitted, for integrity, to ensure proper operation.

8.2.8 Remote monitoring operations (if applicable)

8.2.8.1 Disconnect the primary power supply, then operate one of each type of input device while on standby power. Verify that an alarm signal is received at the remote panel after the device is operated. Reconnect the primary power supply.

8.2.8.2 Simulate each type of fault condition and verify receipt of fault conditions at the remote station.

8.2.9 Control panel primary power source

8.2.9.1 Verify that the control panel is connected to a dedicated unswitched circuit and is labelled properly. This panel shall be readily accessible, but access shall be restricted to authorized personnel only.

8.2.9.2 Test a primary power failure in accordance with the manufacturer's specification, with the system fully operated on standby power.

8.2.10 Completion of functional tests

When all functional tests are complete (8.2.6 to 8.2.9), reconnect each storage container so that activation of the release circuit will release the extinguishant. Return the system to its fully operational design condition. Notify the central alarm station and all concerned personnel at the end-user's facility 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.

8.3 Completion certificate and documentation

The installer shall provide the user with a completion certificate, a complete set of instructions, calculations and drawings showing the system as-installed, and a statement that the system complies with all the appropriate requirements of this document, and giving details of any departure from appropriate recommendations. The certificate shall give the design concentrations and, if carried out, reports of any additional test including the door fan test.

9 Inspection, maintenance, testing and training

9.1 General

This clause specifies the requirements for inspection, maintenance and testing of a gaseous fire-extinguishing system and for the training of inspection and maintenance personnel.

9.2 Inspection

9.2.1 General

9.2.1.1 At least annually, or more frequently as required by the authority, all systems shall be thoroughly inspected and tested for proper operation by competent personnel.

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

9.2.1.3 The storage container contents shall be checked at least every six months as follows.

- a) Liquefied gases: for halocarbon agents, if a container shows a loss of agent in quantity of more than 5 % or a loss of pressure (adjusted for temperature) of more than 10 %, it shall be refilled or replaced.
- b) Non-liquefied gases: for inert gas agents, the pressure is an indication of agent quantity. If a container shows a loss of agent quantity or a loss of pressure (adjusted for temperature) of more than 5 %, it shall be refilled or replaced.

9.2.1.4 All extinguishant removed from containers during service or maintenance procedures shall be collected and recycled, or disposed of in an environmentally sound manner, and in accordance with existing laws and regulations.

Inert gas mixtures based on those gases normally found in the earth's atmosphere are exempted from this requirement.

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

9.2.2 Container

Containers shall be subjected to periodical tests as required by the relevant national standard.

9.2.3 Hose

All system hoses shall be examined annually for damage. If a visual examination shows any defect, the hose shall be replaced.

9.2.4 Enclosures

9.2.4.1 At least every 12 months it shall be determined whether boundary penetration or other changes to the protected enclosure have occurred that could affect leakage and extinguishant performance. If this cannot be visually determined, it shall be positively established by repeating the test for enclosure integrity in accordance with [Annex E](#).

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

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

It is recommended that the type of hazard within the enclosure, and the volume it occupies, be regularly checked to ensure that the required concentration of extinguishant can be achieved and maintained.

9.3 Maintenance

9.3.1 General

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

NOTE The continued capability for the effective performance of a firefighting system depends on fully adequate service procedures with, where possible, periodic testing.

Installers shall provide the user with a record in which inspection and service details can be entered.

9.3.2 User's programme of inspection

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

The user's inspection programme is intended to detect faults at an early stage to allow rectification before the system operates. A suitable programme is as follows.

- a) Weekly: Visually check the hazard and the integrity of the enclosure for changes that 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 and weighing devices, if fitted, for correct reading and take the appropriate action specified in the users' manual.
- b) Monthly: Check that all personnel who 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.

9.3.3 Service schedule

A service schedule shall include requirements for periodic inspection and test for the complete installed system, including pressurized containers, as specified in the appropriate national standards.

The schedule shall be carried out by a competent person who shall provide the user with 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 the release of extinguishant. A suitable schedule is provided in [Annex F](#).

9.4 Training

All persons who 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, in particular regarding safety issues.

Annex A (normative)

Working documents

A.1 General

This document shall be prepared only by persons fully experienced in the design of extinguishing systems. Deviation from these working documents shall require permission from the authority (see [3.2](#)).

A.2 Working documents

Working documents shall include the following items:

- a) drawings, to an indicated scale of the extinguishant distribution system, including containers, location of containers, piping and nozzles, valves and pressure-reducing devices (if fitted) and pipe hanger spacing;
- b) name of owner and occupant;
- c) location of the 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) type of extinguishant being used;
- g) extinguishing or inerting 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 extinguishant;
- j) description of the nozzle(s) used, including inlet size, orifice port configuration, and orifice size/code and orifice size of pressure-reducing devices, if applicable;
- 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 the extinguishant 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.

A.3 Specific details

A.3.1 Pre-engineered systems

For pre-engineered systems, the end-user shall be provided with the manufacturer's system design and maintenance information.

A.3.2 Engineered systems

For engineered systems, the end-user shall be provided with the manufacturer's system design and maintenance information.

Details of the system shall include the following:

- a) information and calculations on the amount of extinguishant;
- b) container storage pressure and extinguishant quantity;
- c) capacity of the container;
- d) the location, type and flow rate of each nozzle, including equivalent orifice area and pressure-reducing devices, if applicable;
- e) the location, size and equivalent lengths or resistance coefficients of pipe fittings and hoses; pipe size reduction and orientation of tees shall be clearly indicated;
- f) the location and size of the storage facility.

Information shall be submitted about the location and function of the detection devices, operating devices, auxiliary equipment and electrical circuitry if used. Apparatus and devices shall be identified. Any special features shall be adequately explained. The version of the flow calculation program shall be identified on the computer calculation printout.

Annex B (normative)

Determination of flame-extinguishing concentration of gaseous extinguishants by the cup burner method

B.1 General

This annex specifies the minimum requirements for determining the flame-extinguishing concentration of a gaseous extinguishant in the air for flammable liquids and gases, employing the cup burner apparatus.

B.2 Principle

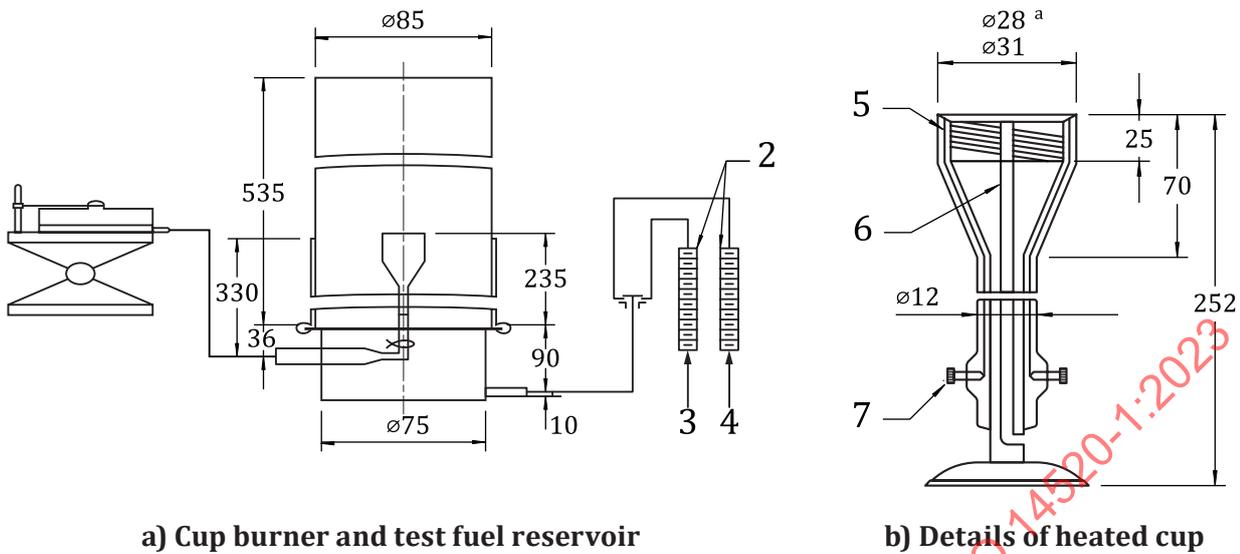
Diffusion flames of fuels burning in a round reservoir (cup), centrally positioned in a coaxially flowing air stream, are extinguished by the addition of a gaseous extinguishant to the air.

B.3 Requirements for apparatus

B.3.1 General

The cup burner apparatus for these measurements shall be arranged and constructed as in [Figure B.1](#), with the dimensions as shown; the tolerance for all dimensions shall be $\pm 5\%$ unless otherwise indicated.

Dimensions in millimetres

**Key**

- 1 levelling jack
- 2 rotameters
- 3 air
- 4 extinguishant
- 5 heating wire between inner and outer walls
- 6 thermocouple tube
- 7 heater terminal
- a Outer diameter range.

Figure B.1 — Cup burner apparatus**B.3.2 Cup**

The cup shall be round and shall be constructed of glass, quartz or steel. It shall have an outside diameter in the range of 28 mm to 31 mm, with a wall thickness of 1 mm to 2 mm. It shall have a 45° chamfer into the top edge of the cup. There shall be a means of measuring the temperature of the fuel inside the cup at a location 2 mm to 5 mm below the top of the cup. The cup shall be substantially similar in shape to the example shown in [Figure B.1](#). A cup intended for use with gaseous fuels shall have means of attaining a uniform gas flow at the top of the cup (e.g. the cup may be packed with refractory materials).

B.3.3 Chimney

The chimney shall be of round glass or quartz construction. It shall have an inside diameter of 85 mm \pm 2 mm and a wall thickness of 2 mm to 5 mm, with a height of 535 mm \pm 5 mm.

B.3.4 Diffuser

The diffuser shall have a means of fitting to the bottom end of the chimney. It shall have a means of admitting a premixed stream of air and extinguishant and have a means of uniformly distributing the air/extinguishant flow across the cross-section of the chimney. The temperature of the air/extinguishant mixture within the diffuser shall be 25 °C \pm 10 °C, measured with a calibrated temperature sensor.

B.3.5 Fuel supply

A liquid fuel supply shall be capable of delivering liquid fuel to the cup while maintaining a fixed, but adjustable, liquid level therein.

A gaseous fuel supply shall be capable of delivering a fuel gas at a controlled and fixed rate to the cup.

B.3.6 Manifold

A manifold shall receive air and extinguishant and deliver them as a single mixed stream to the diffuser.

B.3.7 Air supply

A means for delivering air to the manifold shall allow adjustment of the airflow rate. It shall have a calibrated means of measuring the airflow rate.

B.3.8 Extinguishant supply

A means for delivering extinguishant to the manifold shall allow adjustment of the extinguishant flow rate. If the method according to [B.7.2](#) is used for the determination of the extinguishant concentration, there shall be a calibrated means of measuring the extinguishant flow rate.

B.3.9 Delivery system

The delivery system shall deliver a representative and measurable sample of the agent to the cup burner in gaseous form.

B.4 Requirements for materials

B.4.1 Air

Air shall be clean, dry and oil-free. The oxygen concentration shall be a volume fraction of $(20,9 \pm 0,5) \%$. The source and the oxygen content of the air used shall be recorded.

NOTE "Air" supplied in commercial high-pressure containers can have an oxygen content significantly different from 20,9 %.

B.4.2 Fuel

Fuel shall be of a certified type and quality.

B.4.3 Extinguishant

The extinguishant shall be of a certified type and meet the specifications of the supplier. Multi-component extinguishants should be provided premixed. Liquefied extinguishants shall be provided as a pure extinguishant, i.e. not pressurized with nitrogen. Prior to commencing tests, the composition of the extinguishing gas shall be analysed.

B.5 Procedure for flammable liquids

B.5.1 Place the flammable liquid in the fuel supply reservoir.

B.5.2 Admit fuel to the cup, adjusting the liquid level to within 5 mm to 10 mm of the top of the cup.

B.5.3 Operate the heating arrangement for the cup to bring fuel temperature to $25 \text{ °C} \pm 3 \text{ °C}$ or to $5 \text{ °C} \pm 3 \text{ °C}$ above the open cup flash point, whichever is higher. During this period, the liquid level in the cup shall be adjusted so that the fuel level is above the means for temperature measurement of the fuel.

NOTE The fuel temperature given in [B.5.3](#) is intended to be the temperature at the start of the test.

B.5.4 Adjust the airflow to achieve a flow rate of 40 l/min.

B.5.5 Ignite the fuel.

B.5.6 Allow the fuel to burn for a period of 60 s (+10 s, -0 s) before beginning the flow of extinguishant. During this period, the liquid level in the cup should be adjusted so that the fuel level is within 1 mm of the top of the cup.

B.5.7 Begin the flow of extinguishing agent. Increase the flow rate of the extinguishing agent in a stepwise manner until flame extinguishment occurs. A brief interval (about 10 s) should be allowed between changes in flow rate. As the extinguishing point is approached, the size of increments in the agent flow rate should be as small as practicable. Final flow rate adjustments should be of the size of the smallest scale division of the measuring apparatus. The means of flow regulation and measurement should allow for adjustments in agent flow rate which result in an increase in the extinguishant concentration of no more than 3 % of the previous value.

On an initial run, it is convenient to use relatively large flow increments to ascertain the approximate extinguishant flow required for extinguishment, and on subsequent runs to start at a flow rate close to the critical and to increase the flow by small amounts until extinguishment is achieved. This initial run shall not be used for the determination of extinguishing concentration.

B.5.8 Determine the extinguishing concentration of the extinguishant in accordance with [B.7](#).

B.5.9 Prior to subsequent tests, remove the fuel from the cup and remove any deposits of residue or soot that can be present on the cup.

B.5.10 Repeat steps [B.5.2](#) to [B.5.9](#) for four subsequent tests (five tests in total).

B.5.11 Determine the extinguishing concentration of the extinguishant in accordance with [B.7](#) by establishing the average from five tests.

B.6 Procedure for flammable gases

B.6.1 A cup intended for use with gaseous fuels shall have a means of attaining a uniform gas flow at the top of the cup. For example, the cup used for liquid fuels may be packed with refractory materials.

B.6.2 Gaseous fuel shall be from a pressure-regulated supply with a calibrated means of adjusting and measuring the gas flow rate.

B.6.3 Adjust the airflow to 40 l/min.

B.6.4 Begin fuel flow to the cup and adjust the flow rate to attain a flame height of approximately 80 mm. The fuel temperature shall be $25\text{ °C} \pm 10\text{ °C}$.

B.6.5 Ignite the fuel.

B.6.6 Allow the fuel to burn for a period of 60 s before the beginning flow of the extinguishant.

B.6.7 Begin the flow of extinguishant. Increase the extinguishant flow rate in increments until flame extinguishment occurs and record the air, extinguishant and fuel flow rates at extinguishment. The extinguishant flow rate increment should result in an increase in the extinguishant concentration of no

more than 3 % of the previous value. Adjustments in the extinguishant flow rate are to be followed by a brief waiting period (10 s) to allow the new proportions of extinguishant and air in the manifold to reach the cup position.

On an initial run, it is convenient to use relatively large flow increments to ascertain the approximate extinguishant flow required for extinguishment and on subsequent runs to start at a flow rate close to the critical and to increase the flow by small amounts until extinguishment is achieved.

B.6.8 Upon flame extinguishment, shut off the flow of flammable gas.

B.6.9 Prior to subsequent tests, remove deposits of residue or soot if present on the cup.

B.6.10 Repeat [B.6.3](#) to [B.6.9](#) for four subsequent tests (five tests in total).

B.6.11 Determine the extinguishing concentration of the extinguishant in accordance with [B.7](#) by establishing the average of the five tests.

B.7 Extinguishant extinguishing concentration

B.7.1 Preferred method

The preferred method for determining the concentration of extinguishant vapour in the extinguishant plus air mixture which just causes flame extinguishment is to use a gas-analysing device, calibrated for the concentration range of the extinguishant-air mixtures being measured. The device may have continuous sampling capability (e.g. on-line gas analyser) or may be of a type that analyses discrete samples (e.g. gas chromatography). Continuous measurement techniques are preferred.

Alternatively, the remaining concentration of oxygen in the air/extinguishant mixture in the chimney below the cup can be measured with a continuous oxygen-analysis device. The oxygen concentration value is influenced by the extinguishant concentration. The extinguishant concentration is then calculated in [Formula \(B.1\)](#):

$$C_E = 100 \left(1 - \frac{C_O}{C_S} \right) \quad (\text{B.1})$$

where

C_E is the extinguishant concentration, as a volume fraction in percent;

C_O is the oxygen concentration of the air/extinguishant mixture in the chimney, as a volume fraction in percent;

C_S is the oxygen concentration in the supply air, as a volume fraction in percent.

B.7.2 Alternative method

The extinguishant concentration in the extinguishant plus air mixture may, alternatively, be calculated from the measured flow rates of the extinguishant and air. Where mass flow rate devices are used, the resulting mass flow rates need to be converted to volumetric flow rates; see [Formula \(B.2\)](#):

$$V_1 = m_1 / \rho_1 \quad (\text{B.2})$$

where

V_1 is the volumetric flow rate of gas i , in litres per minute;

m_1 is the mass flow rate of gas i , in grams per minute;

ρ_1 is the density of gas i , in grams per litre.

Care should be taken to use the actual vapour density. The vapour density of many halogenated hydrocarbons at ambient temperature and pressure can differ by several percent from that calculated by the ideal gas law.

EXAMPLE The density of HFC-227ea vapour at a pressure of 101,3 kPa and temperature of 295 K is approximately 2,4 % higher than would be calculated for an ideal gas. At a pressure of 6,7 kPa (6,6 %), however, the difference between the actual vapour density and that calculated for an ideal gas is less than 0,2 %.

Published property data should be used where possible. Estimating techniques may be used when published data are lacking. The source of physical property values used should be recorded in the test report.

The concentration of extinguishant as a volume fraction in percent, C_E , is calculated in [Formula \(B.3\)](#):

$$C_E = 100 \frac{q_{\text{ext}}}{q_{\text{air}} - q_{\text{ext}}} \quad (\text{B.3})$$

where

C_E is the extinguishant concentration, as a volume fraction in percent;

q_{air} is the volumetric flow rate of the air, in litres per minute;

q_{ext} is the volumetric flow rate of the extinguishant, in litres per minute.

B.8 Reporting of results

The extinguishing tests shall be documented in a written report according to ISO/IEC 17025 and the report shall contain at least the following information:

- a) schematic diagram of the apparatus, including dimensions and description of materials used;
- b) date of the report;
- c) source and an assay of the extinguishant, fuel and air;
- d) test conditions, including the following:
 - 1) barometric pressure;
 - 2) laboratory temperature or temperature of the air entering the base of the chimney, if different from laboratory temperature;
 - 3) humidity of air supplied to chimney;
- e) for each test, the fuel temperature at the start of the test, the fuel temperature at the time of extinguishment, and the temperature of the air/extinguishant mixture at extinguishment;
- f) extinguishant, gaseous fuel and airflow rates at extinguishment; if method [B.7.1](#) is used, the extinguishant concentration or the oxygen concentration instead of the extinguishant flow rate;
- g) method used to determine the extinguishing concentration;
- h) extinguishant concentration at extinguishment for each test;
- i) measurement error analysis.

Annex C (normative)

Fire extinguishment/area coverage fire test procedure for engineered and pre-engineered extinguishing units

C.1 Requirements

C.1.1 An engineered or pre-engineered extinguishing system unit shall mix and distribute its extinguishant and shall totally flood the enclosure when tested in accordance with this test method at the design limits of the operating system and most severe installation conditions.

C.1.2 The effectiveness of the nozzle distribution shall be determined in accordance with [C.5](#).

C.1.3 The extinguishant concentrations for Class A fuels shall be determined in accordance with [C.6.1](#) and [C.6.3](#).

C.1.4 The extinguishant concentrations for Class B fuels shall be determined in accordance with [C.6.2](#).

C.1.5 The tolerances applicable to dimensions specified in the descriptions of test facilities shall be $\pm 5\%$, if not otherwise stated.

C.2 Type of test and report of test results

C.2.1 Type of test

The tests described herein consider the intended use and limitations of the extinguishing system unit, with specific reference to the following:

- a) the maximum area coverage for each type of nozzle at the minimum enclosure height;
- b) the maximum enclosure height for each type of nozzle;
- c) the operating temperature range of the system;
- d) location of the nozzle in the protected area;
- e) either maximum length and size of piping and number of fittings to each nozzle or minimum nozzle pressure;
- f) maximum discharge time;
- g) maximum fill density;
- h) extinguishing concentrations for specific fuel types.

The tests to be conducted are listed in [Table C.1](#).

Table C.1 — Tests to be conducted

Test objective	Enclosure size	Test fires	Reference
Nozzle distribution verification			C.5
Nozzle minimum. height/maximum area coverage	To suit nozzle	heptane test cans	C.5.1
Nozzle maximum. height	≥100 m ³ no side less than 4 m height: to suit nozzle	heptane test cans	C.5.2
Extinguishing concentration	≥100 m ³ no side less than 4 m height: at least 3,5 m	(a) wood crib (b) heptane pan (c) polymeric sheet (i) PMMA (ii) Polypropylene (iii) ABS	C.6.1 C.6.2 C.6.3

C.2.2 Reporting of test results

A written report documenting the test results shall be prepared in accordance with ISO/IEC 17025, by an internationally recognized testing laboratory. In addition to the information described in [C.5.1.5](#), [C.5.2.5](#), [C.6.1.5](#), [C.6.2.5](#), and [C.6.3.5](#), the report shall contain at least the following information for each series of tests.

- a) Description of the extinguishing system unit including:
 - 1) Piping system schematic drawing including a description of the following:
 - i) agent containers (model, volume and superpressurization level, if employed);
 - ii) manifolds, if employed;
 - iii) piping (material, wall thickness, length, diameters, and fittings);
 - iv) pressure transducer location attached to the pipe;
 - v) nozzle (material, distribution type, orifice description including number, size and arrangement);
 - vi) for liquefied agents, location of the temperature measuring device just outside the nozzle;
 - 2) For engineered extinguishing system units, identification of the flow calculation software program employed.
- b) Description of the test enclosure, preferably in schematic form, including:
 - 1) materials of construction for enclosure;
 - 2) measured length, width, and height;
 - 3) calculated area and net volume;
 - 4) location and measured dimensions of closable openings and pressure relief vents;
 - 5) location of sensors within the enclosure.
- c) Description of the instrumentation including:
 - 1) data acquisition software employed, including the sampling rate;

- 2) description of instrumentation including:
 - i) manufacturer and model number;
 - ii) accuracy and resolution.
- d) Verification of extinguishing agent composition by a certificate of conformance or by test.
- e) Recording of data including the following:
 - 1) agent container mass
 - i) before and after filling;
 - ii) before and after discharge;
 - 2) agent quantity within the container;
 - 3) agent pressure after filling at $20\text{ °C} \pm 2\text{ °C}$;
 - 4) just prior to ignition of the test fuel
 - i) agent container conditioning time and temperature;
 - ii) agent container pressure after conditioning;
 - iii) atmospheric pressure;
 - iv) enclosure temperature;
 - v) enclosure oxygen concentration;
 - 5) graphs for the following as a function of time
 - i) enclosure oxygen concentration;
 - ii) nozzle pressure;
 - iii) enclosure temperature;
 - iv) for liquefied agents, nozzle liquid jet temperature;
 - v) for liquefied agents, enclosure agent concentration during cold discharge tests;
 - 6) discharge time;
 - 7) mass of agent discharged into the test enclosure;
 - 8) extinguishment time from the end of discharge;
 - 9) average nozzle pressure determined from nozzle pressure graphs as a function of time;
 - 10) extinguishing concentration.

C.3 Extinguishing system

C.3.1 For the nozzle distribution verification tests described in [C.5.1](#) and [C.5.2](#), before conducting each test, the agent containers shall be conditioned at the minimum operating temperature $\pm 2\text{ °C}$ for a minimum period of 16 h or the agent conditioned to the minimum operating temperature $\pm 2\text{ °C}$ as

measured by a thermocouple within the container. The minimum operating temperature shall be the same as specified in the extinguishing system unit manufacturer's installation instructions.

The extinguishing system shall be assembled as follows:

- a) pre-engineered-type extinguishing system unit — using its maximum piping limitations for the number of fittings and length of pipe to the discharge nozzles and nozzle configuration(s) as specified in the manufacturer's design and installation instructions;
- b) engineered-type extinguishing system unit — using a piping arrangement that results in the minimum nozzle design pressure at $20\text{ °C} \pm 2\text{ °C}$.

C.3.2 For the extinguishant concentration tests described in [C.6.1](#), [C.6.2](#) and [C.6.3](#), before conducting each test, the agent containers shall be conditioned at $20\text{ °C} \pm 2\text{ °C}$ for a minimum period of 16 h or the agent conditioned to $20\text{ °C} \pm 2\text{ °C}$ as measured by a thermocouple within the container.

The nozzle(s) shall be of the 360° type and representative of the extinguishing system manufacturer's commercial 360° type nozzles. The jet energy from the nozzle(s) shall not influence the development of the fire and shall not distribute the agent directly towards the test fire. The nozzle(s) shall be located as follows:

- a) one 360° type nozzle — nozzle located in the centre of the ceiling and within 30 cm from the ceiling;
- b) more than one 360° type nozzle — nozzles located symmetrically with respect to the centre of the ceiling and within 30 cm from the ceiling.

C.3.3 For the nozzle distribution verification tests described in [C.5.1](#) and [C.5.2](#) and the extinguishant concentration tests described in [C.6.1](#), [C.6.2](#) and [C.6.3](#), the extinguishing system shall be arranged and dimensioned as follows.

- a) Superpressurized liquefied extinguishants — the system arrangement shall be such that, when the agent is conditioned to $20\text{ °C} \pm 2\text{ °C}$, the discharge time of the pre-liquid gas-phase plus the two-phase flow shall be 8 s to 10 s, inclusive.
- b) Non-superpressurized liquefied extinguishants — the system arrangement shall be such that, when the agent is conditioned to $20\text{ °C} \pm 2\text{ °C}$, the discharge time of the pre-liquid gas-phase plus the two-phase flow shall be 8 s to 10 s, inclusive. The discharge is permitted to be limited by cutting off the discharge with appropriate means positioned close to the nozzle, subject to the agent quantity discharged into the test enclosure being between 65 % to 90 % of the agent quantity stored in the containers.
- c) Non-liquefied extinguishants — the system arrangement shall be such that, when the agent is conditioned to $20\text{ °C} \pm 2\text{ °C}$, the discharge time shall be 50 s to 60 s, inclusive. The discharge is permitted to be limited by cutting off the discharge with appropriate means positioned close to the nozzle, subject to the agent quantity discharged into the test enclosure being between 65 % and 90 % of the agent quantity stored in the containers.

C.4 Extinguishing concentration

C.4.1 Extinguishing agent concentration

The extinguishing agent concentration for tests [C.5.1](#), [C.5.2](#), [C.6.1](#), [C.6.2](#) and [C.6.3](#) shall be 76,9 % (i.e. 100/safety factor, where the safety factor is 1,3) of the minimum design concentration specified in the extinguishing system unit manufacturer's design and installation instructions at the ambient temperature of $20\text{ °C} \pm 2\text{ °C}$ within the enclosure. In the tests described in [C.5.1](#) and [C.5.2](#), the same extinguishing concentration shall be used as in the tests described in [C.6.2](#).

The quantity of extinguishant to obtain the specified concentration within the enclosure can be determined by using [Formula \(C.1\)](#) for liquefied gases (see [7.7.2](#)) or [Formula \(C.2\)](#) for non-liquefied gases (see [7.7.3](#)).

These formulae are reproduced here for convenience.

Liquefied gas agent:

$$m = \left(\frac{C}{100 - C} \right) \frac{V}{v} \quad (\text{C.1})$$

Non-liquefied gas:

$$m = \frac{V}{v} \ln \left(\frac{100}{100 - C} \right) \quad (\text{C.2})$$

where

- m is the total flooding quantity, in kilograms;
- C is the design concentration, in percent by volume;
- V is the net volume of the hazard, in cubic metres (i.e. enclosed volume minus fixed structures impervious to extinguishant);
- v is the specific volume, in cubic metres per kilogram: $v = k_1 + k_2 \times T$:
 - k_1, k_2 are the constants specific to the extinguishant being used, supplied by the extinguishant manufacturer;
 - T is the minimum anticipated ambient temperature of the protected volume, in degrees centigrade.

It is important to note that the agent-specific volume, v , calculated using the formulae above, is the value corresponding to sea-level atmospheric pressure. Where the atmospheric pressure differs from that standard-situation (e.g. because the test location is above sea level) the agent-vapour-specific volume is greater than the sea-level value as calculated above and as given in column 2 of [Table 3](#) in the extinguishant-specific subclauses of this document. Use of a sea-level value of agent-specific volume, v , at elevated test locations (i.e. above sea level) will result in the development of an agent concentration higher than the target value, C .

The correct agent quantity is calculated by multiplying the value for the agent-vapour-specific volume at sea-level (as calculated above and as given in column 2 of [Table 3](#) in the extinguishant-specific subclauses of this document) with the ratio expressed in [Formula \(C.3\)](#):

$$101,3 / P_{\text{ATM}} \quad (\text{C.3})$$

where P_{ATM} is the atmospheric pressure at the test location before the test in kPa.

C.4.2 Cold discharge test

A cold discharge test (i.e. with no fires present) using the same quantity of agent ($\pm 2\%$) as in the fire tests shall be conducted to verify the actual concentration of extinguishant delivered into the enclosure.

For liquefied extinguishants, the agent concentration shall be measured.

For non-liquefied extinguishants, the agent concentration or the oxygen concentration shall be measured.

The following procedure shall be used for verification of the agent concentration:

The mass of agent discharged during the cold discharge test shall be used to calculate the agent concentration by use of [Formulae \(C.4\)](#) and [\(C.5\)](#), using the density of the extinguishing agent at 20 °C and 1 013 mbar⁴⁾:

$$C_E = 100 \frac{x}{1+x} \quad (\text{C.4})$$

for non-liquefied gases:

$$C_E = 100 \frac{e^x - 1}{e^x} \quad (\text{C.5})$$

where

C_E is the concentration of extinguishing gas, in vol. %;

$$x = \frac{m}{\rho \cdot V}$$

m is the mass of gas, in kg;

ρ is the density of gas at 20 °C and 1 013 mbar;

V is the volume of the test enclosure, in m³.

This calculated agent concentration is compared with the concentration measured in the cold discharge. The measured agent concentration shall be within 1 % of the calculated agent concentration.

NOTE Under these conditions, the formula is taken as verified even without taking into account the measured values for room temperature at the start of the test and atmospheric pressure. The reason for this is that while a compensation of different influencing factors can potentially take place, as long as those factors do not change during the test series, it does not influence the test result.

If there is a difference of more than 2 % of agent concentration or more than the required measuring accuracy, or if the conditions (e.g. temperature of test enclosure) are not identical for cold discharge and fire test, the formulae have to be corrected to take into account the difference between the real behaviour of the test room and the theory.

For this correction, the possible reasons for the difference between calculation and measurement have to be investigated and the calculation formula has to be modified accordingly:

- a) different density (due to temperature and/or atmospheric pressure, for example) => use data (temperature and atmospheric pressure) measured at the start of cold discharge test;
- b) the behaviour of gas leaving the specific test enclosure does not comply 100 % with the assumptions used in the formulas => use general correction factor for the term x [see [Formula \(C.4\)](#)].

The result is a modified calculation formula which is then applicable for this specific test series.

In the case of inert gases, the oxygen concentration can be measured. Then for calculating oxygen concentration from agent concentration and vice versa, the measured start concentration of oxygen shall be taken into account, using [Formula \(C.6\)](#):

$$C_E = 100 \left(1 - \frac{C_O}{C_{\text{start}}} \right) \quad (\text{C.6})$$

4) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

where

- C_E is the extinguishant concentration, as a volume fraction in percent;
- C_O is the oxygen concentration measured in the test enclosure, as a volume fraction in percent;
- C_{start} is the oxygen concentration measured in the test enclosure at the start of the test, as a volume fraction in percent.

The extinguishing concentration for each fire test is then calculated from the highest mass of agent that has been used in the three positive fire tests. For the calculation, the formula verified (and if necessary modified) on the basis of the cold discharge test shall be used.

This means that for evaluation of the fire test data in case of using the modified formula, the room temperature and atmospheric pressure at the beginning of each fire test have to be chosen; the general correction factor is room-specific and stays the same.

C.5 Nozzle distribution verification tests

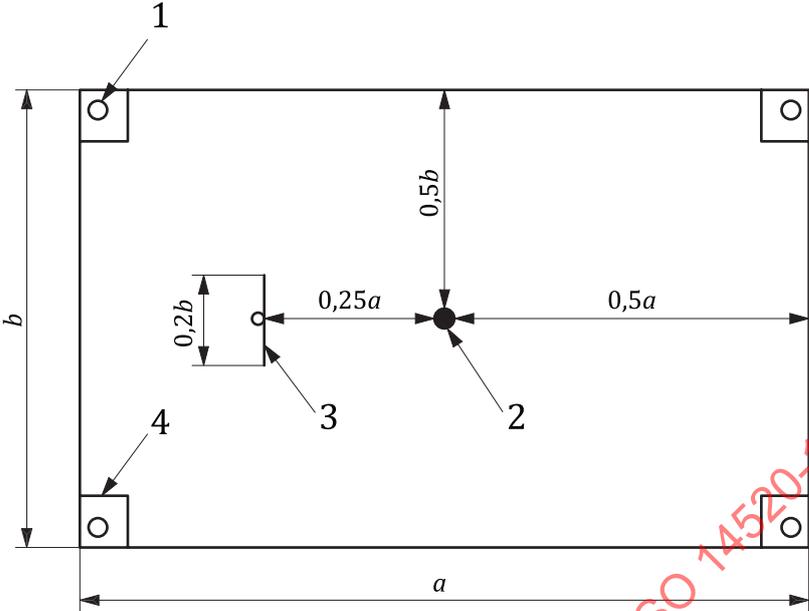
C.5.1 Nozzle minimum height/maximum area coverage test

C.5.1.1 Test facility

C.5.1.1.1 Construction

The test enclosure shall meet the following requirements.

- a) The area, $a \times b$ (see [Figures C.1](#) and [C.2](#)), and height, H , of the enclosure shall correspond respectively to the maximum nozzle area coverage and minimum nozzle height as specified in the extinguishing system unit manufacturer's installation instructions.
- b) A means of pressure relief shall be provided to limit the pressure change with a cold discharge to ± 300 Pa.
- c) Closable openings shall be provided directly above the test cans to allow for ventilation before system actuation.
- d) One baffle shall be installed between the floor and ceiling with the height of the enclosure. It shall be installed halfway between the nozzle location and one wall of the enclosure. The baffle shall be perpendicular to the long walls of the enclosure and 20 % of the length of the short walls of the enclosure (see [Figure C.1](#) for 360° nozzle and [Figure C.2](#) for 180° nozzle).

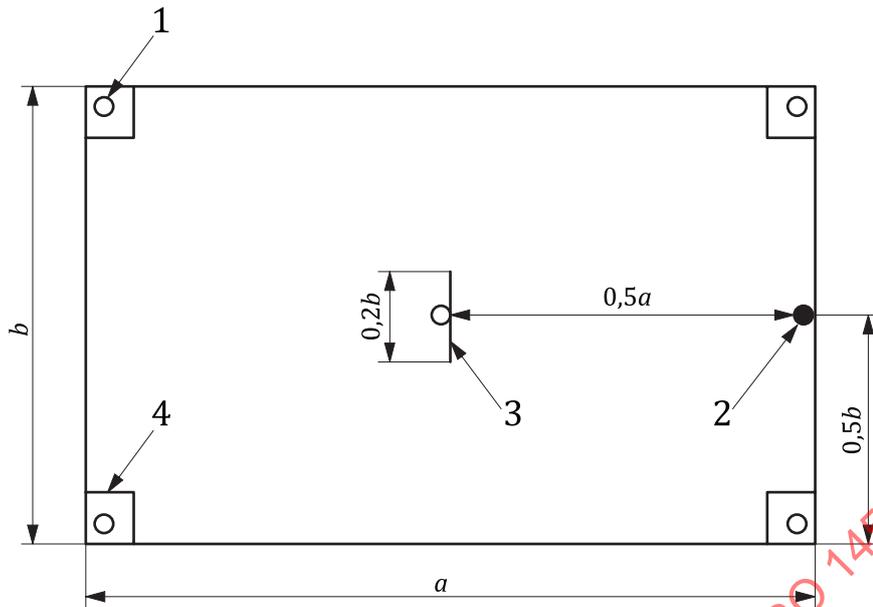


- Key**
- 1 test cans
 - 2 nozzle
 - 3 baffle
 - 4 vents

NOTE $a \times b$ = maximum nozzle area coverage for a single nozzle.

Figure C.1 — Example configuration for nozzle minimum height/maximum area coverage test for 360° nozzle

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Key

- 1 test cans
- 2 nozzle
- 3 baffle
- 4 vents

NOTE $a \times b$ = maximum nozzle area coverage for a single nozzle.

Figure C.2 — Example configuration for nozzle minimum height/maximum area coverage test for 180° nozzle

C.5.1.1.2 Instrumentation

Sampling and storage of data from the sensors described below shall occur at a rate of at least 10 Hz.

NOTE The single data points to determine agent mass and atmospheric pressure are not required to be sampled and stored at a rate of at least 10 Hz.

C.5.1.1.2.1 Oxygen concentration sensors

The oxygen concentration shall be measured and recorded using a calibrated oxygen analyser having an accuracy of 0,1 vol. % oxygen or better. The sensing equipment shall continuously monitor and record the oxygen level within the enclosure throughout the test. The accuracy of the measuring devices shall not be influenced by any of the fire products.

At least three sensors shall be located within the enclosure (see [Figures C.3](#) and [C.4](#)). All sensors shall be located horizontally 850 mm to 1 250 mm from the centre of the enclosure and at least three sensors at the following heights: 0,1 H , 0,5 H and 0,9 H (H = height of the enclosure).

C.5.1.1.2.2 Nozzle pressure sensor

During system discharge, the nozzle pressure shall be measured and recorded by a pressure transducer attached to the pipe at a distance no greater than 1 m from the nozzle.

C.5.1.1.2.3 Enclosure temperature sensors

The temperature within the enclosure shall be measured and recorded (See [Figures C.3](#) and [C.4](#)). At least one sensor shall be located horizontally 850 mm to 1 250 mm from the centre of the enclosure and at the following height: $0,5 H$ (H = height of the enclosure).

The temperature in the test enclosure shall be $20\text{ °C} \pm 5\text{ °C}$ at the beginning of each test.

C.5.1.1.2.4 Nozzle temperature sensor

During system discharge of liquefied extinguishants, the liquid jet temperature just outside the nozzle shall be measured and recorded.

C.5.1.1.2.5 Agent concentration sensors

For the cold discharge tests with liquefied extinguishants, the agent concentration shall be measured and recorded by a calibrated extinguishant analyser appropriate for the extinguishant in use having an accuracy of 0,2 vol. % or better.

For the cold discharge tests with non-liquefied extinguishants, the agent concentration or alternatively the oxygen concentration shall be measured and recorded. For measurement of agent concentration, the requirements specified for liquefied extinguishants apply. For measurement of oxygen concentration, the requirements according to [C.5.1.1.2.1](#) apply.

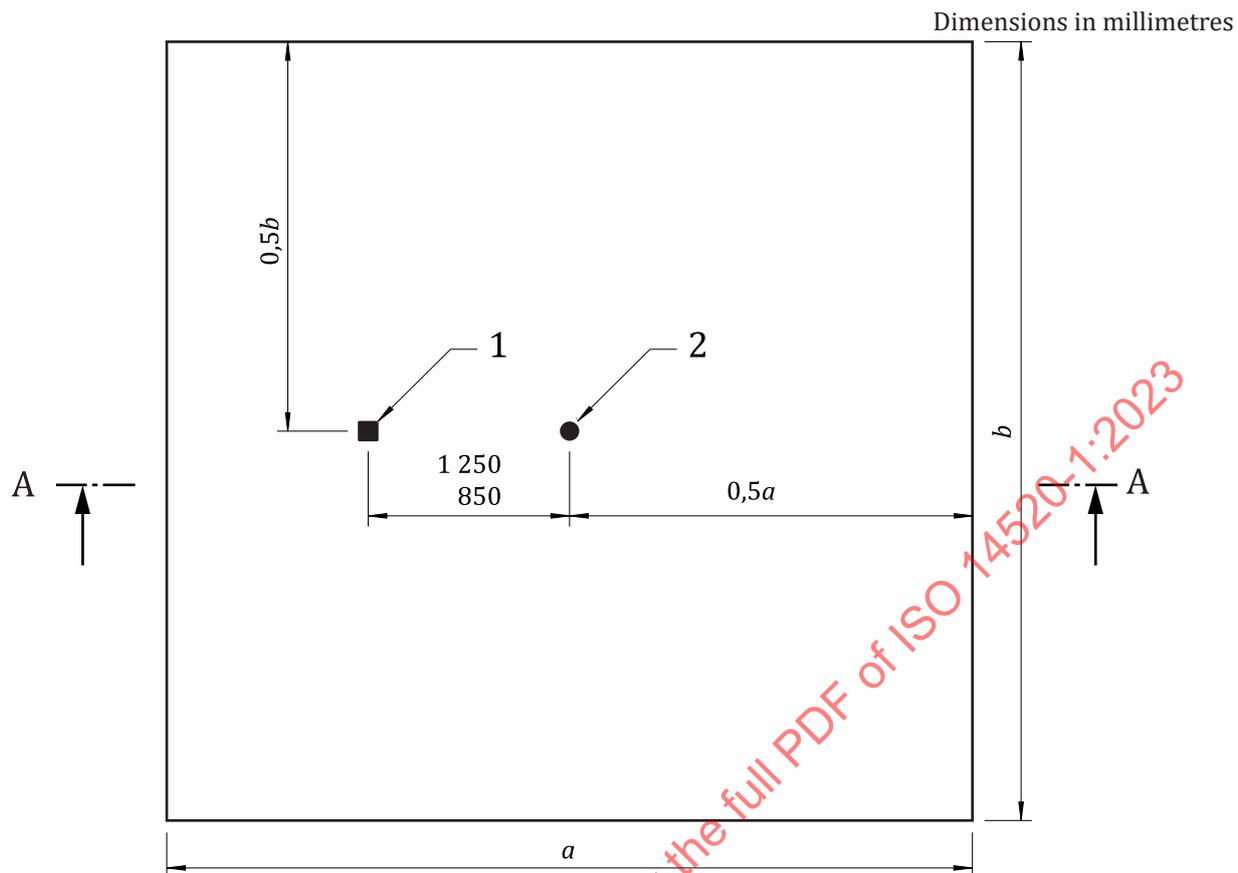
The sensors for measurement of agent concentration or oxygen concentration shall be located as specified in [C.5.1.1.2.1](#). The sensing equipment shall continuously monitor and record the concentration within the enclosure at least until the concentration stabilizes.

C.5.1.1.2.6 Agent mass

The mass of agent discharged shall be determined by calculation from the measured mass of the agent container before and after filling the container and before and after the discharge. The mass shall be measured and recorded using a calibrated weighing device capable of measuring the mass to one decimal place (0,1 kg) or better.

C.5.1.1.2.7 Atmospheric pressure

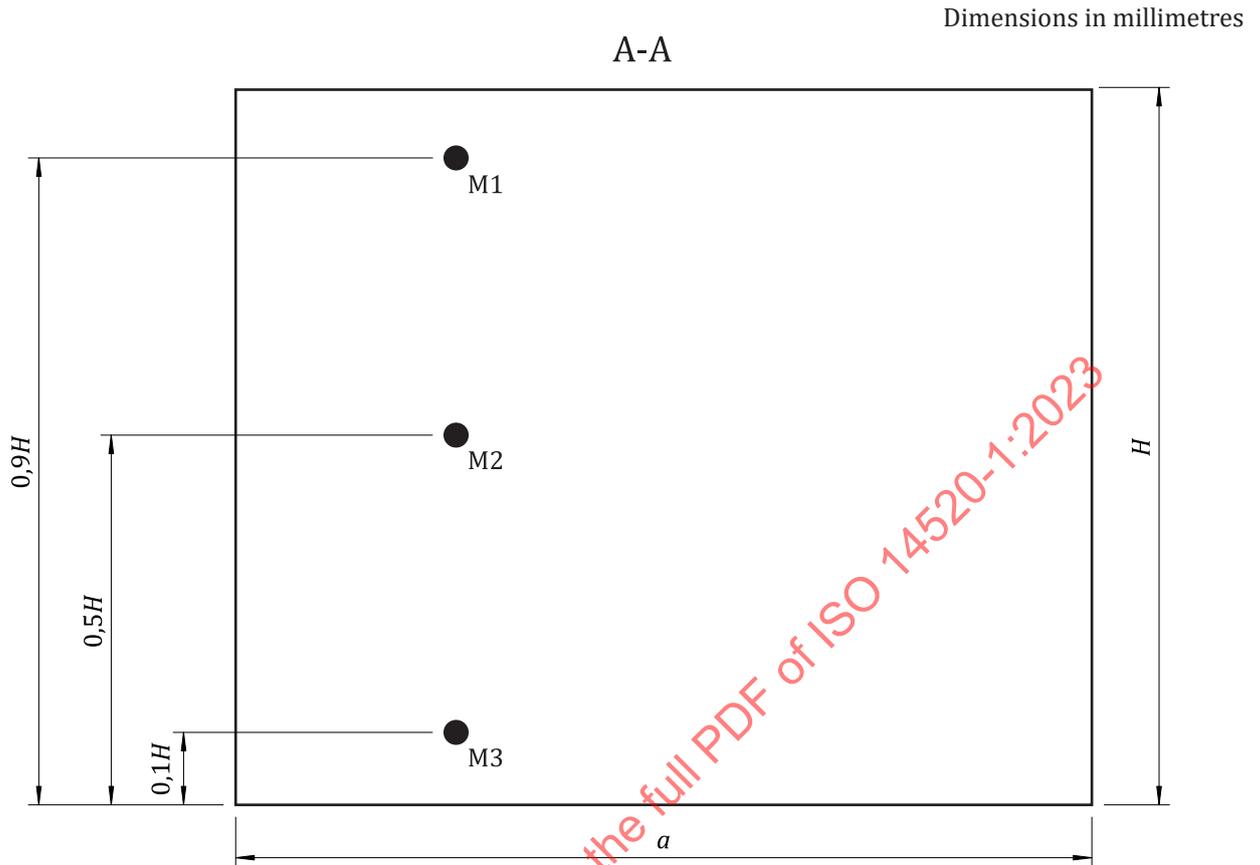
The atmospheric pressure shall be determined before each test. The atmospheric pressure shall be measured and recorded using a calibrated device having an accuracy of 100 Pa or better.



Key

- 1 measuring point
- 2 nozzle

Figure C.3 — Plan view instrumentation placement for nozzle minimum height/maximum area coverage test



NOTE The measuring points at heights $0,9 H$, $0,5 H$ and $0,1 H$ (M1 to M3), are permitted to be at different horizontal distances from the centre of the enclosure provided each is within a horizontal distance of 850 mm to 1 250 mm from the centre of the enclosure.

Figure C.4 — Side view instrumentation placement for nozzle minimum height/maximum area coverage test

C.5.1.2 Fuel specification

C.5.1.2.1 Test cans

The test cans shall be cylindrical $80 \text{ mm} \pm 5 \text{ mm}$ in diameter and at least 100 mm high, made of mild or stainless steel with a thickness of 5 mm to 6 mm.

C.5.1.2.2 Heptane specification

The heptane used shall have the following characteristics:

- a) distillation
 - 1) initial boiling point: $90 \text{ }^\circ\text{C}$ minimum;
 - 2) drypoint: $100 \text{ }^\circ\text{C}$ maximum;
- b) density (at $15,6 \text{ }^\circ\text{C}$): $(700 \pm 50) \text{ kg/m}^3$.

C.5.1.2.3 Fuel-test can configuration

The test cans may contain either heptane or heptane on water. If they contain heptane and water, the heptane shall be at least 50 mm deep. The level of heptane in the cans shall be at least 50 mm below the top of the can.

A thermocouple is permitted to be located 30 mm above the centre of each fire test can as additional information.

C.5.1.2.4 Test can placement

A test shall be placed in each corner of the enclosure within 50 mm of the corners of the enclosure wall. Also, one or two test cans, depending on enclosure height, shall be placed directly behind the baffle (see [Figures C.1](#) and [C.2](#)). The top of the test cans shall be positioned within 300 mm of the top or bottom of the enclosure, or both top and bottom if the enclosure height can accommodate such placement.

C.5.1.3 Test procedure

C.5.1.3.1 Pretesting

The composition of the extinguishing agent used shall be verified by a certificate of conformance or by test.

C.5.1.3.2 Operation

The heptane-filled test cans shall be ignited and allowed to burn for at least 30 s with the closable openings in the open position.

After at least 30 s all openings shall be closed, and the extinguishing system shall be manually actuated. At the time of actuation of the system, the oxygen concentration within the enclosure shall be no less than 20,4 vol. %. During the test, the oxygen concentration shall not change more than 1,5 vol. % due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the measured oxygen concentration in this test (averaged over the three sensors).

NOTE End of discharge is the point when discharge has effectively ceased. For superpressurized liquefied extinguishants, it is the instant when the discharge is predominantly gaseous. For non-superpressurized liquefied extinguishants and non-liquified extinguishants where a cut-off mechanism is used to stop the discharge, it is the instant when the pressure at the nozzle reduces to zero.

C.5.1.3.3 Recording of data

After the required pre-burn period, record the following data for each test.

- a) The effective discharge time: i.e. for liquefied extinguishants the time of the pre-liquid gas-phase plus the time of the two-phase flow; for non-liquefied extinguishants, the time from opening the container valve(s) to cutting off the discharge; the discharge time for liquefied extinguishants shall be determined by nozzle pressure, nozzle temperature or combination of both.
- b) The time from the end of agent discharge required to achieve extinguishment, in seconds; this time shall be determined by visual observation or other suitable means.
- c) The total mass of extinguishant discharged into the test enclosure.

C.5.1.4 Determination of distribution performance of the nozzle

All test cans shall be extinguished within 30 s of the end of agent discharge.

As an alternative to the use of the test cans, the concentration of the extinguishing agent (or for non-liquefied gases, the oxygen concentration) is permitted to be measured at the locations specified

for the steel test cans. The concentration shall be measured at each location and shall be at least the extinguishing concentration, to be reached 30 s after the end of discharge time at the latest.

C.5.1.5 Reporting of test results

In addition to the data specified in [C.5.1.3.3](#), documentation of performance in [C.5.1.4](#), and the information in [C.2.2](#), at least the following shall be reported for each series of tests.

- a) Description of the test enclosure, preferably in the form of a schematic, including the following:
 - 1) baffle width, location, and orientation;
 - 2) location of the nozzle(s) within the test enclosure;
 - 3) test can locations within the test enclosure.
- b) Description of fuel specifications, including the following:
 - 1) test can material and dimensions;
 - 2) heptane characteristics by a certificate of conformance or by test;
 - 3) heptane depth and the level below the top of the can.
- c) Description of test method including details for operation including the following:
 - 1) pre-burn duration;
 - 2) oxygen concentration at system discharge.

C.5.2 Nozzle maximum height test

C.5.2.1 Test facility

C.5.2.1.1 Construction

The test enclosure shall meet the following requirements.

- a) The test enclosure shall have a minimum volume of 100 m³. The floor dimensions shall be at least 4 m wide by 4 m long. The test enclosure shall have the maximum ceiling height as specified in the extinguishing system unit manufacturer's installation instructions.
- b) A means of pressure relief shall be provided to limit the pressure change with a cold discharge to ± 300 Pa.
- c) Closable openings shall be provided directly next to or above the test cans to allow for ventilation before system actuation.
- d) One baffle shall be installed between the floor and ceiling with the height of the enclosure. It shall be installed halfway between the nozzle location and one wall of the enclosure. The baffle shall be perpendicular to the long walls of the enclosure and 20 % of the length of the short wall of the enclosure (see [Figure C.1](#) for 360° nozzle and [Figure C.2](#) for 180° nozzle).

C.5.2.1.2 Instrumentation

Instrumentation of the enclosure is as described in [C.5.1.1.2](#).

C.5.2.2 Fuel specification

Test fire can construction, configuration, placement and fuel specifications shall be as given in [C.5.1.2](#).

C.5.2.3 Test procedure

C.5.2.3.1 Pretesting

The composition of the extinguishing agent used shall be verified by a certificate of conformance or by test.

C.5.2.3.2 Operation

The heptane shall be ignited and allowed to burn for at least 30 s with the closable openings in the open position.

After at least 30 s all openings shall be closed, and the extinguishing system shall be manually actuated. At the time of actuation of the system, the oxygen concentration within the enclosure shall be no less than 20,4 vol. %. During the test, the oxygen concentration shall not change more than 1,5 vol. % due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

C.5.2.3.3 Recording of data

Data shall be recorded as specified in [C.5.1.3.3](#).

C.5.2.4 Determination of distribution performance of the nozzle

Using the extinguishing concentration for heptane, determined in accordance with [C.6.2](#), all test cans shall be extinguished within 30 s of the end of agent discharge.

As an alternative to the use of the heptane steel cans, the concentration of the extinguishing agent (or for non-liquefied gases, the oxygen concentration) can be measured at the locations specified for the steel test cans. The concentration shall be measured at each location and shall be at least the extinguishing concentration, to be reached no longer than 30 s after the end of discharge time.

C.5.2.5 Reporting of test results

In addition to the data specified in [C.5.2.3.3](#), documentation of performance in [C.5.2.4](#), and the information in [C.2.2](#), at least the following shall be reported for each series of tests:

- a) Description of the test enclosure, preferably in the form of a schematic, including the following:
 - 1) baffle width, location, and orientation;
 - 2) location of the nozzle(s) within the test enclosure;
 - 3) test can locations within the test enclosure.
- b) Description of fuel specifications, including the following:
 - 1) test can material and dimensions;
 - 2) heptane characteristics by a certificate of conformance or by test;
 - 3) heptane depth and the level below the top of the can.
- c) Description of test method including details for operation including the following:
 - 1) pre-burn duration;
 - 2) oxygen concentration at system discharge.

C.6 Extinguishing concentration tests

C.6.1 Wood crib test

C.6.1.1 Test facility

C.6.1.1.1 Construction

The test enclosure shall meet the following requirements.

- a) The test enclosure shall have a minimum volume of 100 m³. The height shall be at least 3,5 m. The floor dimensions shall be at least 4 m wide by 4 m long.
- b) A means of pressure relief shall be provided to limit the pressure change with a cold discharge to ± 300 Pa.

C.6.1.1.2 Instrumentation

Sampling and storage of data from the sensors described below shall occur at a rate of at least 10 Hz.

NOTE The single data points to determine agent mass and atmospheric pressure are not required to be sampled and stored at a rate of at least 10 Hz.

C.6.1.1.2.1 Oxygen concentration sensors

The oxygen concentration shall be measured and recorded using a calibrated oxygen analyser having an accuracy of 0,1 vol. % oxygen or better. The sensing equipment shall continuously monitor and record the oxygen level within the enclosure throughout the test. The accuracy of the measuring devices shall not be influenced by any of the fire products.

At least three sensors shall be located within the enclosure (see [Figures C.5](#) and [C.6](#)). One sensor shall be located horizontally 600 mm to 1 000 mm away from the test object at the equivalent height of the top of the test object. The other sensors shall be located horizontally 600 mm to 1 000 mm away from the test object and at least two sensors at the following heights: 0,1 H and 0,9 H (H = height of the enclosure).

C.6.1.1.2.2 Nozzle pressure sensor

During system discharge, the nozzle pressure shall be measured and recorded by a pressure transducer attached to the pipe at a distance no greater than 1 m from the nozzle.

C.6.1.1.2.3 Enclosure temperature sensors

The temperature within the enclosure shall be measured and recorded (see [Figures C.5](#) and [C.6](#)). One sensor shall be located centrally 100 mm above the test object. One sensor shall be located horizontally 600 mm to 1 000 mm from the test object and at the equivalent height of the top of the test object. At least one sensor shall be located horizontally 600 mm to 1 000 mm from the test object and at the following height: 0,9 H (H = height of the enclosure).

The temperature in the test enclosure shall be 20 °C \pm 5 °C at the beginning of each test.

C.6.1.1.2.4 Nozzle temperature sensor

During system discharge of liquefied extinguishants, the liquid jet temperature just outside the nozzle shall be measured and recorded.

C.6.1.1.2.5 Agent concentration sensors

For the cold discharge tests with liquefied extinguishants, the agent concentration shall be measured and recorded by a calibrated extinguishant analyser appropriate for the extinguishant in use having an accuracy of 0,2 vol. % or better. The sensing equipment shall continuously monitor and record the concentration within the enclosure at least until the concentration stabilizes.

For the cold discharge tests with non-liquefied extinguishants, the agent concentration or alternatively the oxygen concentration shall be measured and recorded. For measurement of agent concentration, the requirements specified for liquefied extinguishants apply. For measurement of oxygen concentration, the requirements according to [C.6.1.1.2.1](#) apply. The sensing equipment shall continuously monitor and record the concentration within the enclosure at least until the concentration stabilizes.

The sensors for measurement of agent concentration or oxygen concentration shall be located as specified in [C.6.1.1.2.1](#).

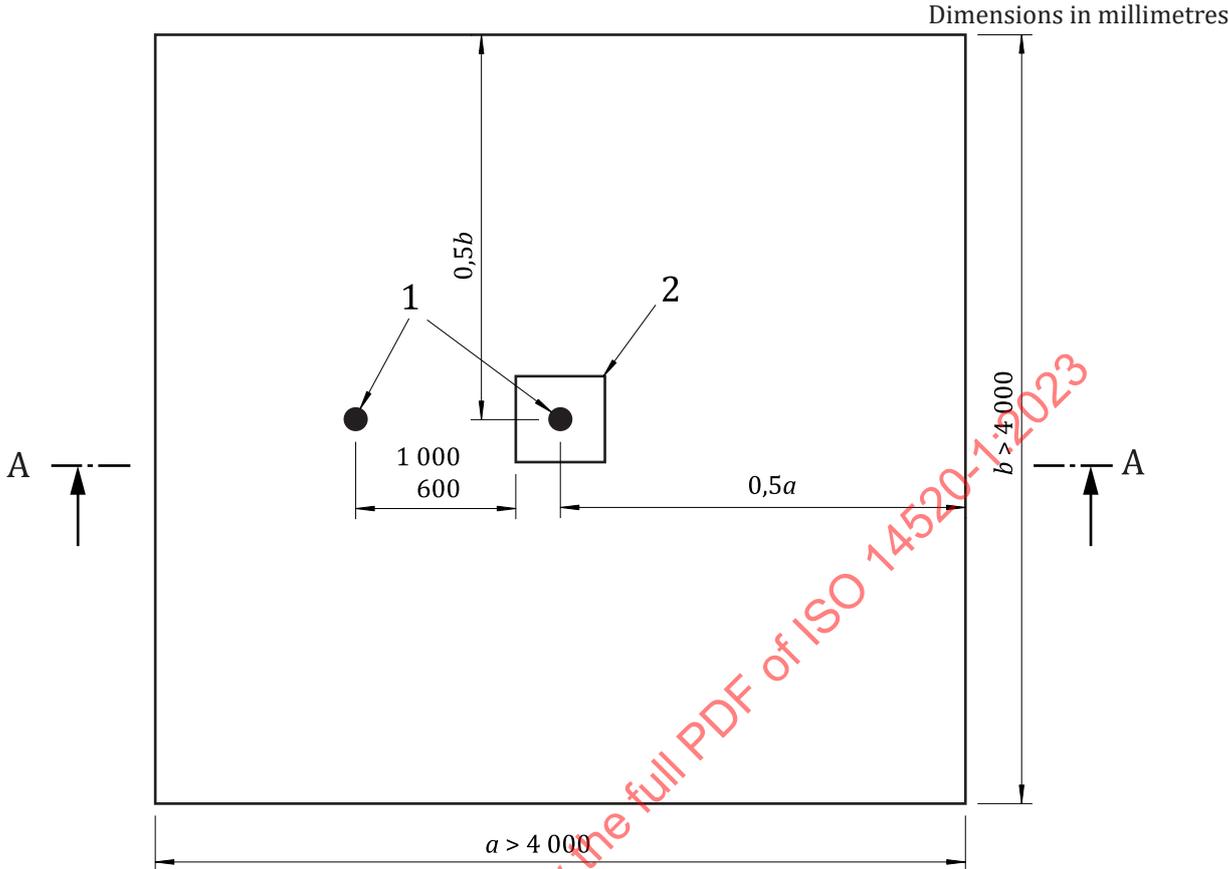
C.6.1.1.2.6 Agent mass

The mass of agent discharged shall be determined by calculation from the measured mass of the agent container before and after filling the container and before and after the discharge. The mass shall be measured and recorded using a calibrated weighing device capable of measuring the mass to one decimal place (0,1 kg) or better.

C.6.1.1.2.7 Atmospheric pressure

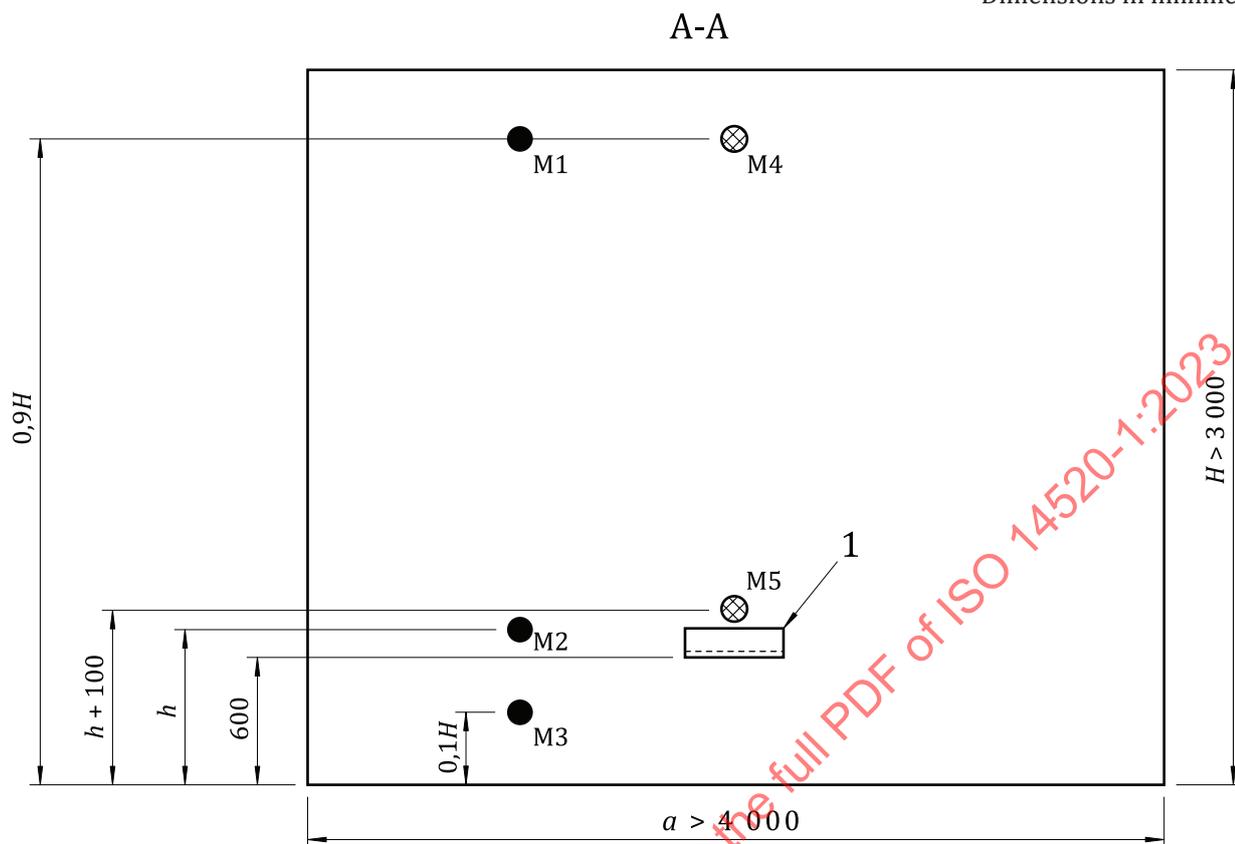
The atmospheric pressure shall be determined before each test. The atmospheric pressure shall be measured and recorded using a calibrated device having an accuracy of 100 Pa or better.

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- Key**
- 1 measuring point
 - 2 test object

Figure C.5 — Plan view of instrumentation placement for the extinguishing concentration test

**Key**

- 1 test object
 h altitude

Figure C.6 — Side view of instrumentation placement for the extinguishing concentration test

C.6.1.2 Fuel specification

C.6.1.2.1 Crib igniter fuel

Ignition of the crib is achieved by burning 1,5 l of heptane (specified in [C.5.1.2.2](#)) on a 12,5 l layer of water in a square steel pan 0,25 m² in area, 100 mm in height and with a wall thickness of 6 mm (see [Figure C.7](#)).

Dimensions in millimetres

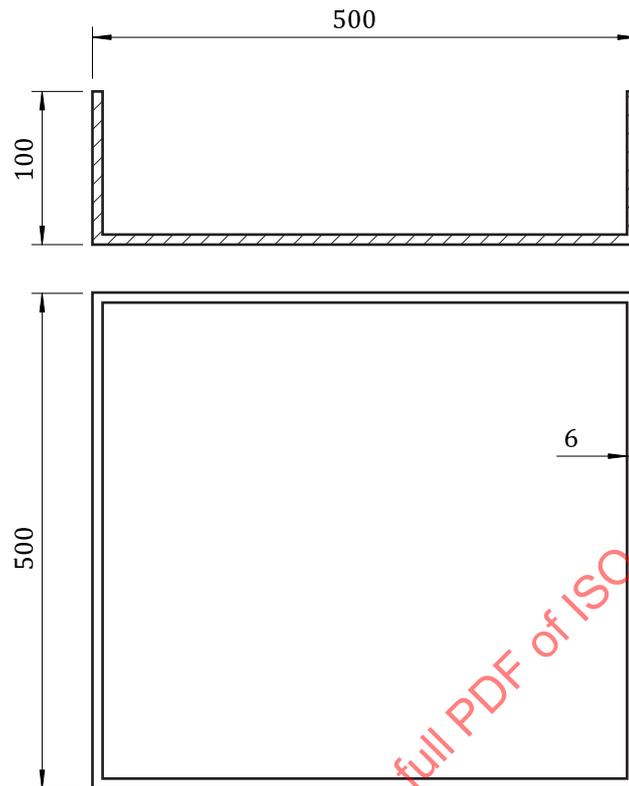


Figure C.7 — Pan geometry for the wood crib and heptane pan fire test

C.6.1.2.2 Fire configuration and placement

The wood crib shall consist of four layers of six, approximately 40 mm × 40 mm × (450 ± 50) mm long, kiln spruce or fir lumber having a moisture content between 9 % and 13 %. Place the alternate layers of wood members at right angles to one another. Evenly space the individual wood members in each layer forming a square determined by the specified length of the wood members. Staple or nail together the wood members forming the outside edges of the crib.

The crib shall be pre-burned on a stand supporting the crib. The distance from the bottom of the crib to the top of the pan holding the igniter fuel (specified in [C.5.1.2.1](#)) shall be 300 mm. The bottom of the crib shall be 600 mm above the floor.

C.6.1.3 Test procedure

C.6.1.3.1 Pretesting

The composition of the extinguishing agent used shall be verified by a certificate of conformance or by test. Record the weight and the moisture of the crib before the test.

C.6.1.3.2 Operation

Centre the crib with the bottom of the crib approximately 300 mm above the top of the pan on a test stand constructed to allow for the bottom of the crib to be exposed to the atmosphere. The pre-burning shall not be influenced by weather conditions such as rain, wind, etc. The maximum wind speed in the proximity of the fire shall be 3 m s⁻¹. If necessary, adequate means for protection against wind, etc. may be used. Record the weather conditions including the location of pre-burn, air temperature, humidity and wind speed.

Ignite the heptane and allow the crib to burn freely. The crib shall be allowed to burn freely for a total pre-burn time of 6 min (+10 s, -0 s).

At the time of actuation of the system, the oxygen concentration within the enclosure at the level of the crib shall be no less than 20,4 vol. %. During the test, the oxygen concentration shall not change more than 1,5 vol. % due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

From the end of a system discharge, the enclosure shall remain sealed for a total of 10 min. After the soak period, remove the crib from the enclosure and observe whether sufficient fuel remains to sustain combustion and look for signs of re-ignition. The following shall be recorded:

- a) presence and location of burning embers;
- b) whether or not the glowing embers or crib re-ignites;
- c) the weight of the crib after the test.

If necessary, amend the extinguishant concentration and repeat the experimental programme until three successive, successful extinguishments are achieved.

C.6.1.3.3 Recording of data

After the required pre-burn period, record the following data for each test.

- a) The effective discharge time: i.e. for liquefied extinguishants the time of the pre-liquid gas-phase plus the time of the two-phase flow; for non-liquefied extinguishants, the time from opening the container valve(s) to cutting off the discharge; the discharge time for liquefied extinguishants has to be determined by nozzle pressure, nozzle temperature or combination of both.
- b) The time required to achieve extinguishment in seconds; this time shall be determined by visual observation or other suitable means.
- c) The total mass of extinguishant discharged into the test enclosure.
- d) The soaking time (time from the end of system discharge until the opening of the test enclosure).
- e) The temperature profile of the wood crib.

NOTE End of discharge is the point when discharge has effectively ceased. For superpressurized liquefied extinguishants, it is the instant when the discharge is predominantly gaseous. For non-superpressurized liquefied extinguishants and non-liquified extinguishants where a cut-off mechanism is used to stop the discharge, it is the instant when the pressure at the nozzle reduces to zero.

C.6.1.4 Determination of design extinguishant concentration

The extinguishant concentration is that concentration that achieves extinguishment of the fire over three successive tests (no re-ignition or existence of burning embers after 10 min after the end of discharge). Alternatively to three successive tests, three non-successive tests that comply with the requirements are permitted to be used provided the highest concentration is used. The design concentration is the extinguishment concentration multiplied by an appropriate safety factor.

C.6.1.5 Reporting of test results

In addition to the data specified in [C.6.1.3.3](#), documentation of performance in [C.6.1.4](#), and the information in [C.2.2](#), at least the following shall be reported for each series of tests.

- a) Description of the test enclosure, preferably in the form of a schematic, including the following:
 - 1) test object location within the test enclosure.
- b) description of fuel specifications, including the following:
 - 1) pan material and dimensions;
 - 2) heptane characteristics by a certificate of conformance or by test;
 - 3) water quantity and heptane quantity within the pan;
 - 4) wood crib material, dimensions, construction, weight and moisture content.
- c) Description of test method including details for operation including the following:
 - 1) location and orientation of wood crib with respect to pan for pre-burn;
 - 2) weather conditions that can influence the pre-burn;
 - 3) pre-burn duration;
 - 4) oxygen concentration at system discharge;
 - 5) duration of soak period;
 - 6) after the soak period, observations for signs of reignition;
 - 7) wood crib weight following the test.

C.6.2 Heptane pan test

C.6.2.1 Test facility

C.6.2.1.1 Construction

Construction of the enclosure is as described in [C.6.1.1.1](#).

C.6.2.1.2 Instrumentation

Instrumentation of the enclosure is as described in [C.6.1.1.2](#).

C.6.2.2 Fuel specification

C.6.2.2.1 Heptane

The heptane is as specified in [C.5.1.2.2](#).

C.6.2.2.2 Fire configuration and placement

The fire shall be in a square steel pan of 0,25 m², 100 mm high with a wall thickness of 6 mm as specified in [C.6.1.2.1](#). The test pan shall contain 12,5 l of heptane. The resulting heptane surface is then 50 mm below the top of the pan.

The steel pan shall be located in the centre of the test enclosure with the bottom 600 mm above the floor of the test enclosure.

C.6.2.3 Test procedure

C.6.2.3.1 Pretesting

The composition of the extinguishing agent used shall be verified by a certificate of conformance or by test.

C.6.2.3.2 Operation

The heptane shall be ignited and allowed to burn for at least 30 s.

After at least 30 s all openings shall be closed, and the extinguishing system shall be manually actuated. At the time of actuation of the system, the oxygen concentration within the enclosure shall be no less than 20,4 vol. %. During the test, the oxygen concentration shall not change more than 1,5 vol. % due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

If necessary, amend the extinguishant concentration and repeat the experimental programme until three successive, successful extinguishments are achieved.

C.6.2.3.3 Recording of data

Data shall be recorded as specified in [C.6.1.3.3](#) except for (e).

C.6.2.4 Determination of design extinguishant concentration

The extinguishant concentration is that concentration that achieves extinguishment of the fire over three successive tests (no flaming 30 s after the end of the extinguishant discharge). Alternatively, to three successive tests, three non-successive tests that comply with the requirements are permitted to be used provided the highest concentration is used. The design concentration is the extinguishing concentration multiplied by an appropriate safety factor.

C.6.2.5 Reporting of test results

In addition to the data specified in [C.6.2.3.3](#), documentation of performance in [C.6.2.4](#), and the information in [C.2.2](#), at least the following shall be reported for each series of tests:

- a) Description of the test enclosure, preferably in the form of a schematic, including the following:
 - 1) test object location within the test enclosure.
- b) Description of fuel specifications, including the following:
 - 1) pan material and dimensions;
 - 2) heptane characteristics by a certificate of conformance or by test;
 - 3) water quantity and heptane quantity within the pan and heptane surface distance below the top of the pan.
- c) Description of test method including details for operation including the following:
 - 1) pre-burn duration;
 - 2) oxygen concentration at system discharge.

C.6.3 Polymeric sheet fire test

C.6.3.1 Test facility

C.6.3.1.1 Construction

Construction of the enclosure is as described in [C.6.1.1.1](#).

C.6.3.1.2 Instrumentation

Instrumentation of the enclosure is as described in [C.6.1.1.2](#).

C.6.3.2 Fuel specification

C.6.3.2.1 Igniter fuel

The ignition source is a heptane pan (constructed of 2 mm thick mild or stainless steel), internal dimensions of 51 mm × 112 mm and 21 mm deep and centred with the top of the pan 12 mm below the bottom of the polymeric sheets (see [Figure C.8](#)). The 51 mm side of the pan is orientated parallel to the sheets of polymeric fuel. The pan is filled with 6 ml of commercial-grade heptane (specified in [C.5.1.2.2](#)) on a water base of 40 ml.

C.6.3.2.2 Polymeric fuel

Tests are to be conducted with three polymeric fuels:

- a) polymethylmethacrylate (PMMA),
- b) polypropylene (PP), and
- c) acrylonitrile-butadiene-styrene polymer (ABS).

Polymeric material properties are given in [Table C.2](#).

Table C.2 — Polymeric material properties

25 kW/m ² exposure in cone calorimeter (ISO 5660-1)								
Fuel	Colour	Density kg/m ³	Ignition time		180°C average heat release rate		Effective heat of combustion	
			s	Tolerance	kW/m ²	Tolerance	MJ/kg	Tolerance
PMMA	Black	1,19	77	±30 %	286	±25 %	23,3	±25 %
PP	Natural (White)	0,905	91	±30 %	225	±25 %	39,6	±25 %
ABS	Natural (cream)	1,0 4	115	±30 %	484	±25 %	29,1	±25 %

C.6.3.2.3 Polymeric fuel array

Each polymeric fuel array article shall consist of four sheets of one type of polymeric fuel specified in [C.6.3.2.2](#). Each polymeric sheet shall have the following dimensions:

- height: 405 mm ± 5 mm;
- width: 200 mm ± 5 mm;
- thickness: 10 mm ± 1 mm.

Sheets are spaced and located as shown in Figures C.8 and C.9. The bottom of the fuel array is located 203 mm from the floor. The fuel sheets shall be mechanically fixed at the required spacing.

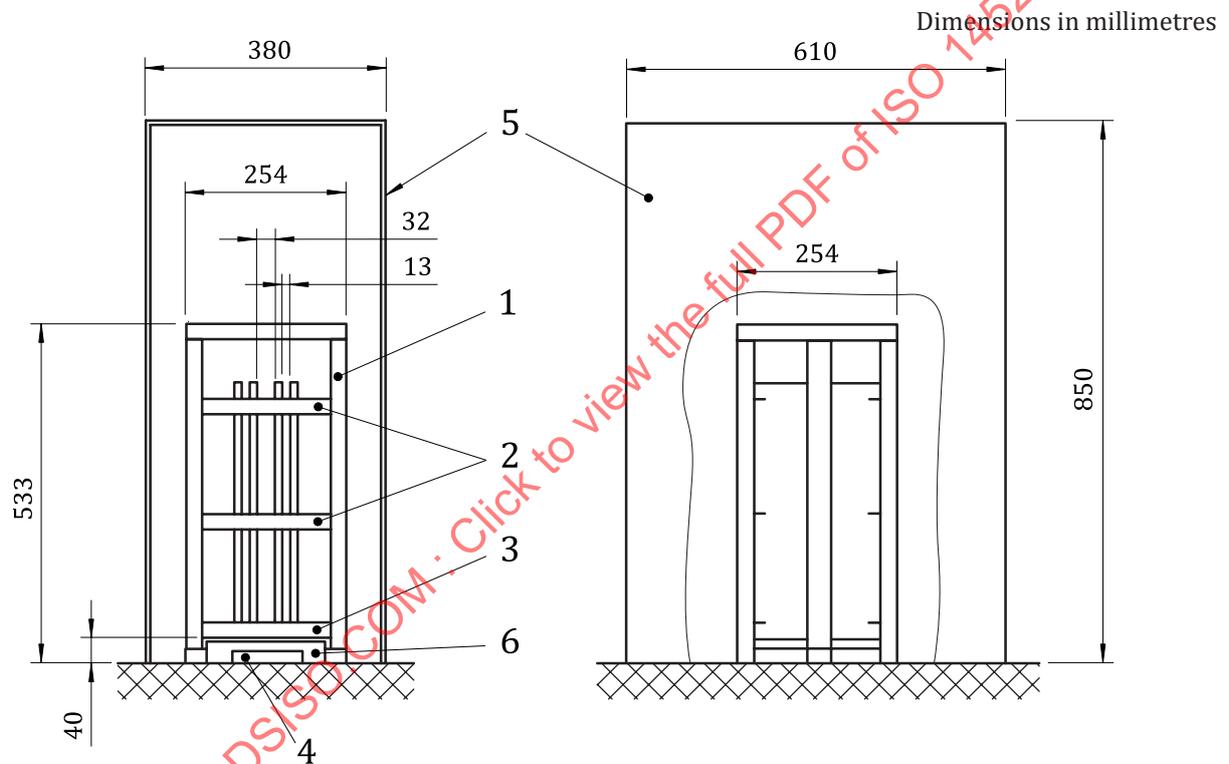
The fuel array shall be located centrally within the enclosure.

C.6.3.2.4 Fuel shield

A fuel shield consisting of a metal frame with sheet metal on the top and two sides shall be provided around the fuel array as indicated in Figures C.8 and C.9. The fuel shield is 380 mm wide, 850 mm high and 610 mm deep. The 610 mm (width) × 850 mm (height) sides and the 610 mm (width) × 380 mm (depth) top are metal sheet. The two remaining sides and bottom are open.

The metal sheet shall have a wall thickness of 2 mm to 3 mm.

The fuel array is oriented in the fuel shield such that the 200 mm dimensions of the fuel array is parallel to the 610 mm side of the fuel shield.

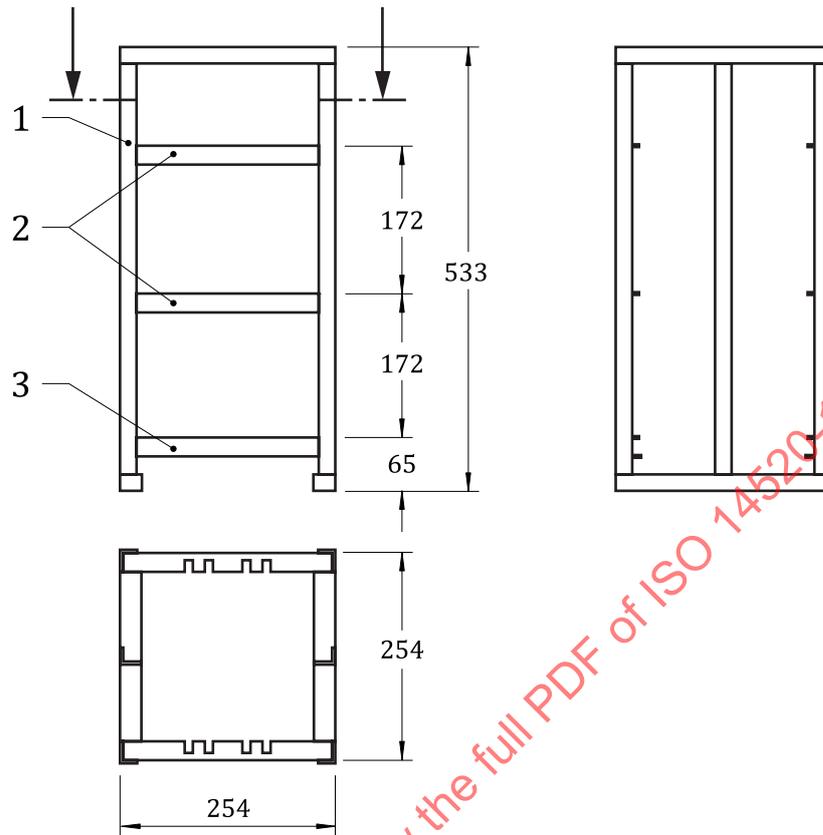


Key

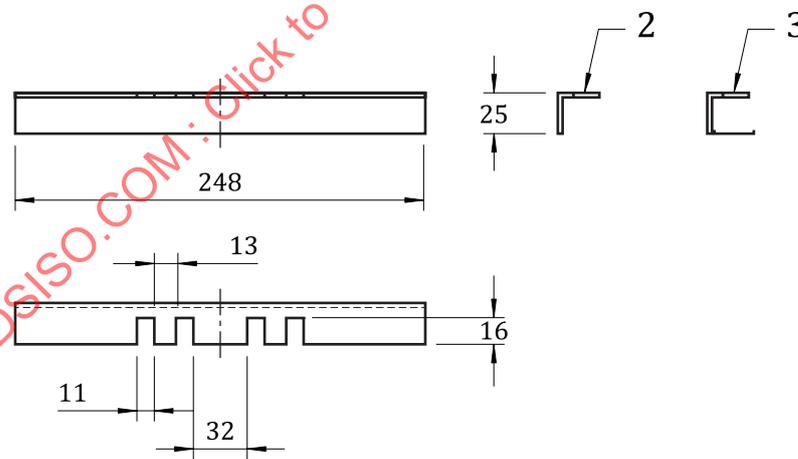
- 1 vertical metal angle frame
- 2 fuel guide bars (angle form)
- 3 fuel guide bars (U-form)
- 4 heptane pan
- 5 channel metal frame covered with metal sheeting on top and two sides
- 6 drip tray

Figure C.8 — Polymeric sheet fire

Dimensions in millimetres



a) Front, side, and plan view



b) Details of fuel guides

Key

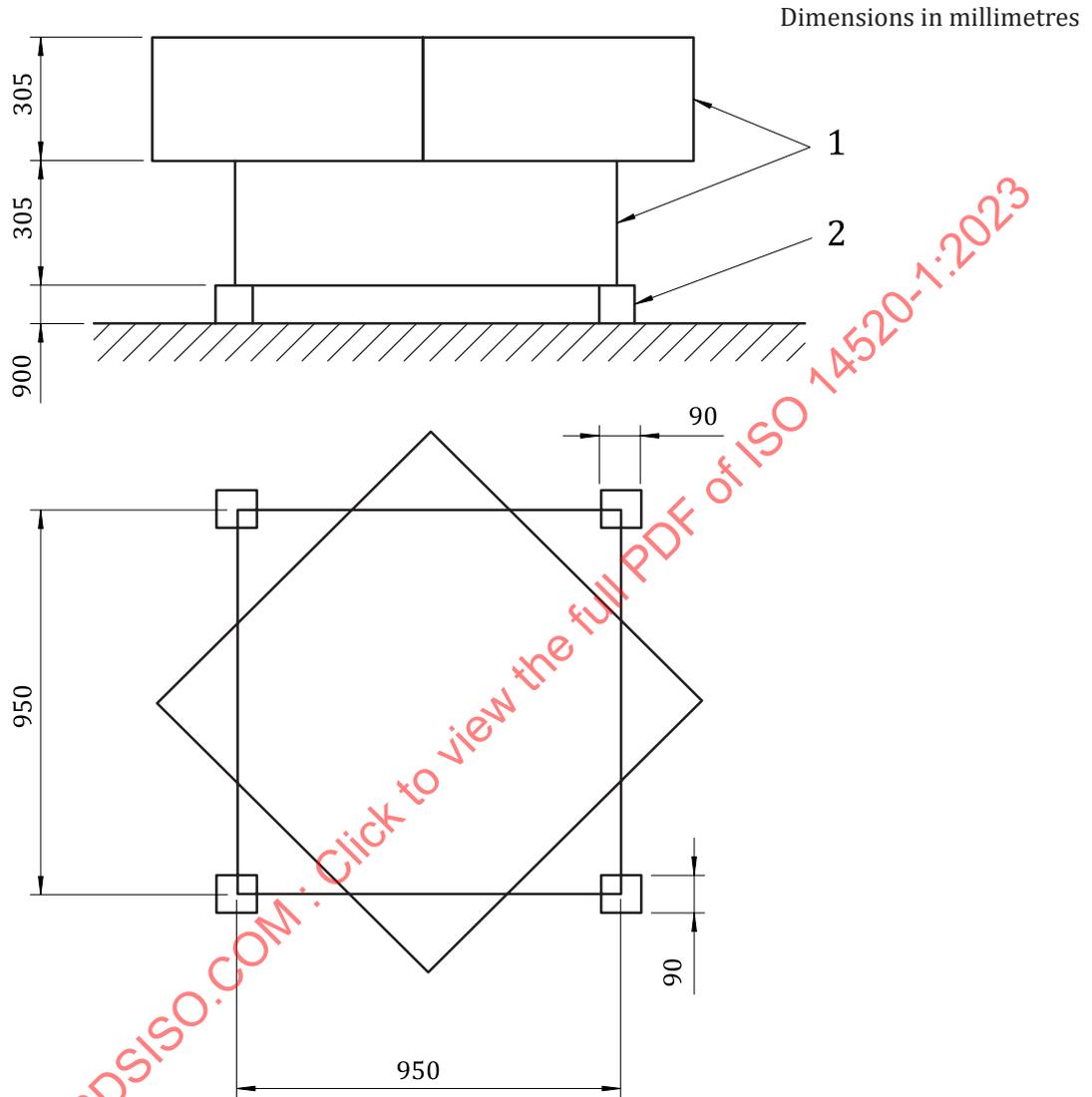
- 1 vertical metal angle frame
- 2 fuel guide bars (angle form)
- 3 fuel guide bars (U-form)

NOTE Material: 3 mm thick metal.

Figure C.9 — Support rack for polymeric sheets

C.6.3.2.5 External baffles

External baffles are constructed as shown in Figure C.10 and are located around the exterior of the fuel shield. The baffles are placed 90 mm above the floor. The top baffle is rotated 45° with respect to the bottom baffle.



- Key**
- 1 polycarbonate or metal baffles
 - 2 cinder block

Figure C.10 — Polymeric fire baffle arrangement

C.6.3.3 Test procedure

C.6.3.3.1 Pretesting

The composition of the extinguishing agent used shall be verified by a certificate of conformance or by test. Record the weight of the plastic sheets before the test.

C.6.3.3.2 Operation

The heptane shall be ignited and allowed to burn completely. At least 210 s after ignition of the heptane, all openings shall be closed, and the extinguishing system shall be manually actuated.

At the time of actuation of the system, the oxygen concentration within the enclosure at the level of the fuel shall be no less than 20,4 vol. %. During the test, the oxygen concentration shall not change more than 1,5 vol. % due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

The enclosure shall remain sealed for a total of 10 min after the end of discharge. After the soak period, ventilate the enclosure and observe whether sufficient fuel remains to sustain combustion and look for signs of re-ignition.

The following shall be recorded:

- a) presence and location of burning fuel;
- b) whether or not the fire re-ignites;
- c) the weight of the fire structure after the test.

If necessary, amend the extinguishant concentration and repeat the experimental programme until three successive, successful extinguishments are achieved.

C.6.3.3.3 Recording of data

After the required pre-burn period, record the following data for each test:

- a) The effective discharge time: i.e. for liquefied extinguishants the time of the pre-liquid gas-phase plus the time of the two-phase flow; for non-liquefied extinguishants, the time from opening the container valve(s) to cutting off the discharge; the discharge time for liquefied extinguishants shall be determined by nozzle pressure, nozzle temperature or a combination of both.
- b) The time to achieve “knock-down” of the flames, that means the time when there are only flames at the top edges of the two inner polymeric sheets, in seconds; this time shall be determined by visual observation or other suitable means.
- c) The time required to achieve extinguishment, in seconds; this time shall be determined by visual observation or other suitable means.
- d) The total mass of extinguishant discharged into the test enclosure.
- e) The soaking time (time from the end of system discharge until the opening of the test enclosure).

NOTE End of discharge is the point when discharge has effectively ceased. For superpressurized liquefied extinguishants, it is the instant when the discharge is predominantly gaseous. For non-superpressurized liquefied extinguishants and non-liquefied extinguishants where a cut-off mechanism is used to stop the discharge, it is the instant when the pressure at the nozzle reduces to zero.

C.6.3.4 Determination of design extinguishant concentration

The extinguishing concentration for each fuel is that concentration that achieves extinguishment of the fire over three successive tests. Extinguishment is characterized by the following criteria:

- a) at most, 60 s after the end of discharge, flames are present only at the top edges of the two inner polymeric sheets;
- b) at most, 180 s after the end of discharge, no visible flames are present;
- c) when the test enclosure is ventilated 10 min after the end of discharge re-ignition does not occur.

Alternatively, to three successive tests for each fuel, three non-successive tests that conform to the requirements are permitted to be used provided the highest concentration for the test fuel is used.

The minimum design concentration is the highest of the extinguishment concentrations for the three fuels (see [C.6.3.2.2](#)) multiplied by an appropriate safety factor.

C.6.3.5 Reporting of test results

In addition to the data specified in [C.6.3.3.3](#), documentation of performance in [C.6.3.4](#), and the information in [C.2.2](#), at least the following shall be reported for each series of tests:

- a) Description of the test enclosure, preferably in the form of a schematic, including the following:
 - 1) test object location and orientation within the test enclosure.
- b) Description of fuel specifications, including the following:
 - 1) pan material and dimensions;
 - 2) heptane characteristics by a certificate of conformance or by test;
 - 3) polymeric sheet dimensions, description in accordance with [Table C.2](#), and data demonstrating compliance with the cone calorimeter properties in accordance with [Table C.2](#);
 - 4) support rack material and dimensions;
 - 5) external baffle material and dimensions;
 - 6) fuel array weight with and without polymeric sheets.
- c) Description of test method including details for operation including the following:
 - 1) location and orientation of polymeric sheets with respect to pan;
 - 2) pre-burn duration of heptane;
 - 3) pre-burn duration of fuel array;
 - 4) oxygen concentration at system discharge;
 - 5) duration of soak period;
 - 6) after the soak period, observations for signs of reignition;
 - 7) fuel array weight with polymeric sheets following the test.

Annex D (informative)

Method of evaluating inerting concentration of a fire extinguishant

D.1 General

This annex specifies a method for determining the inerting or inhibiting concentration of the extinguishant based on flammability diagram data on ternary systems (fuel, extinguishant, air).

D.2 Principle

Fuel/extinguishant/air mixture at a pressure of 1,013 bar⁵⁾ absolute or 14,7 psia is ignited using a gap spark and the rise in pressure is measured.

D.3 Apparatus

D.3.1 Test vessel, spherical, with a capacity of $7,9 \pm 0,25$ L, with inlet and vent ports, thermocouple and pressure transducer, as shown in [Figure D.1](#).

D.3.2 Igniter, for nominal resistance of 1 ohm comprising four graphite rods ("H" pencil leads) held together by two wire ties at either end, leaving a gap between the ties of approximately 3 mm.

D.3.3 Capacitors, two 525 mF, 450 V, wired in series with the igniter.

D.3.4 Internal mixing fan, suitable to withstand the temperature and overpressure of an explosion.

D.4 Procedure

D.4.1 The sphere ([D.3.1](#)) and components should be at nominal room temperature ($22 \text{ °C} \pm 3 \text{ °C}$). Note any temperature difference outside of this range.

D.4.2 Connect the pressure transducer to a suitable recording device to measure the pressure rise in the test vessel to the nearest 70 Pa.

D.4.3 Evacuate the test vessel ([D.3.1](#)).

D.4.4 Admit the extinguishant up to the concentration required by the partial pressure method and, if a liquid, allow time for evaporation to occur.

D.4.5 Admit fuel vapour and air [(50 ± 5) % relative humidity] up to the concentration required by the partial pressure method until the pressure in the vessel is 1,013 bar⁶⁾ absolute or 14,7 psia.

D.4.6 Turn on the fan ([D.3.4](#)) and allow to mix for 1 min. Turn off the fan and wait for 1 min for the mixture to reach quiescent conditions.

5) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm².

6) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm².

D.4.7 Charge the capacitors ([D.3.3](#)) to a potential of 720 V to 740 V (d.c.), producing stored energy of 68 J to 70 J.

D.4.8 Close the switch and discharge the capacitors.

NOTE The capacitor discharge current results in ionization of the graphite rod surface causing a corona spark to jump across the connector gap.

D.4.9 Measure and record the pressure rise, if any.

D.4.10 Clean the inside of the test vessel with distilled water and cloths to avoid any build-up of decomposition residues.

D.4.11 Retain the fuel/air ratio and repeat the test using varying amounts of extinguishant until conditions are found that bracket a pressure rise of 0,07 times the initial pressure.

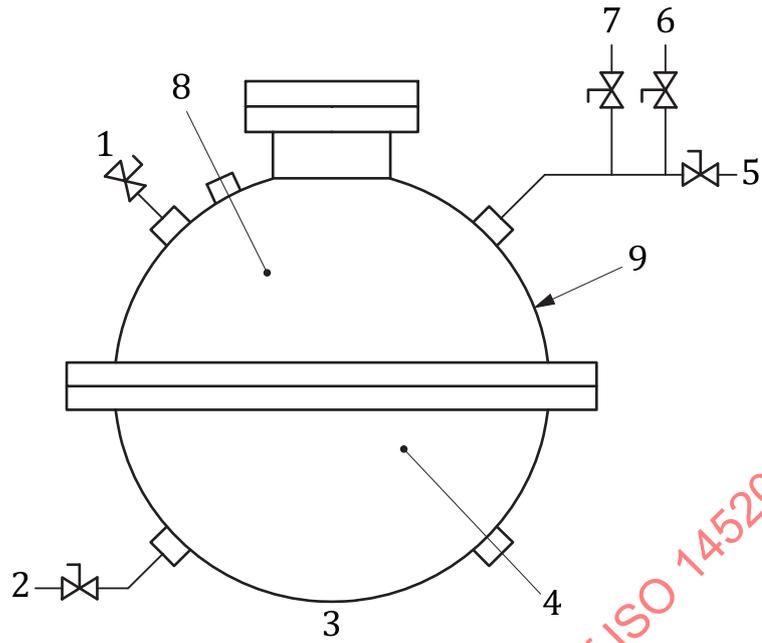
NOTE The definition of the flammable boundary is taken as that composition that just produces a pressure rise of 0,07 times the initial pressure or 1 psi when the initial pressure is 1,013 bar⁷⁾ absolute or 14,7 psia.

D.4.12 Repeat, varying the fuel/air ratio and the extinguishant concentration to establish the highest extinguishant concentration needed to inert the mixture.

D.5 Inerting concentration

The inerting concentration is the concentration established in [D.4.12](#).

7) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1N/mm².



Key

- | | | | |
|---|-------------------|---|----------------|
| 1 | septum port | 6 | vacuum |
| 2 | gas inlet | 7 | pressure gauge |
| 3 | 7,9 l test vessel | 8 | thermocouple |
| 4 | igniter | 9 | test chamber |
| 5 | vent | | |

Figure D.1 — Inerting apparatus

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Annex E (normative)

Door fan test for determining of minimum hold time

E.1 General

This annex contains information for establishing the integrity of rooms and enclosures for maintaining the extinguishant concentration for the relevant period (hold time). It includes details of testing and assumes that the air-handling plant will not be operating during the hold time.

This procedure cannot be used to predict what extinguishant concentrations might develop in adjoining spaces.

This procedure is only suitable providing:

- a) an adequate return air path exists (see [E.2.4.2](#) and [E.2.7.1.3](#)), and
- b) the fan unit(s) can develop an enclosure pressure of 25 Pa (this is a function of the size of the enclosure, its integrity, and the number and capacities of the fans. See [E.2.2.1](#) and [E.2.7.4.3](#)).

The calculation procedures used are suitable for both heavier-than-air extinguishants and extinguishants that are lighter than air. The hold time calculation models, for enclosures without continuous mixing, assume that the enclosure is either a standard enclosure or a non-standard enclosure. A standard enclosure has a uniform horizontal cross-sectional area with horizontal upper and lower boundaries. A non-standard enclosure is one with a non-uniform horizontal cross-sectional area and/or sloping upper and/or lower boundaries.

NOTE For gas/air mixtures heavier than air, the calculation procedures have been verified by comparison of calculation results from door fan testing with hold times from real flooding tests. This has not yet been done for gas mixtures lighter than air.

E.2 Test for determination of predicted hold time

E.2.1 Principle

A fan is temporarily located within an access opening to pressurize and depressurize the enclosure. A series of pressure and airflow measurements are 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 the other half (the lower leakage area) is at the lowest point in the enclosure.
- b) The direction of flow through the enclosure, during the hold time, is downwards for extinguishants heavier than air, and upwards for extinguishants lighter than air.
- c) That all leak flow is one-dimensional, i.e. ignoring stream functions.
- d) 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.

- e) That the enclosure and surroundings are at a temperature of 20 °C, and atmospheric pressure is 1,013 bar⁸⁾ absolute.

E.2.2 Apparatus

E.2.2.1 Fan unit, consisting of a frame that 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.

E.2.2.2 Pressure measuring devices, two in number, one to measure enclosure differential pressure and one to measure fan flow pressure.

E.2.2.3 Flexible tubing, for connecting the pressure measuring devices.

E.2.2.4 Chemical smoke pencils and/or smoke generator.

E.2.2.5 Thermometers, two in number, for measuring ambient temperatures.

E.2.2.6 Signs, reading “DO NOT OPEN — PRESSURE TEST IN PROGRESS” and “DO NOT CLOSE — PRESSURE TEST IN PROGRESS”, displayed during the test operation.

NOTE Additional apparatus, such as measuring tapes, a barometer for measuring atmospheric pressure, torches, ladders, tools to remove floor and ceiling tiles, computer or a calculating device, camera, can be necessary or convenient.

E.2.3 Calibration and accuracy of the apparatus

E.2.3.1 Fan unit

The fan unit ([E.2.2.1](#)) shall be calibrated at intervals and by the method recommended by the manufacturer. Records shall be kept and also copies of the appropriate calibration certificates. The flow rate shall be accurate to $\pm 5\%$ of the measured value.

E.2.3.2 Pressure measuring devices

The pressure measuring devices ([E.2.2.2](#)) shall be accurate to ± 1 Pa and shall be calibrated at regular intervals. Records shall be maintained and where appropriate calibration certificates. The pressure measuring device to measure the fan flow pressure can have a different accuracy as long as the requirements for the accuracy of the flow rate (see [E.2.3.1](#)) are fulfilled. The atmospheric pressure measurement shall be accurate to ± 100 Pa.

If inclined manometers are used, change the fluid at the intervals recommended by the manufacturer. Level and zero inclined manometers before each test.

E.2.3.3 Temperature measuring devices

Temperature measuring devices shall be accurate to ± 1 °C.

E.2.4 Preliminary preparation

E.2.4.1 Obtain a description of air-handling equipment and extinguishant extraction systems, serving the enclosure and its surroundings, from the user.

8) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm²

E.2.4.2 Check for the following.

- a) Raised platform floors and false ceiling spaces.
- b) Visually obvious leaks in the enclosure.
- c) Adequate return paths outside the enclosure between all leaks and the fan unit.
- d) Conflicting activities in and around the enclosure.
- e) Leakage areas in the hold time condition by visually checking the door closure or other opening selected for mounting the fan unit.

E.2.4.3 Provide the following information to the user.

- a) Description of the test.
- b) Time required to complete the test.
- c) What assistance will be needed from the user's staff.
- d) Information on any necessary disturbance to the building or its services during the test; e.g. removal of floor or ceiling tiles, a shutdown of air handling systems, holding doors open and/or shut.

E.2.5 Evaluation of enclosure

E.2.5.1 General

Obtain or prepare a sketch plan showing the enclosure and its surroundings, the location of the 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, closed, on, off during the hold time) of each door, hatch, damper and other significant items (e.g. fans), and which access opening(s) is (are) to be used for the fan unit.

Show the location of floor and sink drains.

E.2.5.2 Mixing during hold time

Enclosures with continuous mixing are enclosures in which there will be continuous good mixing e.g. due to strong heat sources or recirculating air handling equipment so that an interface does not form and a uniform extinguishant concentration is maintained throughout the enclosure during the hold time.

Enclosures without continuous mixing are enclosures in which there is partial or no mixing during the hold time so that an interface forms between the extinguishant/air mixture and the incoming air.

If it is uncertain whether the enclosure is one with or without continuous mixing, then perform the hold time calculations for both cases. Use the lower of the two hold time values.

E.2.6 Measurement of enclosure

E.2.6.1 Standard enclosures without continuous mixing

Standard enclosures are those with a uniform horizontal cross-sectional area and horizontal upper and lower boundaries. Measure the protected enclosure as necessary and record the following:

- a) The overall height of the protected enclosure from its lowest to its highest point, H_0 .
- b) The required protected height from the lowest point in the enclosure, H .

- c) The net volume of the protected enclosure, V .

E.2.6.2 Non-standard enclosures without continuous mixing

Non-standard enclosures are those with the non-uniform horizontal cross-sectional area, such as enclosures with non-horizontal upper and/or lower boundaries. Measure the protected enclosure as necessary and record the following:

- a) The overall height of the protected enclosure from its lowest to its highest point, H_0 .
- b) The required protected height from the lowest point in the enclosure, H .
- c) The net volume of the protected enclosure, V .
- d) The horizontal cross-sectional area, A , at various heights, sufficient to determine its variation with height so that V_e and dV_e can be evaluated using [Formulae \(E.24\)](#) and [\(E.25\)](#) (see [E.2.8.9.3](#)).

E.2.6.3 Enclosures of any shape with continuous mixing

Measure the protected enclosure as necessary and record the following:

- a) The overall height of the protected enclosure from its lowest to its highest point, H_0 .
- b) The net volume of the protected enclosure, V .

E.2.6.4 Opening for mounting the fan unit

If the door or other closure, replaced by the fan unit for the test, has significant measurable leakage openings in the hold time condition, then these should be measured and recorded.

E.2.7 Test procedure

E.2.7.1 Preparation

E.2.7.1.1 Advise supervisory personnel in the area of the test.

E.2.7.1.2 Remove papers and objects likely to be disturbed by the air stream from the fan.

E.2.7.1.3 Block open sufficient doors outside the enclosure envelope to provide an adequate return path for air between the fan unit and the enclosure boundaries while correcting any breach of any requirements of the facility, including requirements for security, fire protection and environmental boundaries.

E.2.7.1.4 Using the sketch plan (see [E.2.5](#)), set the enclosure air-handling equipment and extinguishant extraction systems to the state they would be in during the hold time, except that:

- a) recirculating air-handling equipment without fresh air make-up or exhaust which does not give a bias pressure across the enclosure boundary or otherwise preclude accurate testing, and which would be shut down on extinguishant discharge, may be left operating during the test if this is needed to avoid temperature build-up in equipment such as computers; and
- b) air-handling equipment, with fresh air makeup or exhaust, which would continue to operate on extinguishant discharge should be shut down as it can create excessive bias pressure during the integrity test.

E.2.7.1.5 Post the appropriate signs on doors (see [E.2.2.6](#)).

E.2.7.1.6 Open doors and remove floor or ceiling tiles within the extinguishant-protected portions of the enclosure envelope so that the extinguishant-protected volume is treated as one space. Do not remove false ceiling tiles if the volume above the false ceiling is not protected with extinguishant.

CAUTION — The removal of raised floor tiles creates a serious safety hazard. Appropriate precautions should be taken.

E.2.7.1.7 Set all doors and windows and other openings in the enclosure envelope to the state they would be during the hold time.

E.2.7.1.8 Check that liquid traps in the floor and sink drains are sealed with liquid.

E.2.7.1.9 Record the conditions (enclosure, surroundings and services) during the fan test.

E.2.7.2 Setting up the door fan unit

E.2.7.2.1 Set up the fan unit in an access opening leading from the enclosure into the largest volume of building space which will complete the airflow path from the fan, via the enclosure, leaks, and building space back to the fan.

E.2.7.2.2 Gently blow into or suck from, the flexible tubing so that the readings of the pressure measuring devices traverse the full scale. Hold the maximum reading for not less than 10 s.

Release the pressure and zero the devices.

E.2.7.2.3 Connect the enclosure differential pressure measuring device and the fan 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 the readings.

E.2.7.2.4 Use the fan(s) to raise or lower the pressure of the enclosure to the maximum safe pressure obtainable. Check all dampers with smoke and ensure that they are closed 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.

E.2.7.2.5 Ensure that there will be no pressure differential between the area of the fan outside the enclosure and along the return air paths around the boundary of the enclosure under test. This may be done visually or by pressure measurement.

E.2.7.3 Measurement of bias pressure during fan testing (P_{bt})

E.2.7.3.1 P_{bt} is used to correct the measured inside-outside enclosure pressure differential to calculate the enclosure leakage characteristics.

E.2.7.3.2 Seal the fan unit and, without the fan(s) operating, allow the enclosure differential pressure reading to stabilize if possible (which can take up to 30 s) and record the pressure differential, P_{bt} , and its direction. Take P_{bt} as positive if the inside pressure is above the outside pressure, and negative if the inside pressure is below the outside pressure. If the magnitude of P_{bt} is greater than 3 Pa (i.e. $|P_{bt}| > 3$ Pa), it should be reduced before proceeding with the integrity test.

E.2.7.3.3 Make every effort to reduce the static pressure, P_{bt} , by shutting down air handling equipment even though it can operate during the hold time.

If a subfloor pressurization air-handler cannot be shut down for the test and leaks exist in the subfloor, these leaks cannot be accurately measured. During the test, as many floor tiles as necessary should

be lifted to eliminate the effect of subfloor pressurization, or every effort should be made to reduce subfloor leaks to insignificance.

CAUTION — The removal of raised floor tiles creates a serious safety hazard. Appropriate precautions should be taken.

E.2.7.3.4 If P_{bt} fluctuates (e.g. due to wind effects), it is unlikely to achieve the necessary correlation accuracy in the fan test results. The fluctuations need to be reduced, before accurate fan tests can be carried out, by sealing leakage paths between the enclosure and the source of fluctuating pressure.

E.2.7.4 Measurement of leakage rate

E.2.7.4.1 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. Verify the temperatures at the end of the test.

E.2.7.4.2 Unseal the fan inlet or outlet and connect the fan flow pressure measuring device.

E.2.7.4.3 Use the fan unit to depressurize the enclosure to the maximum extent, but preferably by not more than 60 Pa, as at higher differential pressures the flow characteristics of the leak paths can change. Allow the enclosure differential pressure reading to stabilize (which can take up to 30 s) and record the pressure differential i.e. $(P_f + P_{bt})$ 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 or $10 |P_{bt}|$ whichever is the higher. At each pressure difference, measure the airflow and pressure difference across the enclosure/fan boundary. After the fan and instrumentation have stabilized, the average over an interval equal to, or greater than, 10 s should be used if fluctuations are observed. If stable readings cannot be obtained at the minimum pressure difference (10 Pa or $10 |P_{bt}|$) then only go down to the lowest pressure at which stable readings can be obtained.

E.2.7.4.4 Use the fan unit to pressurize the enclosure and repeat the procedure of [E.2.7.4.3](#). Again, record values of $(P_f + P_{bt})$, which will be positive.

E.2.7.4.5 Repeat the zero-flow pressure difference (bias pressure P_{bt}) measurement. If the reading differs from the initial zero flow pressure difference reading by more than 1 Pa, repeat the test.

E.2.7.5 Field calibration check

E.2.7.5.1 Calculate the enclosure's equivalent leakage area (average of pressurization and depressurization), at a reference pressure differential of 10 Pa, using [Formula \(E.27\)](#) (see [E.3.2](#)).

E.2.7.5.2 In a sheet of a rigid material, less than 3 mm thick and free of any penetrations, cut a sharp-edged circular calibration check orifice. The area of the orifice shall be large enough to cause an easily measurable increase in the enclosure's leakage rate, but not so large that a different range of the fan unit shall be used to measure the increased flow. A geometrical area of about 50 % of the enclosure's equivalent leakage area is likely to be suitable. Install the sheet in an unused fan unit port if possible. Otherwise, install the sheet in some other convenient enclosure opening but consider that this will modify the enclosure's leakage characteristic and reduce the accuracy of the field calibration check.

E.2.7.5.3 Seal the fan unit and orifice, repeat the measurement of bias pressure during fan testing (see [E.2.7.3](#)) and record the value of P_{bt} .

Open the calibration check orifice and repeat the measurement of leakage rate (see [E.2.7.4](#)).

E.2.7.5.4 Calculate the equivalent leakage area (average of pressurization and depressurization) of the enclosure with the orifice at reference pressure differential (10 Pa).

E.2.7.5.5 The measured equivalent leakage area of the calibration orifice is the equivalent leakage area of the enclosure with the orifice minus the equivalent leakage area of the enclosure alone.

E.2.7.5.6 The field calibration check is acceptable if the measured equivalent leakage area of the orifice is within $\pm 15\%$ of its geometrical area. If the difference is greater than 15 %, the fan unit should be recalibrated.

E.2.7.6 Measurement of bias pressure under hold time conditions (P_{bh})

E.2.7.6.1 P_{bh} is the bias pressure under hold time conditions that are used in the calculation of the hold time.

E.2.7.6.2 Set the enclosure, its surroundings, and services, to the conditions that would apply during the hold time using the information from [E.2.5](#).

E.2.7.6.3 Seal the fan unit and, without the fan(s) operating, connect a manometer to measure the pressure differential, P_{bh} , and its direction. Measure between a single fixed reference point inside the enclosure, and:

- a) a point immediately outside the upper leakage, and
- b) a point immediately outside the lower leakage.

Allow the enclosure differential pressure reading to stabilize if possible (which can take up to 30 s) and record the pressure differential, P_{bh} , and its direction for both positions. Take P_{bh} as positive if the inside pressure is above the outside pressure, and negative if the inside pressure is below the outside pressure.

If the enclosure is large, repeat the pairs of measurements at several points to determine the average value of P_{bh} , but note that if P_{bh} varies significantly from place to place then it can cause non-uniform flow through leakage areas, invalidating the hold time equation.

The value of P_{bh} for hold time calculations is given by:

- for extinguishants heavier than air ($\rho_a < \rho_e$), $P_{bh} = P_{bh}(\text{lower}) - P_{bh}(\text{upper})$
- for extinguishants lighter than air ($\rho_a > \rho_e$), $P_{bh} = P_{bh}(\text{upper}) - P_{bh}(\text{lower})$

The tubing used to connect the manometer to the points outside the upper and lower leakages should be filled with air at ambient temperature, so that the measured value of P_{bh} will not be affected by gravity acting on the air between the upper and lower leakage.

E.2.7.6.4 If P_{bh} fluctuates (e.g. due to wind effects), the predicted hold time will be uncertain. In this case, use the most negative value of P_{bh} when checking whether flow reversal will occur (see [E.2.8.4](#)) and the most positive value when calculating the predicted hold time (see [E.2.8.6](#), [E.2.8.7](#), [E.2.8.8](#) and [E.2.8.9](#)).

E.2.7.6.5 If the bias pressure P_{bh} has a numerical value greater than 25 % of the initial extinguishant/air column pressure [see [Formulae \(E.6\)](#) in [E.2.8.4](#)], i.e. $|P_{bh}| > 0,25 P_{mi}$ then the hold time is likely to be low and the enclosure will not hold the specified extinguishant concentration. The source of the excessive bias pressure should be identified (and traced using inert smoke) and if possible, permanently reduced. If it cannot be permanently reduced it shall be recognized that the hold time can be adversely affected.

E.2.8 Calculation

E.2.8.1 Selection of appropriate hold time equation

For enclosures without continuous mixing, the standard enclosure hold time equation is easier to solve than the non-standard enclosure equation. In certain circumstances, it may be acceptable to use the standard enclosure equation to calculate the hold time for a non-standard enclosure, although the non-standard enclosure equation will be more accurate.

For enclosures where the horizontal cross-sectional area decreases from the top of the enclosure to the bottom (e.g. a ship's hull or a flat-topped and vertical walled room with a cable trench), the standard enclosure equation will underestimate the hold time (in the upper part of the enclosure) for extinguishants heavier than air, and overestimate it (in the lower part) for extinguishants lighter than air.

For enclosures where the horizontal cross-sectional area increases from the top of the enclosure to the bottom (e.g. enclosures with pitched roofs), the standard enclosure equation will overestimate the hold time (in the upper part) for extinguishants heavier than air, and underestimate it (in the lower part) for extinguishants lighter than air.

It is important to use the non-standard enclosure equation when the standard enclosure equation will overestimate the hold time because the standard enclosure equation can predict a pass for an enclosure that would fail.

It is less important to use the non-standard enclosure equation when the standard enclosure equation will underestimate the hold time, although the standard enclosure equation can predict a failure for an enclosure that would pass.

Expert advice should be sought in case of doubt.

E.2.8.2 Symbols

The symbols of the quantities, and their units, used in the calculation are given in [Table E.1](#).

Table E.1 — Symbols, quantities and units

Symbol	Quantity	Unit
A	horizontal cross-sectional area at height H	m^2
A_e	effective leakage area	m^2
C	extinguishant concentration at height h	% vol.
c_i	initial concentration of extinguishant in the air for the enclosure at the beginning of the hold time	% vol.
c_{\min}	minimum concentration of extinguishant in the air at height H in the enclosure at the end of the hold time — not less than the extinguishing concentration	% vol.
E_A	equivalent leakage area	m^2
E_p	leakage opening area	m^2
F	lower leakage fraction, effective leakage area of lower leaks divided by effective leakage area of all leaks	dimensionless
g_n	acceleration due to gravity	m/s^2
H	height from the lowest point in the enclosure	m
H_e	height of the equivalent sharp interface	m
H_o	overall height of the enclosure	m
H_p	required protected height — required height of c_{\min} at the end of the hold time	m
^a	1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1N/mm ² .	

Table E.1 (continued)

Symbol	Quantity	Unit
I_t	interface thickness constant [see Formula (E.7) and table for values for each agent]	m
I_p	Interface position constant [see Formula (E.7) and table for values for each agent]	dimensionless
k_0	leakage characteristic [see Formula (E.1)]	$\text{m}^3/(\text{s} \cdot \text{Pa} \cdot \text{n})$
k_1	leakage characteristic [see Formula (E.11)]	$\text{m}^3/(\text{s} \cdot \text{Pa} \cdot \text{n})$
k_2	correlation constant [see Formula (E.14)]	$[\text{kg}^n \text{m}^{3(1-n)}]/(\text{s} \cdot \text{Pa} \cdot \text{n})$
k_3	simplifying constant [see Formula (E.15)]	m/s^2
k_4	simplifying constant [see Formula (E.16)]	$\text{Pa} \cdot \text{m}^3/\text{kg}$
n	leakage characteristic [see Formula (E.11)]	1
P_{bh}	bias pressure during the hold time	Pa
P_{bt}	bias pressure at the time of the fan test	Pa
P_c	atmospheric pressure during fan calibration	bar^a
P_f	differential pressure produced by the fan	Pa
P_{mi}	initial extinguishant/air column pressure	Pa
P_{mf}	final extinguishant/air column pressure	Pa
P_{ref}	reference pressure difference for equivalent leakage area	Pa
P_t	atmospheric pressure at the time of fan test	bar^a
Q	volume flow rate in through the upper leaks and out through the lower leaks	m^3/s
Q_f	measured airflow rate through the fan	m^3/s
Q_1	airflow rate, temperature and pressure corrected to reference conditions (20 °C, 1,013 bar^a atmospheric pressure)	m^3/s
Q_{ref}	enclosure air leakage rate at pressure difference P_{ref}	m^3/s
r or r^2	correlation coefficient	
t	predicted hold time [see Formulae (E.17) to (E.20)]	s
T_c	atmospheric temperature during calibration of the fan unit	°C
T_e	air temperature inside the enclosure	°C
T_o	air temperature outside the enclosure	°C
V	enclosure net volume	m^3
V_e	volume of extinguishant in the enclosure [see Formula (E.21)]	m^3
V_{ef}	final value of V_e	m^3
V_{ei}	initial value of V_e	m^3
ρ_a	air density (1,205 at 20 °C and 1,013 bar^a)	kg/m^3
ρ_e	extinguishant density at 20 °C and 1,013 bar^a atmospheric pressure	kg/m^3
ρ_m	extinguishant/air mixture density at 20 °C and 1,013 bar^a atmospheric pressure	kg/m^3
ρ_{mf}	extinguishant/air mixture density at the concentration c_{\min} 20 °C and 1,013 bar^a atmospheric pressure	kg/m^3
ρ_{mi}	extinguishant/air mixture density at initial concentration c_i , 20 °C and 1,013 bar^a atmospheric pressure	kg/m^3
^a	1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm ² .	

E.2.8.3 Depressurization and pressurization leakage characteristics

From the measured values of $(P_f + P_{bt})$ and P_{bt} , calculate the values of P_f and, using the fan calibration data (see [E.2.3.1](#)), the corresponding airflow rates Q_f through the fan.

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

$$|Q_f| = k_0 |P_f|^n \quad (\text{E.1})$$

Determine k_0 , n , and the correlation coefficient (r or r^2) using ordinary least squares regression to fit:

$\ln |Q_f| = \ln k_0 + n \ln |P_f|$ to the data. Check that the correlation coefficient of each set is not less than $r = 0,99$ or $r^2 = 0,98$. The two sets will almost always have different values of k_0 and n .

If the correlation coefficient is too low,

- repeat the test,
- check for fluctuating bias pressure, and
- check for damper/vent movement during the test.

Calculate the corrected values of k_0 using [Formulae \(E.2\)](#) and [\(E.3\)](#), as appropriate, and call them k_1 .

For depressurization:

$$k_1 = k_0 \left(\frac{P_c (T_e + 273)}{P_t (T_c + 273)} \right)^{1/2} \left(\frac{T_o + 273}{T_e + 273} \right) \left(\frac{P_t (20 + 273)}{1,013 (T_o + 273)} \right)^n \quad (\text{E.2})$$

For pressurization:

$$k_1 = k_0 \left(\frac{P_c (T_o + 273)}{P_t (T_c + 273)} \right)^{1/2} \left(\frac{T_e + 273}{T_o + 273} \right) \left(\frac{P_t (20 + 273)}{1,013 (T_e + 273)} \right)^n \quad (\text{E.3})$$

NOTE [Formulae \(E.2\)](#) and [\(E.3\)](#) correct the flow rates for the effects of temperature and pressure differences on air density, assuming that:

- the flowmeter is of the usual type that gives a pressure signal proportional to the air density and the square of the volume flow rate, and
- for a given inside-outside pressure difference, the volume flow rate through the enclosure leakage is inversely proportional to the air density to the power n .

The correction is approximate as the second assumption is an approximation, and the effects of humidity and viscosity are ignored.

E.2.8.4 Column pressures

Calculate the density of the extinguishant/air mixture at 20 °C at the initial concentration using [Formula \(E.4\)](#):

$$\rho_{mi} = \rho_e \frac{c_i}{100} + \rho_a \frac{100 - c_i}{100} \tag{E.4}$$

For enclosures with continuous mixing, calculate the density of the extinguishant/air mixture at 20 °C at the concentration, c_{min} , using [Formula \(E.5\)](#):

$$\rho_{mf} = \rho_e \frac{c_{min}}{100} + \rho_a \frac{100 - c_{min}}{100} \tag{E.5}$$

Calculate the initial extinguishant/air mixture column pressure, P_{mi} , using [Formula \(E.6\)](#):

$$P_{mi} = g_n H_o |\rho_{mi} - \rho_a| \tag{E.6}$$

For enclosures without continuous mixing, if c_{min} is less than 0,5 c_i then take the equivalent sharp interface height H_e as equal to H . Otherwise, calculate H_e as follows:

$$H_e = H + I_t \left(\frac{c_{min}}{c_{i(p)}} - I_p \right) \tag{E.7}$$

If $H_e \geq H_o - I_p * I_t$ then the interface has not fully developed and [Formula \(E.8\)](#) should be used

$$H_e = H_o - (H_o - H) \frac{I_p \cdot c_i}{c_{min}} \tag{E.8}$$

For extinguishants heavier than air and $c_{min} \geq 0,5 c_i$ the value of H_e shall be in the range $0,5 H_o \leq H_e \leq H_o$. If this is not the case, the Formulae for H_e and hold time are not valid (as there will be no extinguishant/air mixture at the initial concentration remaining in the enclosure).

For all enclosures, calculate the final extinguishant/air mixture column pressure, P_{mf} .

For all extinguishants in enclosures without continuous mixing, [Formula \(E.9\)](#) applies:

$$P_{mf} = g_n H_e |\rho_{mi} - \rho_a| \tag{E.9}$$

For all extinguishants in enclosures with continuous mixing, [Formula \(E.10\)](#) applies:

$$P_{mf} = g_n H_e |\rho_{mf} - \rho_a| \tag{E.10}$$

For all enclosures, if P_{bh} is negative, check that P_{mf} is greater than the absolute value of P_{bh} . If this is not the case, the hold time equations are not valid (as bias pressure will cause flow reversal).

The values for the interface thickness, I_t , and the interface position, I_p , are shown in [Table E.2](#).

Table E.2 — Values for the interface thickness, I_t , and the interface position, I_p

Agents	I_p	I_t
Inert agents	0,63	1,30
Carbon dioxide	0,63	1,30
FK-5-1-12	0,52	0,45
HFC-227ea	0,68	0,80
HFC-125	0,61	1,10