INTERNATIONAL STANDARD

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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

Reference number
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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 14520 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14520-1 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 8, *Gaseous media fire extinguishing systems*.

ISO 14520 consists of the following parts, under the general title *Gaseous fire-extinguishing systems — Physical properties and system design*:

— *Part 1: General requirements*

— *Part 2: CF_3I extinguishant*

— *Part 3: FC-2-1-8 extinguishant*

— *Part 4: FC-3-1-10 extinguishant*

— *Part 6: HCFC Blend A extinguishant*

— *Part 7: HCFC 124 extinguishant*

— *Part 8: HCFC 125 extinguishant*

— *Part 9: HFC 227ea extinguishant*

— *Part 10: HFC 23 extinguishant*

— *Part 11: HFC 236fa extinguishant*

— *Part 12 IG-01 extinguishant*

— *Part 13: IG-100 extinguishant*

— *Part 14: IG-55 extinguishant*

— *Part 15: IG-541 extinguishant*

Annexes A to E form a normative part of this part of ISO 14520. Annex F is for information only.

Introduction

Fire fighting systems covered in this part of ISO 14520 are designed to provide 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 part of ISO 14520 has been prepared to meet this need.

In particular, new requirements to eliminate the need to release extinguishants during testing and commissioning procedures are included. These are linked to the inclusion of enclosure integrity testing.

The requirements of this part of ISO 14520 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 might affect implementation of the recommendations.

It has been assumed in the preparation of this part of ISO 14520 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.

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

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

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. In addition, 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 at the risk of crippling financial loss. The importance of maintenance cannot be too highly emphasized.

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

Part 1: General requirements

1 Scope

This part of ISO 14520 specifies requirements and gives recommendations for the design, installation, testing, maintenance and safety of gaseous fire fighting systems in buildings, plant 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, plant 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 characteristics by an appropriate independent authority. This part of ISO 14520 is not applicable to explosion suppression.

This part of ISO 14520 is not intended to indicate approval of the extinguishants listed therein by the appropriate authorities, as other extinguishants may be equally acceptable. CO_2 is not included as it is covered by other International Standards.

This part of ISO 14520 is applicable to the extinguishants listed in Table 1. It is essential that it be used in conjunction with the separate parts of ISO 14520 for specific extinguishants, as cited in Table 1.

Table 1 — Listed extinguishants

Extinguishant	Chemical	Formula	Trade name	International Standard
CF_3I	Trifluoroiodomethane	CF_3I	Triodide	ISO 14520-2
FC-2-1-8	Perfluoropropane	$CF_3CF_2CF_3$	CEA 308	ISO 14520-3
FC-3-1-10	Perfluorobutane	C_4F_{10}	CEA 410	ISO 14520-4
HCFC Blend A			NAF S-III	ISO 14520-6
HCFC-123 HCFC-22 HCFC-124	Dichlorotrifluoroethane Chlorodifluoromethane Chlorotetrafluoroethane Isopropenyl-1-methylcyclohexene	$CHCl_2CF_3$ $CHClF_2$ $CHClFCF_3$ $C_{10}H_{16}$		
HCFC 124	Chlorotetrafluoroethane	$CHClFCF_3$	FE-241	ISO 14520-7
HCFC 125	Pentafluoroethane	CHF_2CF_3	FE-25	ISO 14520-8
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3	FM-200	ISO 14520-9
HFC 23	Trifluoromethane	CHF_3	FE-13	ISO 14520-10
HFC 236fa	Hexafluoropropane	$CF_3CH_2CF_3$	FE-36	ISO 14520-11
IG-01	Argon	Ar	Argotec	ISO 14520-12
IG-100	Nitrogen	N_2		ISO 14520-13
IG-55	Nitrogen (50 %) Argon (50 %)	N_2 Ar	Argonite	ISO 14520-14
IG-541	Nitrogen (52 %) Argon (40 %) Carbon dioxide (8 %)	N_2 Ar CO_2	Inergen	ISO 14520-15

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 14520. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 14520 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3941, *Classification of fires*.

ISO 14520-2, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 2:* CF_3I *extinguishant*.

ISO 14520-3, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 3: FC-2-1-8 extinguishant*.

ISO 14520-4, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 4: FC-3-1-10 extinguishant*.

ISO 14520-6, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 6: HCFC Blend A extinguishant*.

ISO 14520-7, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 7: HCFC 124 extinguishant*.

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

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

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

ISO 14520-11, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 11: HFC 236fa extinguishant*.

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

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

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

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

IEC 60364-7, *Electrical installation of buildings — Part 7: Requirements for special installations or locations*.

3 Terms and definitions

For the purposes of this part of ISO 14520, the term "bar" shall be taken as "gauge", unless otherwise indicated. Concentrations or quantities expressed in percentages (%) shall be taken as by volume, unless otherwise indicated.

For the purposes of this part of ISO 14520, the following terms and definitions apply.

3.1
approved
acceptable to a relevant authority (see 3.2)

NOTE In determining the acceptability of installations or procedures, equipment or materials, the authority may base acceptance on compliance with the appropriate 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 This may 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 extinguishant that does not leave a residue upon evaporation (see Table 1)

3.5
clearance
air gap between equipment, including piping and nozzles and unenclosed or uninsulated live electrical components at other than ground potential

3.6 Concentration

3.6.1
design concentration
concentration of extinguishant, including a safety factor, required for system design purposes

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 fire involving 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 pipe and nozzles in which the size of each section of pipe and nozzle orifice has been calculated in accordance with relevant parts of ISO 14520

NOTE The design flow rates from nozzles may vary according to the design requirements of the hazard.

3.8
fill density
mass of extinguishant per unit volume of container

3.9
flooding quantity
mass or volume of extinguishant required to achieve the design concentration within the protected volume within the specified discharge time

3.10
gross 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 greater than the fire extinguishing concentration surrounds the hazard

3.12
inspection
visual check to give reasonable assurance that the extinguishing system is fully charged and operable

NOTE 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 into the discharge piping downstream of the agent containers; or another type of device that mechanically prevents agent container actuation

NOTE 1 The actuation of this device provides an indication of system isolation.

NOTE 2 The intent is to prevent the discharge of 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 to give maximum assurance that the extinguishing system will operate as intended

NOTE It includes a thorough examination and any necessary repair or replacement of system components.

3.17
maximum working pressure
equilibrium pressure within a container at the maximum working temperature

NOTE 1 For liquefied gases this is at the maximum fill density and may include superpressurization.

NOTE 2 The equilibrium pressure for a container in transit can differ from that in storage within a building.

3.18
modular system
system consisting of distributed storage containers, usually of the pre-engineered type, in which each unit is designed to protect a given volume which is within its permitted limitations and which in total provide cover for the whole hazard

3.19
no observed adverse effect level
NOAEL
highest concentration at which no adverse toxicological or physiological effect has been observed

3.20
non-liquefied gas
gas or gas mixture (normally an inert gas) which, under service pressure and allowable service temperature conditions, is always present in the gaseous form

3.21
normally unoccupied area
area not normally occupied by people but which may 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 No deviation is permitted from the limits specified by the manufacturer or authority.

3.23
selector valve
valve installed in the discharge piping downstream of the agent containers, to direct the agent to the appropriate hazard enclosure

NOTE It is used where one or more agent containers are arranged to selectively discharge agent to any of several separate hazard enclosures.

3.24
superpressurization
addition of a gas to the extinguishant container, where necessary, to achieve the required pressure for proper system operation

3.25
total flooding system
system arranged to discharge extinguishant into an enclosed space to achieve the appropriate design concentration.

3.26
unoccupiable area
area which cannot be occupied due to dimensional or other physical constraints

EXAMPLE Shallow voids and cabinets.

4 Use and limitations

4.1 General

Throughout this part of ISO 14520 the word "shall" indicates a mandatory requirement; the word "should" indicates a recommendation or that which is advised but not required.

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

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

The extinguishants referred to in this part of ISO 14520 are electrically non-conductive media.

The extinguishants and specialized system parameters are each covered individually in the parts of ISO 14520 for specific extinguishants. These parts shall be used in conjunction with this part of ISO 14520.

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

a) chemicals containing their own 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 may 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.

4.3 Electrostatic discharge

Care shall be taken when discharging extinguishant into potentially explosive atmospheres. Electrostatic charging of conductors not bonded to earth may occur during the discharge of extinguishant. These conductors may 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 employing 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 normally shall be designed to function properly from –20 °C to +50 °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 with reference to the hazards associated with particular extinguishants in the supplementary parts of ISO 14520. Unnecessary exposure to all gaseous extinguishants shall be avoided.

Adherence to ISO 14520 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 amounts 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 must 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 quantity 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.

Clearly, 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 could make the area untenable for human occupancy.

5.2 Safety precautions

5.2.1 For normally occupied areas

The minimum safety precautions taken shall be in accordance with Table 2.

Table 2 — Minimum safety precautions

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

5.2.2 For normally unoccupied areas

The maximum concentration shall not exceed the LOAEL for the extinguishant used unless a lock-off valve 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 was 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.

5.2.3 For unoccupiable areas

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

5.3 Occupiable areas

In areas which are protected by total flooding systems and which 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 from fire to life or property, extinguishing systems shall incorporate a pre-discharge alarm with a time delay sufficient to allow personnel evacuation prior to 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 which 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 that are distinctive from all other alarm signals, that will operate immediately on commencement of time delay upon detection of the fire.

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 may be brought into the area, to ensure their correct actions when the system operates.

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

— self-contained breathing apparatus should be supplied and personnel trained in its use;

— personnel should not enter the enclosure until it has been verified as being safe to do so.

5.4 Electrical hazards

Where exposed electrical conductors are present, clearances no smaller than those given in Table 3 shall be provided, where practicable, between the electrical conductors and all parts of the system that may be approached during maintenance. Where these clearance distances cannot be achieved, warning notices shall be provided and a safe system of maintenance work shall be adopted.

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

5.5 Electrical earthing

Systems within electrical substations or switchrooms shall be efficiently bonded and earthed to prevent the metalwork 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 shall comply with 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 against simultaneously.

Table 3 — Safety clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out

Maximum rated voltage	Minimum clearance from any point on or about the permanent equipment where a person may be required to stand[a]	
	To the nearest unscreened live conductor in air (section clearance)	To the nearest part not at earth potential of an insulator[b] supporting a live conductor (ground clearance)
kV	m	m
15	2,6	2,5
33	2,75	
44	2,90	
66	3,10	
88	3,20	
110	3,35	
132	3,50	
165	3,80	
220	4,30	
275	4,60	

[a] Measured from 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 circuit breaker.

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 comply with the relevant part of this standard.

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 so as 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 so as 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 to potential damage due to mechanical, chemical or other causes. Where potentially damaging exposure or unauthorized interference are likely, suitable enclosures or guards shall be provided.

NOTE Direct 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 that part of ISO 14520 relating to the specific extinguishant.

The containers used in these systems shall be designed to meet the requirements of relevant national standards.

Where required, the container and valve assembly should be fitted with a pressure relief device complying with 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 name-plate 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 Manifolded containers

When two or more containers are connected into 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,

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 comply with 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, spelter 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, should 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 piping;

b) means for safe manual venting (see 6.3.1.4);

c) automatic relief of over pressures, where required.

Over-pressure relief devices shall be designed to operate at a pressure not greater 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, should 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 unwanted opening of the container valve. The means of pressure venting shall not prevent operation of the container valve.

6.3.1.6 The manifolds to the container and valve assembly shall be hydraulically tested by the manufacturer to a minimum pressure of 1,5 times maximum working pressure (see 3.17), or as required by the appropriate national standards.

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 this calculation, 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.

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 allowable 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 shall not be used.

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 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 pipe work 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 4.

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) $\leqslant$ 25 mm pipe $\leqslant$ 100 mm;

b) > 25 mm pipe $\leqslant$ 250 mm.

Movement of pipework caused by temperature fluctuations arising from environment or the discharge of extinguishant may be considerable particularly over long lengths and should be considered in the support fixing methods.

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.

Table 4 — Maximum pipework spans

Nominal diameter of 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

6.3.5.2 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;

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;

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.

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

In order 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.

6.4 Detection, actuation and control systems

6.4.1 General

Detection, actuation and control systems may be either automatic or manual. Where they are automatic, 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 national standard, 24-h minimum standby sources of energy shall be used to provide for 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 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 may result in 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 comply with 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 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 fire fighting system by means of 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

c) 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 may not require a manual release, or may 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 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 will occur.

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 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 appropriate action.

6.4.5.3 Alarms indicating failure of supervised devices or equipment shall give 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

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 ISO 14520 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 various parts of ISO 14520 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 as described in this part of ISO 14520, and shall be properly identified. The system design shall within the manufacturer's specified limitations.

NOTE 1 Variations from the nominal 20 °C storage temperature will 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 Balanced and unbalanced system

7.3.2.1 A balanced system shall be one in which:

a) each actual or equivalent pipe length from the container to each nozzle are all within 10 % of each other;

b) the discharge rate of each nozzle is equal (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).

7.3.3 Friction losses

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.

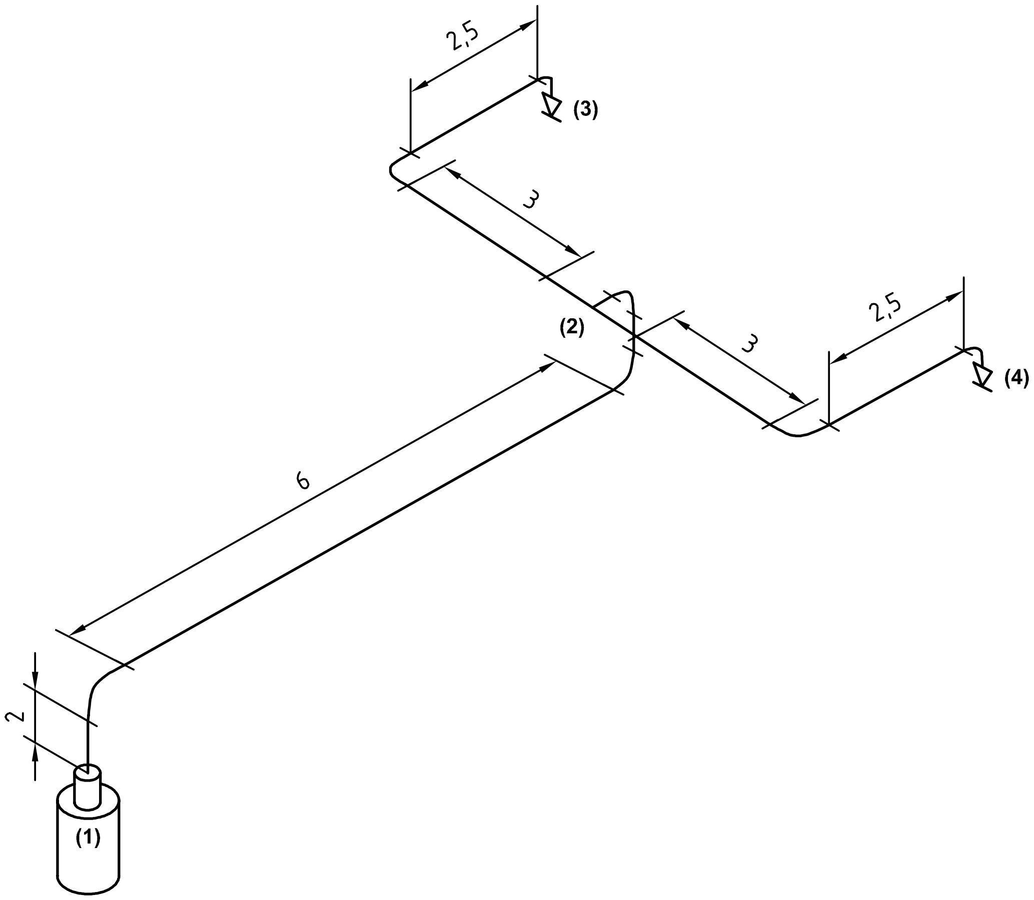
NOTE The flow of a liquefied gas has been demonstrated to be a two-phase phenomenon, the fluid consisting of a mixture of liquid and vapour, the proportions of which are dependent on pressure and temperature. The pressure drop is non-linear, with an increasing rate of pressure loss as the line pressure reduces 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 equations cannot be solved directly, a computer program is usually used to assist with the 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.

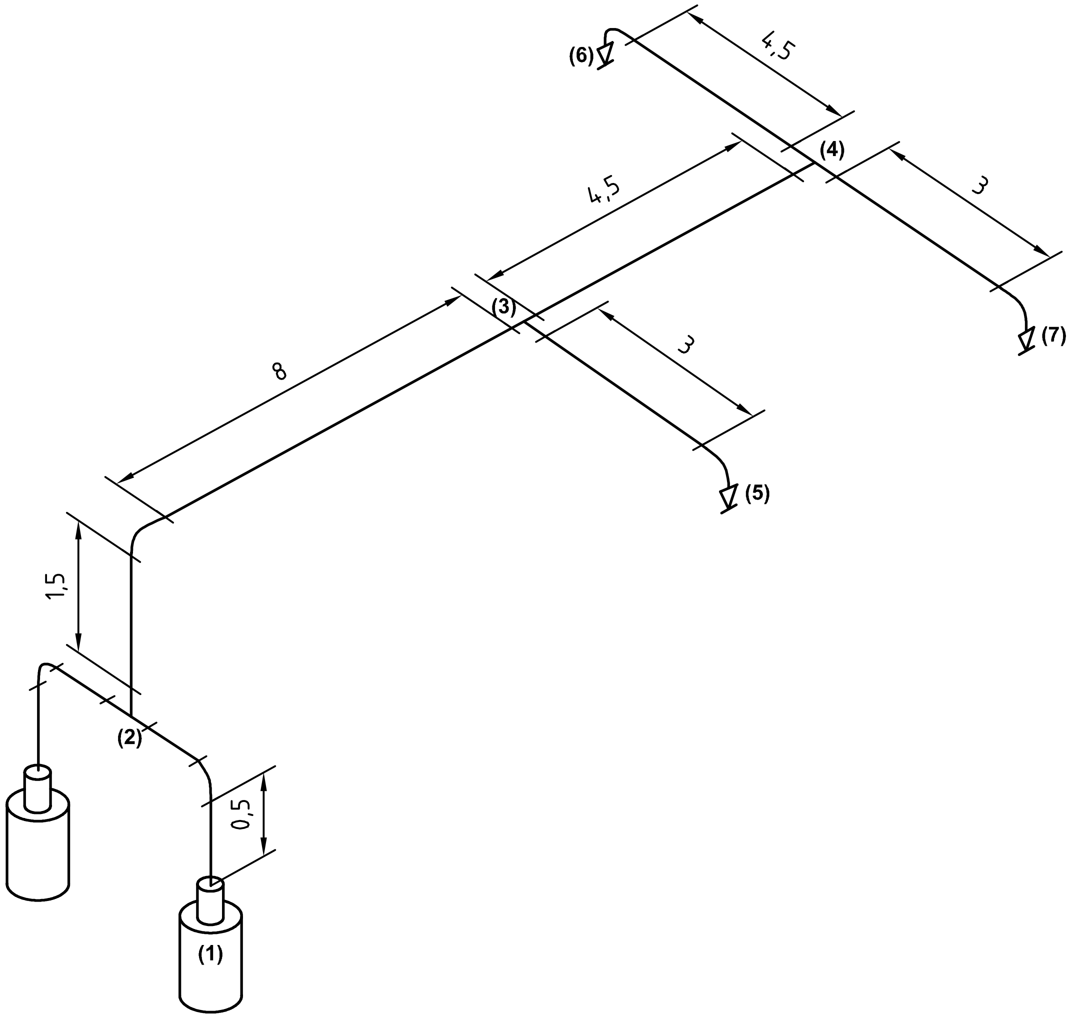
Dimensions in metres



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

7.3.5 Valves and fitting

Valves and fittings 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 cylinder valves shall be listed and shall include syphon tube (where fitted), valve, discharge head and flexible connector.

7.3.6 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.

7.3.7 Drawings

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

7.3.8 Liquefied gases: Specific requirements

7.3.8.1 Allowance shall be made for changes in elevation as specified in the relevant section of that part of ISO 14520 relating to the specific extinguishant.

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

NOTE If 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.

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 aversely affect the performance of the fire-extinguishing system or result in 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 Extinguishant concentration requirements

7.5.1 Flame extinguishment

7.5.1.1 For fire classifications, see ISO 3941.

7.5.1.2 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 heptane using the fire extinguishment/area coverage fire test procedure detailed in annex C. For hazards involving multiple fuels, the value for the fuel requiring the greatest design concentration shall be used.

7.5.1.3 The extinguishing concentration for Class A surface fires shall be determined by test using the fire test procedure described in annex C. The minimum design concentration for Class A fires shall be the extinguishing concentration plus a safety factor of 1,3. For a non-cellulosic Class A fuel, higher design concentrations may be required.

CAUTION — It is recognized that the wood crib fire may not indicate extinguishing concentrations suitable for the protection of plastic fuel hazards (e.g. computer and central rooms). More suitable tests are under development for inclusion in the next revision of ISO 14520. Until such time as these tests are finalized, a concentration not less than 90 % of that determined from the heptane fire test should 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 additional quantity of agent. Circumstances which may not be adequately covered by this factor (although in some cases they are covered by other requirements in this part of ISO 14520) and which may need allowance for additional extinguishant (i.e. more than 30 %) are included but not limited to the following.

a) Where leakage occurs from a non-tight enclosure. This is covered in this part of ISO 14520 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, may cause degradation of the extinguishing agent and hence reduce the efficiency of the agent.

g) Where metal surfaces, heated by the fire, may act as an ignition source if not adequately cooled during agent discharge and hold time.

In practice, application of this part of ISO 14520 is likely to result in higher safety factors, for example by the application of gross volumes rather than net volumes and design of systems for minimum anticipated temperatures, rather than those that apply in real conditions.

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

7.5.2 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 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 shall be determined by the test specified in annex D, plus a safety factor of 10 %.

7.6 Total flooding quantity

7.6.1 General

The amount of extinguishant required to achieve the design concentration shall be calculated from the equations in 3.6.2 or 3.6.3 as appropriate, or from the data in Table 3 *Total flooding quantity* in the parts of this standard for specific extinguishants.

In addition to these calculated concentration requirements, additional quantities of extinguishant may be required by national standards to compensate for any special conditions that would adversely affect the extinguishing efficiency (see 7.5.1), or if required by the physical characteristics of the extinguishant (see 7.9.1.2).

7.6.2 Liquefied gases

$$M = \left(\frac{C}{100 - C} \right) \frac{V}{S} \tag{1}$$

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);

S is the specific volume, in cubic metres per kilogram: $S = k_1 + k_2T$

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 Celsius.

7.6.3 Non-liquefied gas

$$Q = V \frac{S_R}{S} \ln \left(\frac{100}{100 - C} \right) \tag{2}$$

where

Q is the total flooding quantity, in cubic metres, at reference filling temperature and pressure;

C is the design concentration, in percent by volume;

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

S_R is the specific volume, in cubic metres per kilogram, at reference filling temperature and pressure:

$S = k_1 + k_2T$, at temperature T and 1,013 bar absolute pressure; S is the specific volume, in cubic metres per kilogram;

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

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

7.7 Altitude adjustment

The design quantity of the extinguishant shall be adjusted to compensate for ambient pressures that vary more than 11 % (equivalent to approximately 1 000 m of elevation change) from standard sea level pressure (1,013 bar 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 5. Correction factors for specific extinguishants will need to be calculated.

Table 5 — Correction factors

Equivalent altitude m	Correction factor (for ideal gases)
–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

7.8 Duration of protection

7.8.1 It is important that an effective extinguishant concentration not only be achieved, but is 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 resurgence of the initial event once the extinguishant has dissipated.

7.8.2 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 predicted hold time shall be determined by the door fan test specified in annex E, or a full discharge test based on the following criteria.

a) At the start of the hold time, the concentration throughout the enclosure shall be the design concentration.

b) At the end of the hold time, the extinguishant concentration at the height of the tallest hazard in the enclosure shall be not less than the fire extinguishing concentration.

c) The hold time shall be not less than 10 min, unless otherwise specified by the authority.

7.9 System performance

7.9.1 Discharge time

7.9.1.1 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 compliance with this clause.

7.9.1.2 Non-liquefied extinguishant

The discharge time required to achieve 95 % of the design concentration for non-liquefied extinguishants shall not exceed 60 s at 20 °C, or as otherwise required by the authority. Flow calculations performed in accordance with 7.3 or with the approved pre-engineered systems instruction manuals shall be used to demonstrate compliance with this clause.

7.9.2 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 is in compliance with 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.

8.3.2.3 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 may be found in the normal work area, or on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

8.2.3.8 All extinguishant storage containers shall be properly located in accordance with 'approved for construction' set of system drawings.

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 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.

Other assessment methods may normally be used to reduce unnecessary discharge into the environment, for example, the door fan pressurization test specified in annex E. 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 a period of 10 min at 3 bar. At the end of 10 min, the pressure drop shall not exceed 20 % of the test pressure.

b) All closed-section pipework 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 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, 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 compliance with the appropriate national standard and the system drawings. A.c. and d.c. wiring shall not be combined in a common conduit unless properly shielded and grounded.

8.2.5.2 All field circuitry shall be tested for ground fault 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 comply with 6.4 shall be used to provide for 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 type that once interrupted require 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 in close proximity and could be confused or the wrong system actuated. Manual release devices in this instance shall be clearly identified as to which hazard enclosure they protect.

8.2.5.9 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 valves, where fitted, so that activation of the release circuit will not release extinguishant. Reconnect the release circuit with a functional device in lieu of each extinguishant storage container release mechanism.

For electrically actuated release mechanisms, these devices may include suitable lamps, flash bulbs or circuit breakers. Pneumatically actuated release mechanisms may 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 activators, unless testing the valve will release extinguishant.

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

8.2.7.5 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 Operate each type of alarm condition and verify receipt of fault condition 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 to the user 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 part of ISO 14520, 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 At least every 6 months, the container contents shall be checked as follows.

a) Liquefied gases: for halocarbon extinguishants, if a container shows a loss in extinguishant quantity of more than 5 % or a loss in pressure (adjusted for temperature) of more than 10 %, it shall be refilled or replaced.

b) Non-liquefied gases: for inert gas extinguishants that are not liquefied, pressure is an indication of extinguishant quantity. Unless otherwise specified by the authority, if an inert gas extinguishant container shows a loss in pressure (adjusted for temperature) of more than 5 %, it shall be refilled or replaced. Where container pressure gauges or weight-monitoring devices are used for this purpose, they shall be compared to a separate calibrated device at least annually.

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 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 to 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 effective performance of a fire fighting system depends on fully adequate service procedures with, where possible, periodic testing.

Installers should 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 may have to operate. A suitable programme is as follows.

a) Weekly: Visually check the hazard and the integrity of the enclosure for changes which might reduce the efficiency of the system. Carry out a visual check that there is no obvious damage to pipework and that all operating controls and components are properly set and undamaged. Check 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 may have to operate the equipment or system are properly trained and authorized to do so and, in particular, that new employees have been instructed in its use.

9.3.3 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 to the user a signed, dated report of the inspection, advising any rectification carried out or needed.

During servicing, every care and precaution shall be taken to avoid release of extinguishant. A suitable schedule is provided in annex F.

9.4 Training

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

Personnel working in an enclosure protected by a gaseous extinguishant shall receive training in the operation and use of the system, in particular regarding safety issues.

Annex A
(normative)

Working documents

A.1 General

These documents shall be prepared only by persons fully experienced in the design of extinguishing systems. Deviation from these documents shall require permission from the authority.

A.2 Working documents

Working documents shall include the following items:

a) drawings, to an indicated scale of extinguishant distribution system, including containers, location of containers, piping and nozzles, valves and pressure-reducing devices and pipe hanger spacing;

b) name of owner and occupant;

c) location of building in which hazard is located;

d) location and construction of protected enclosure walls and partitions;

e) enclosure cross-section, full height or schematic diagram, including raised access floor and suspended ceiling;

f) 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 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 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 information.

A.3.2 Engineered systems

The details on the system shall include the following:

a) information and calculations on the amount of extinguishant;

b) container storage pressure;

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 pertaining to 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 teh cup burner method

B.1 Scope

This annex specifies the minimum requirements for determining the flame-extinguishing concentration of a gaseous extinguishant in 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 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 shown; the tolerance for all dimensions shall be ± 5 % unless otherwise indicated.

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, and a means of heating the fuel as shown in Figure B.1. 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 ± 2 mm and a wall thickness of 2 mm to 5 mm, with a height of 535 mm ± 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 ± 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 air flow rate. It shall have a calibrated means of measuring the air flow 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 ± 0,5) %. The source and the oxygen content of the air used shall be recorded.

NOTE "Air" supplied in commercial high-pressure cylinders may 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 certified type and meet the specifications of the supplier. Multi-component extinguishants should be provided premixed. Liquefied extinguishants shall be provided as pure extinguishant, i.e. not pressurized with nitrogen.

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 from the top of the cup.

B.5.3 Operate the heating arrangement for the cup to bring fuel temperature to 25 °C ± 3 °C or to 5 °C ± 3 °C above the open cup flash point, whichever is the 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 meant to be the temperature at the start of the test.

B.5.4 Adjust the air flow to achieve a flow rate of 10 l/min.

B.5.5 Ignite the fuel.

B.5.6 Allow the fuel to burn for a period of 60 s to 120 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 from the top of the cup.

B.5.7 Begin the flow of extinguishant. Increase the extinguishant flow rate in increments until flame extinguishment occurs, and record the extinguishant and air flow rates at extinguishment. The extinguishant flow rate increment should result in an increase in the extinguishant concentration of no more than 2 % 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. During this period the liquid level shall be maintained within 1 mm from the top of the cup.

NOTE 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.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 may be present on the cup.

B.5.10 Repeat B.5.1 to B.5.9 using air flow rates of 20 l/min, 30 l/min, 40 l/min and 50 l/min.

B.5.11 Determine the plateau region in the extinguishing concentration/air flow plot (i.e. the range of air flows over which the extinguishing concentration is at a maximum and is independent of the air flow) by plotting the extinguishing concentration as determined in B.5.8 versus the air flow rate.

If there is no plateau region found in this plot, further measurements according to B.5.10 shall be carried out using air flow rates higher than 50 l/min.

B.5.12 Place the flammable liquid in the fuel supply reservoir.

B.5.13 Admit fuel to the cup, adjusting the liquid level to within 5 mm to 10 mm from the top of the cup.

B.5.14 Operate the heating arrangement for the cup to bring the fuel temperature to 25 °C ± 3 °C or to 5 °C ± 3 °C above the open cup flash point, whichever is the 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.5.14 is meant to be the temperature at the start of the test.

B.5.15 Adjust the air flow to achieve a flow rate which is on the plateau region determined in accordance with B.5.11.

B.5.16 Ignite the fuel.

B.5.17 Allow the fuel to burn for a period of 60 s to 120 s before beginning the flow of extinguishant. During this period, the liquid level in the cup shall be adjusted so that the fuel level is within 1 mm from the top of the cup.

B.5.18 Begin the flow of extinguishant. Increase the extinguishant flow rate in increments until flame extinguishment occurs, and record the extinguishant and air flow rates at extinguishment. The extinguishant flow rate increment should result in an increase in the extinguishant concentration of no more than 2 % 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. During this period the liquid level shall be maintained with 1 mm of the top of the cup.

NOTE 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.5.19 Prior to subsequent tests, remove the fuel from the cup and remove any deposits of residue or soot that may be present on the cup.

B.5.20 Repeat B.5.12 to B.5.19 for four subsequent tests.

B.5.21 Determine the extinguishing concentration of the extinguishant for the case of unheated fuel in accordance with B.7 by establishing the average from five tests.

B.5.22 Repeat steps B.5.12 through B.5.20 with the fuel temperature at 5 °C below the boiling point of the fuel, or 200 °C, whichever is the lower. The fuel temperature shall be kept at this defined temperature during the whole test.

B.5.23 Determine the extinguishing concentration of the extinguishant for the case of heated fuel 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 air flow to 10 l/min.

B.6.4 Begin fuel flow to the cup and adjust the flow rate to attain a gas velocity nominally equal to the air velocity past the cup. The fuel temperature shall be 25 °C ± 10 °C.

NOTE The air velocity past the cup can be calculated from the air flow rate and the difference between the cross-section of the chimney and the cross-section of the cup.

B.6.5 Ignite the fuel.

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

NOTE On an initial run, it is convenient to employ 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 Determine the extinguishing concentration of the extinguishant in accordance with B.7.

B.6.11 Repeat steps B.6.4 through B.6.9 at air flow rates of 20 l/min, 30 l/min , 40 l/min and 50 l/min.

B.6.12 Determine the plateau region in the extinguishing concentration/air flow plot (i.e. the range of air flows over which the extinguishing concentration is at a maximum and is independent of the air flow) by plotting the extinguishing concentration as determined in B.6.10 versus the air flow rate.

If there is no plateau region found in this plot, further measurements according to B.5.11 shall be carried out using higher air flow rates than 50 l/min.

B.6.13 Adjust the air flow rate to a value on the plateau in the extinguishing concentration/air flow plot.

B.6.14 Begin fuel flow to the cup and adjust the flow rate to attain a gas velocity equal to the air velocity past the cup. The fuel temperature shall be 25 °C ± 10 °C.

B.6.15 Ignite the fuel.

B.6.16 Allow the fuel to burn for a period of 60 s before beginning the flow of extinguishant.

B.6.17 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.

NOTE On an initial run it is convenient to employ 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.6.18 Upon flame extinguishment, shut off the flow of flammable gas.

B.6.19 Prior to the subsequent tests, remove deposits of residue or soot if present on the cup.

B.6.20 Determine the extinguishing concentration of the extinguishant in accordance with B.7.

B.6.21 Repeat B.6.13 to B.6.20 for four subsequent tests.

B.6.22 Determine the extinguishing concentration of the extinguishant for the case of unheated fuel in accordance with B.7 by establishing the average of 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 which 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 as follows:

$$C = 100 \left(1 - \frac{O_2}{O_2(\text{sup})} \right)$$

where

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

O_2 is the oxygen concentration of the air/extinguishant mixture in the chimney, as a volume fraction in percent;

$O_2(\text{sup})$ 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 employed, the resulting mass flow rates need to be converted to volumetric flow rates as follows:

$$V_i \left(\frac{m_i}{\rho_i} \right)$$

where

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

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

ρ_i 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 may 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, is calculated as follows:

$$C = \frac{V_{ext}}{V_{air} + V_{ext}} \times 100$$

where

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

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

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

B.8 Reporting of results

As a minimum, the following information should be included in the report of results:

a) schematic diagram of apparatus, including dimensions and description of materials used;

b) source and assay of the extinguishant, fuel and air;

c) 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;

d) extinguishant, gaseous fuel and air flow rates at extinguishment; if method B.7.1 is used, the extinguishant concentration or the oxygen concentration instead of the extinguishant flow rate;

e) method employed to determine the extinguishing concentration;

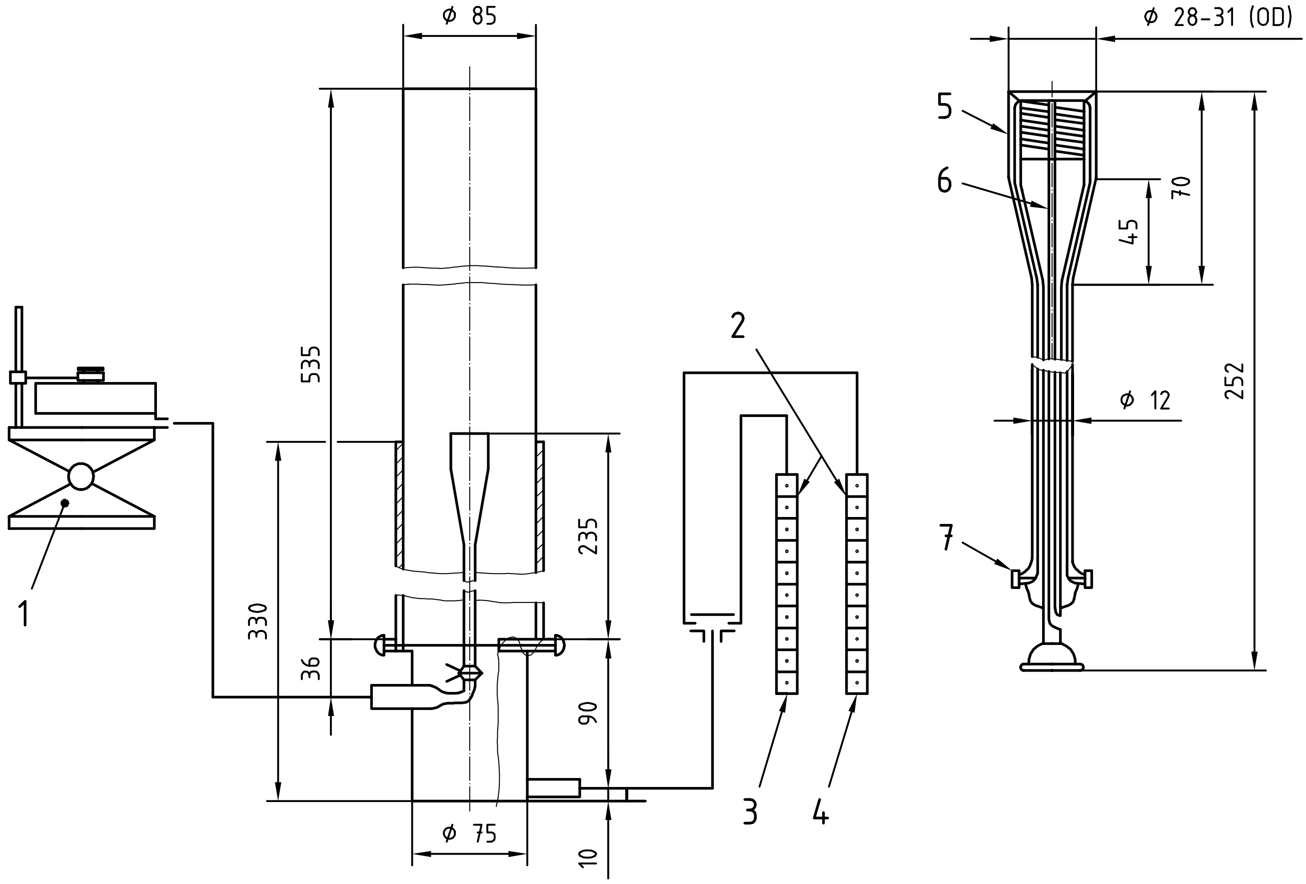
f) extinguishant concentration at extinguishment for each test;

g) extinguishing concentration for unheated fuel and for the fuel heated to 5 °C below its boiling point or 200 °C, whichever is the lower;

h) measurement error analysis;

i) extinguishing concentration/air flow plot and the extinguishant concentration at extinguishment for the tests according to B.5.9 to B.5.11 and B.6.10 to B.6.12.

Dimensions in millimetres



a) **Cup burner and test fuel reservoir**

b) **Details of heated cup**

Key

1 Levelling jack
2 Rotameters
3 Air
4 Extinguishant
5 Heating wire between inner and outer walls
6 Thermocouple tube
7 Heater terminal

Figure B.1 — Cup burner apparatus

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 an enclosure when tested in accordance with this test method under the maximum design limitations and most severe installation instructions. (See also C.1.2.)

C.1.2 When tested as described in C.5 and C.6.2 and C.6.3, an extinguishing system unit shall extinguish all visible flaming within 30 s after the end of the extinguishant discharge. When tested as discribed in C.6.1, an extinguishant system unit shall prevent re-ignition of the wood crib after a 10-min soak period.

C.2 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 area coverage for each type of nozzle;

b) the operating temperature range of the system;

c) location of nozzles in the protected area; the nozzle used in these tests shall not deliver the agent directly onto the test fire;

d) either the maximum length and size of piping and number of fittings to each nozzle, or the minimum nozzle pressure;

e) maximum discharge time;

f) maximum fill density; and

g) extinguishing concentrations for specific fuels.

The tests to be conducted are given in Table C.1.

Table C.1 — Tests to be conducted

Test objective	Enclosure size	Test fires	Clause
Nozzle min. height/max. area coverage	To suit nozzle	Heptane test cans	C.5
Nozzle max. height/extinguishing concentration	⩾ 100 m^3 no side less than 4 m height to suit nozzle (not less than 3,5 m)	a) wood crib b) heptane pan c) heptane test cans	C.6.1 C.6.2 C.6.3
NOTE All tests should be conducted with the same type and style of nozzle.			

C.3 Extinguishing system

C.3.1 The extinguishing system shall be assembled as follows.

a) Pre-engineered-type extinguishing system unit, using its maximum piping limitations with respect to 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^{+2}_{0} °C.

C.3.2 Except for the heptane pan and wood crib extinguishing tests, the agent containers shall be conditioned to the minimum operating temperature specified in the manufacturer's installation instructions.

C.3.3 For the heptane pan and wood crib extinguishing tests, the agent containers are to be conditioned at 20 °C ± 2 °C for a minimum period of 16 h prior to conducting the test. In these tests the jet energy from the nozzles shall not influence the development of the fire.

C.3.4 The extinguishing system shall be arranged and dimensioned with regard to the following.

a) For liquefied extinguishants, the time for the discharge of the pre-liquid gas phase plus the two-phase flow shall be 8 s to 10 s.

b) For non-liquified extinguishants, the time for the discharge shall be 50 s to 60 s.

C.4 Extinguishing concentration

C.4.1 The extinguishing concentration for each test shall be 76,92 % (i.e. 100 divided by the safety factor, where the safety factor is 1,3) of the intended end-use design concentration specified in the manufacturer's design and installation instructions at an ambient temperature of approximately 20 °C within the enclosure. The concentration within the enclosure for all extinguishants shall be calculated using equations (1) and (2) in 7.6. If significant test enclosure leakage does exist, the formula used to determine the test enclosure concentration of extinguishant may be modified to account for the leakage measured.

C.4.2 A cold discharge test using the same quantity of extinguishant shall be conducted to verify the actual concentration of extinguishant.

C.5 Nozzle minimum height/maximum area coverage test

C.5.1 Test facility

C.5.1.1 Construction

The test facility shall meet the following requirements.

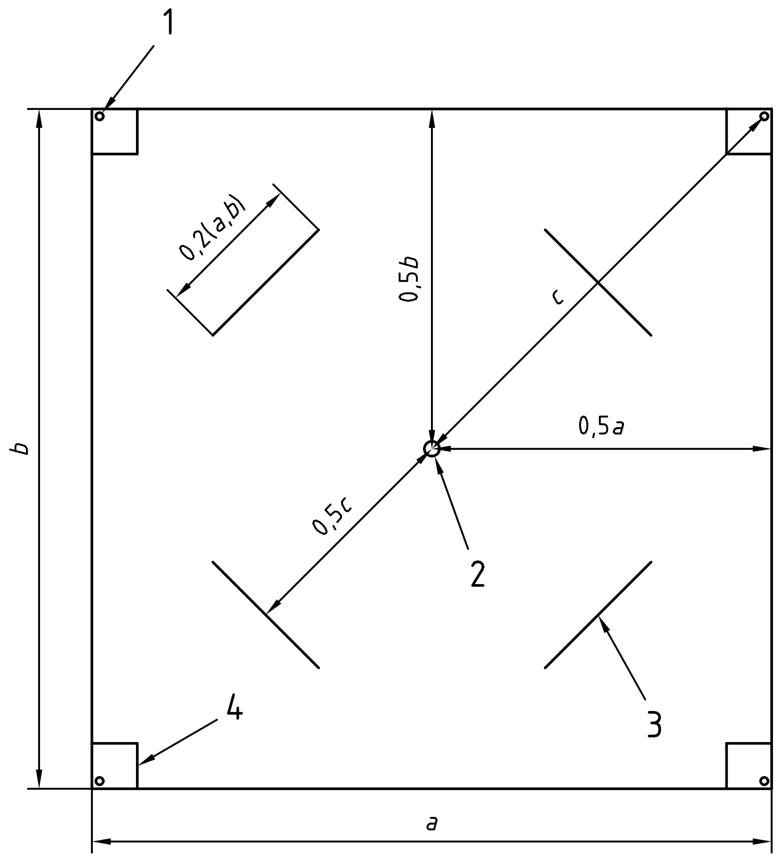
a) The area ($a \times b$) and height (H) of the enclosure (see Figure C.1) shall correspond to the maximum nozzle area coverage and minimum nozzle height specified by the manufacturer.

b) It shall be constructed of appropriate material; if plywood, this shall be at least 9,5 mm thick.

c) A means of pressure relief shall be provided.

d) Closeable openings shall be provided directly above the test cans to allow for venting prior to system actuation.

e) A baffle shall be installed between the floor (a,b) and ceiling (H) halfway between the nozzle location and the walls of the enclosure. The baffle shall be perpendicular to the direction of nozzle discharge, and shall be 20 % of the length or width of the enclosure, whichever is appropriate with respect to the nozzle location.



Key

1 Test can

2 Nozzle

3 Baffle

4 Closeable opening above test can

H is the minimum nozzle height specified by manufacturer for the nozzle;

$a \times b$ is the maximum nozzle area coverage for a single nozzle.

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

C.5.1.2 Instrumentation

C.5.1.2.1 Oxygen concentrations

The oxygen level shall be measured by a calibrated oxygen analyser capable of measuring the percentage oxygen to within at least one decimal place (0,1 %). The sensing equipment shall be capable of continuously monitoring and recording the oxygen concentration inside the enclosure throughout the duration of the test. At least three sensors shall be located within the enclosure (see Figures C.2 and C.3).

The three sensors shall be located at a horizontal distance from the centre of the room of between 850 mm and 1 250 mm and at the following heights above the floor (H is the height of the enclosure):

0,1H, 0,5H and 0,9H

C.5.1.2.2 Carbon dioxide and extinguishing gas concentrations

In addition to the oxygen concentrations, there should also be monitoring of the CO_2 concentration and possibly the concentration of the extinguishant gas. The accuracy of the measuring devices shall not be influenced by any of the fire products.

C.5.1.2.3 Nozzle pressure

The nozzle pressure during system discharge shall be recorded.

C.5.1.2.4 Enclosure temperature

At least the temperature at a horizontal distance from the centre of the room of between 850 mm and 1 250 mm and 0,5H (H is the room height) above the floor shall be recorded (see Figures C.2 and C.3). It is recommended to use K type thermocouples (Ni-CrNi), of diameter 1 mm.

The extinguishing process should be observed with an infrared camera.

C.5.1.2.5 Near nozzle temperature

For liquefied extinguishants, the temperature 10 mm to 30 mm in front of the nozzle, within the nozzle jet, shall additionally be recorded.

C.5.2 Fuel specification

C.5.2.1 Test cans

The test cans shall be cylindrical, 76,2 mm to 88,9 mm in diameter and at least 100 mm high.

C.5.2.2 Heptane

The heptane shall be commercial grade, having the following characteristics.

a) Distillation:

1) initial boiling point 90 °C

2) 50 % 93 °C

3) dry point 96,5 °C

b) Specific gravity (15,6 °C/15,6 °C) 0,719

c) Reid vapour pressure 2,0 psi

d) Research octane rating 60

e) Motor octane rating 50

C.5.2.3 Fire configuration and placement

C.5.2.3.1 The test cans may contain either heptane or heptane and water. If they are to 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.

Dimensions in millimetres

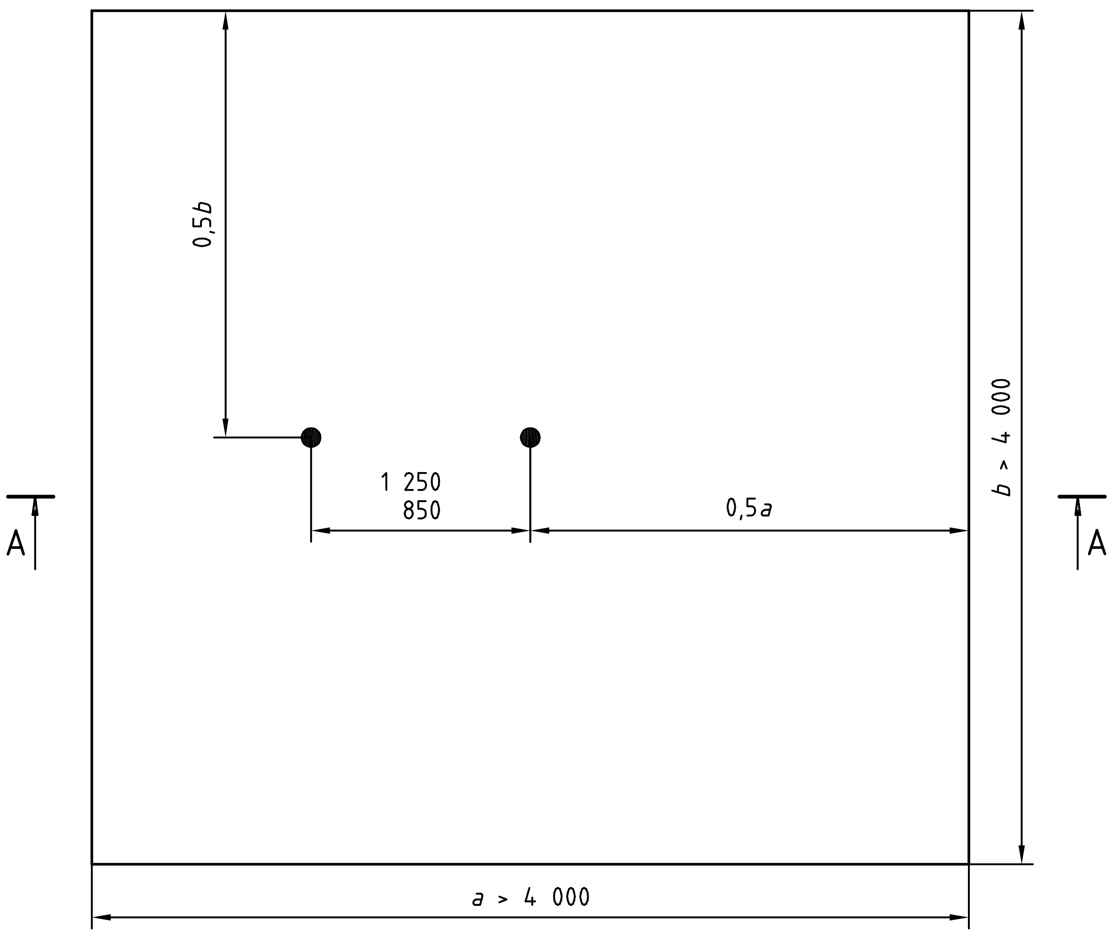
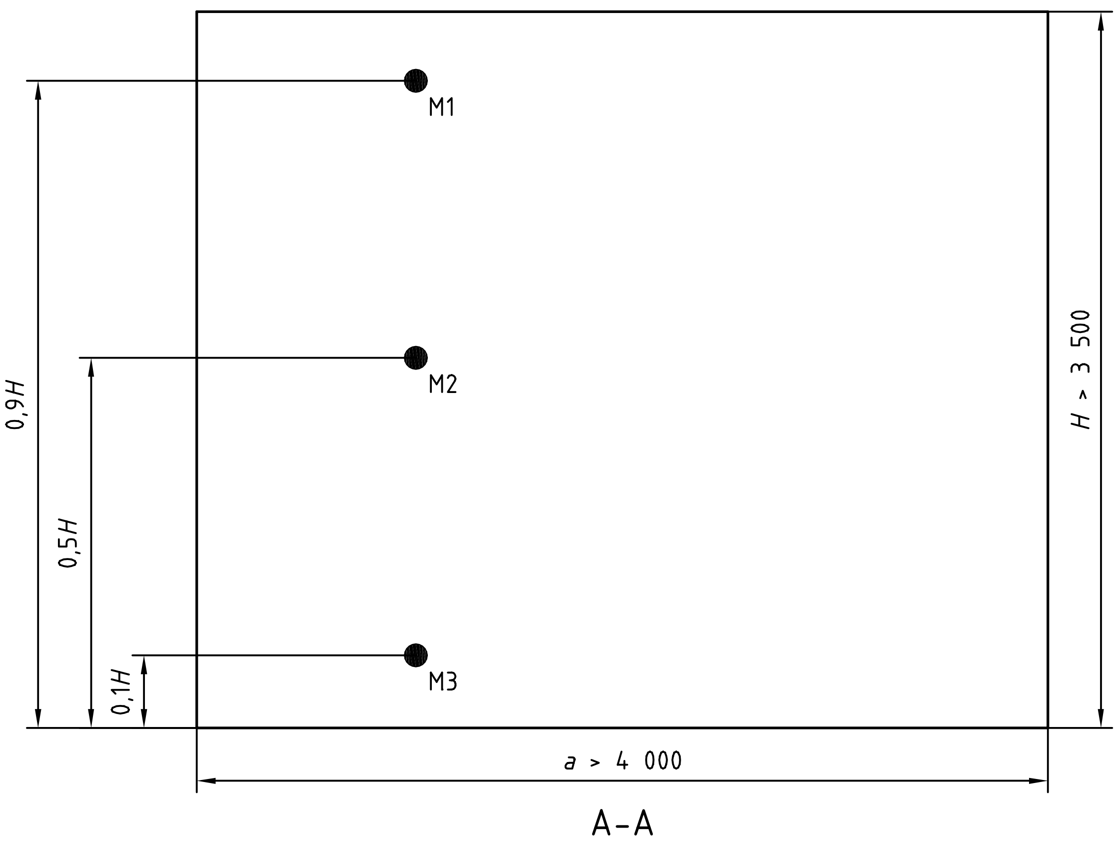


Figure C.2 — Plan view of instrumentation placement for nozzle minimum height/maximum area coverage test

Dimensions in millimetres



Measuring points:

M1 Record O_2 concentration

M2 Record O_2 concentration and temperature

M3 Record O_2 concentration

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

C.5.2.3.2 The test cans shall be placed within 50 mm of the corners of the test enclosure, directly behind the baffle (see C.5.1.1), and located vertically within 300 mm of the top or bottom of the enclosure, or both top and bottom if the enclosure permits such a placement.

C.5.3 Test procedure

C.5.3.1 Prior to commencing the tests, the composition of the extinguishing gas shall be analysed.

C.5.3.2 The heptane-filled test cans shall be ignited and allowed to burn for 30 s with the closeable openings above in the open position.

C.5.3.3 After 30 s, all openings shall be closed and the extinguishing system shall be manually actuated. At the time of actuation of the system, the amount of oxygen within the enclosure shall not be more than 0,5 % lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change by more than 1,5 % due to fire products. This change shall be determined by comparing the oxygen concentration calculated from the extinguishant concentration with the measured oxygen concentration.

C.6 Nozzle maximum height coverage 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 m^3. The height shall be at least 3,5 m. The floor dimensions shall be at least 4 m wide by 4 m long.

b) The test enclosure shall have the maximum ceiling height as specified in the manufacturer's installation instructions.

c) It shall be constructed with either indoor- or outdoor-grade plywood, minimum 9,5 mm thick, or equivalent material.

d) A means of pressure relief shall be provided.

C.6.1.1.2 Instrumentation

C.6.1.1.2.1 Oxygen concentrations

The oxygen concentration shall be measured by a calibrated oxygen analyser capable of measuring the percentage oxygen to within at least one decimal place (0,1 %). The sensing equipment shall be capable of continuously monitoring and recording the oxygen concentration inside the enclosure throughout the duration of the test. At least three sensors shall be located within the enclosure (see Figures C.4 and C.5).

One sensor shall be located at the equivalent height of the top of the test object from the floor, 0,6 m to 1 m away from the test object. The other two sensors shall be located at 0,1H and 0,9H (H is the height of the enclosure) (see Figures C.4 and C.5).

C.6.1.1.2.2 Carbon dioxide and extinguishing gas concentrations

In addition to the oxygen concentrations, there should also be monitoring of the CO_2 concentration and, possibly, the concentration of the extinguishant gas. The accuracy of the measuring devices shall not be influenced by any of the fire products.

C.6.1.1.2.3 Nozzle pressure

The nozzle pressure during system discharge shall be recorded.

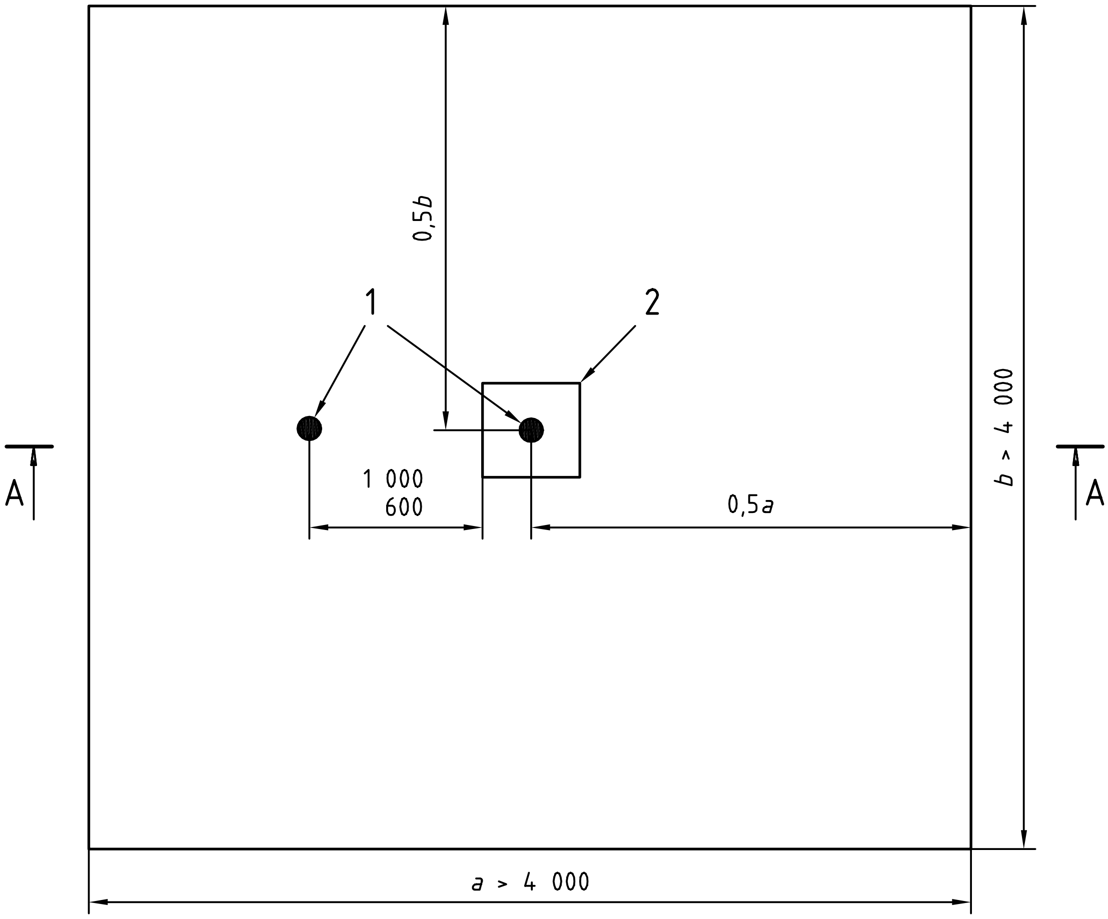
C.6.1.1.2.4 Enclosure temperature

Temperature sensors shall be located centred 100 mm and 0,9H (H is the room height) above the test object, and a third sensor at the equivalent height of the top of the test object from the floor, horizontally 0,6 m to 1 m away from the test object (see Figures C.4 and C.5). It is recommended to use K type thermocouples (Ni-CrNi), of diameter 1 mm. The extinguishing process should be observed with an infrared camera.

C.6.1.1.2.5 Near nozzle temperature

For liquefied extinguishants, the temperature 10 mm to 30 mm in front of the nozzle, within the nozzle jet, shall additionally be recorded.

Dimensions in millimetres



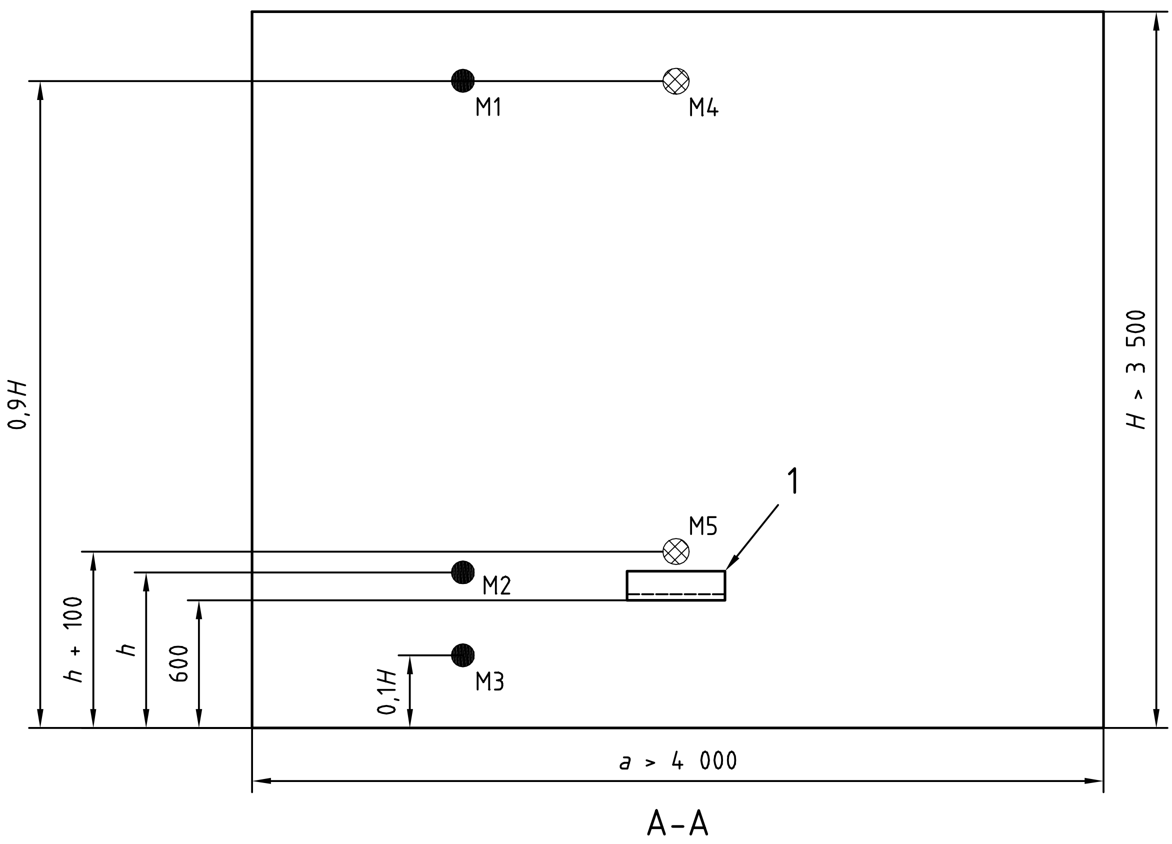
Key

1 Measuring point

2 Test object

Figure C.4 — Plan view of instrumentation placement for nozzle maximum height extinguishing concentration test

Dimensions in millimetres



Key

1 Test object

Measuring points:

M1 Record O_2 concentration

M2 Record O_2 concentration and temperature

M3 Record O_2 concentration

M4 Record temperature

M5 Record temperature

Figure C.5 — Side view of instrumentation placement for nozzle maximum height 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 commercial-grade heptane (specified in C.5.2.2) on a layer of water of 12,5 l in a square steel pan 0,25 m^2 in area, not less than 100 mm in height, and with a wall thickness of 6 mm (specified in C.6.2.2.2).

C.6.1.2.2 Fire configuration and placement

C.6.1.2.2.1 The wood crib shall consist of four layers of six, approximately 40 mm by 40 mm by 450 mm long, of 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 to form a square determined by the specified length of the wood members. Staple or nail together the wood members to form the outside edges of the crib.

C.6.1.2.2.2 The crib shall be pre-burned outside the enclosure on a stand supporting the crib 300 mm above the pan holding the igniter fuel.

After the pre-burn period, the crib shall be moved into the enclosure and be located on a stand supporting the crib centrally within the enclosure 600 mm above the floor.

C.6.1.3 Test procedure

C.6.1.3.1 Operation

C.6.1.3.1.1 Prior to commencing tests the composition of the extinguishing gas shall be analysed.

C.6.1.3.1.2 Centre the crib with the bottom of the crib approximately 300 mm above the top of the pan on a test stand constructed so as to allow for the bottom of the crib to be exposed to the atmosphere. The pre-burning shall take place outside the enclosure, if possible in a sufficiently large room (at least five times the volume of the test enclosure). In any case, the pre-burning shall not be influenced by weather conditions such as rain, wind, sun, 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 the pre-burn, air temperature, humidity and wind speed.

C.6.1.3.1.3 Ignite the heptane and allow the crib to burn freely. The 1,5 l of heptane will provide a burn time of approximately 3 min. After the heptane is exhausted, the crib shall be allowed to burn freely for an additional time of 3 min, resulting in a total pre-burn time of 6 min $\left({}^{+10}_{\ 0}\,\mathrm{s}\right)$ outside the test enclosure.

C.6.1.3.1.4 Just prior to the end of the pre-burn period, move the crib into the test enclosure and place it on a stand so that the bottom of the crib is 600 mm above the floor. Seal the enclosure and actuate the system. The time required to position the burning crib in the enclosure and the actuation of the system discharge shall not exceed 15 s.

C.6.1.3.1.5 At the time of actuation of the system, the amount of oxygen within the enclosure at the level of the crib shall not be more than 0,5 % lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1,5 % due to fire products. This change shall be determined by comparing the oxygen concentration calculated from the extinguishant concentration with the measured oxygen concentration.

C.6.1.3.1.6 After the end of system discharge, the enclosure shall remain sealed for a total of 10 min. After the 10-min soak period, remove the crib from the enclosure and observe to determine that sufficient fuel remains to sustain combustion and for signs of re-ignition. The following shall be recorded:

a) the presence and location of burning embers;

b) whether or not the glowing embers or the crib re-ignites; and

c) the mass of the crib after the test.

C.6.1.3.1.7 If necessary, amend the extinguishant concentration and repeat the experimental programme until three successive, successful extinguishments are achieved.

C.6.1.3.2 Recording of results

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

a) the calculated discharge time of the extinguishant, i.e. the time needed to reach 95 % of the laboratory extinguishant concentration, in seconds;

b) 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-liquified extinguishants the time from opening the container valve(s) to cutting off the discharge;

c) the time required to control the fire or to achieve extinguishment, in seconds;

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);

f) the temperature profile of the wood crib, preferably using an infrared camera.

C.6.1.3.3 Determination of design extinguishant concentration

The laboratory extinguishant concentration is that concentration which achieves satisfactory extinction of the fire over three successive tests. The design concentration is the laboratory concentration multiplied by an appropriate 'safety factor'.

C.6.2 Heptane pan test

C.6.2.1 Test facility

C.6.2.1.1 Construction

The construction of the enclosure shall be as described in C.6.1.1.1.

C.6.2.1.2 Instrumentation

Instrumentation of the enclosure shall be as described in C.6.1.1.2.

C.6.2.2 Fuel specification

C.6.2.2.1 Heptane

The heptane shall be commercial grade as specified in C.5.2.2.

C.6.2.2.2 Fire configuration and placement

The fire shall be in a square steel pan of base 0,25 m^2, height 200 mm, with a wall thickness of 6 mm. The test pan shall contain 50 mm of heptane with the heptane level 50 mm below the top of the pan, i.e. 12,5 l of heptane. 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 Operation

Prior to commencing the tests, the composition of the extinguishing gas shall be analysed.

Ignite the heptane and allow it to burn for 30 s. After 30 s all openings shall be closed and the extinguishing system shall be manually actuated. At the time of actuation of the system, the amount of oxygen within the enclosure shall not be more than 0,5 % lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change by more than 1,5 % due to fire products. This change shall be determined by comparing the oxygen concentration calculated from the extinguishant concentration with the measured oxygen concentration.

C.6.2.3.2 Recording of results

Results shall be recorded as specified in C.6.1.3.2 with the exception of items e) and f).

C.6.2.4 Determination of design extinguishant concentration

Determination of design extinguishant concentration shall be as specified in C.6.1.3.3.

C.6.3 Heptane test cans

C.6.3.1 Test facility

C.6.3.1.1 Construction

Construction of the enclosure shall be as described in C.6.1.1.1.

C.6.3.1.2 Instrumentation

Instrumentation of the enclosure shall be as described in C.5.1.2.

C.6.3.2 Fuel specification

C.6.3.2.1 Heptane

The heptane shall be commercial grade as specified in C.5.2.2.

C.6.3.2.2 Fire construction and placement

Specification of test cans is as described in C.5.2.1. The test can filling requirements and placement within the enclosure are as described in C.5.2.3.

C.6.3.3 Test procedure

C.6.3.3.1 Operation

Prior to commencing tests, the composition of the extinguishing gas shall be analysed.

Ignite the heptane and allow it to burn for 30 s. After 30 s all openings shall be closed and the extinguishing system shall be manually actuated. At the time of actuation of the system, the amount of oxygen within the enclosure shall not be more than 0,5 % lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1,5 % due to fire products. This change shall be determined by comparing the oxygen concentration calculated from the extinguishant concentration with the measure oxygen concentration.

C.6.3.3.2 Recording of results

Results are to be recorded as specified in C.6.1.3.2 with the exception of items e) and f).

C.6.3.4 Test requirement

The laboratory extinguishant concentration is that concentration which achieves satisfactory extinguishment (all test cans extinguished within 30 s after the end of agent discharge) over three successive tests. The design concentration is the laboratory concentration multiplied by an appropriate 'safety factor'.

Annex D
(normative)

Method of evaluating inerting concentration of a fire-extinguishing vapour

D.1 Scope

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 atm (1 bar 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 l ± 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 and components should be at nominal room temperature (22 °C ± 3 °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.4.2 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 atm (1 bar or 14,7 psia).

D.4.6 Turn on the fan and allow to mix for 1 min. Turn off the fan and wait for 1 min for the mixture to reach quiescent conditions.

D.4.7 Charge the capacitors to a potential of 720 V to 740 V (d.c.), producing a 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.

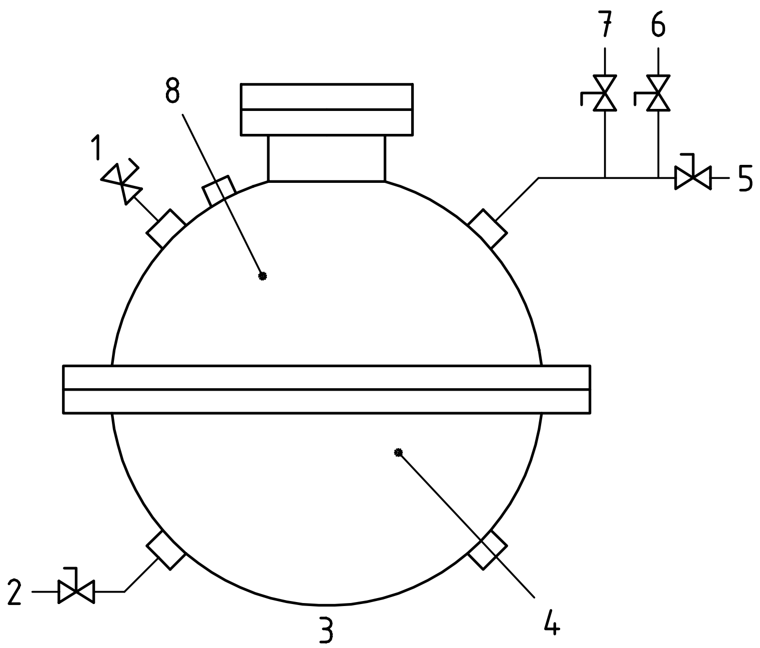
D.4.11 Retain the fuel/air ratio and repeat the test using varying amounts of extinguishant until conditions are found that bracket a pressure rise of 0,07 times the initial pressure.

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 atm (1 bar or 14,7 psia).

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

D.5 Inerting concentration

The inerting concentration is the concentration established in step D.4.12.



Key

1 Septum port
2 Gas inlet
3 Test vessel, 7,9 l
4 Igniter
5 Vent
6 Vacuum
7 Pressure gauge
8 Test chamber

Figure D.1 — Inerting apparatus

Annex E
(normative)

Door fan test for determination of minimum hold time

E.1 Scope

This annex contains information to establish the integrity of rooms and enclosures with respect to maintaining the extinguishant concentration for the relevant period. It includes details of test methods.

E.2 Test for determination of predicted minimum 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 air flow measurements is made from which the leakage characteristics of the enclosure are established.

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

a) That leakage occurs under the worst conditions, i.e. when one-half of the effective leakage area is at the maximum enclosure height and represents the inward leakage of air, and the other half (the lower leakage area) of the total effective leakage area is at the lowest point in the enclosure and represents the outward leakage of extinguishant/air.

b) That all leak flow is one-dimensional, i.e. ignoring stream functions.

c) That flow through any particular leak area is either into or out of the enclosure and either from or into an infinitely large space.

d) That the system is at sea-level, at a temperature of 20 °C, and atmospheric pressure of 1,013 bar absolute.

E.2.2 Apparatus

E.2.2.1 **Fan unit**, consisting of a frame which will fit into and seal an access opening in the enclosure, and one or more variable speed fans, with low flow facilities, capable of giving a differential pressure of not less than 25 Pa across the enclosure boundary.

E.2.2.2 **Two pressure-measuring devices**, 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 **Two thermometers**, to measure ambient temperatures.

E.2.2.6 **Signs**, reading "DO NOT OPEN — PRESSURE TEST IN PROGRESS" and "DO NOT CLOSE — PRESSURE TEST IN PROGRESS".

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

E.2.3 Calibration of apparatus

E.2.3.1 Fan unit

Calibrate the fan unit at the intervals and by the method recommended by the manufacturer. Keep records and, where appropriate, calibration certificates. Use a flowmeter accurate to ± 5 % and a pressure-measuring device accurate to ± 1 Pa.

E.2.3.2 Pressure-measuring devices

The pressure-measuring devices shall be calibrated not more than 12 months before a test. Records shall be maintained and, where appropriate, calibration certificates.

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

E.2.4 Preliminary preparation

E.2.4.1 Obtain a description from the user of the air-handling equipment and extinguishant-extraction systems in the enclosure.

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.2.4.3 Provide the following information to the user:

a) a description of the test;

b) the 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, shutdown of air-handling systems, holding doors open and/or shut).

E.2.5 Evaluation of enclosure

Obtain or prepare a sketch plan showing the walls, 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 or closed when the extinguishant system is discharged) of each door, hatch and damper, and which access opening(s) is(are) to be used for the fan unit.

Show the location of floor and sink drains.

E.2.6 Measurement of enclosure

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

a) the overall height of the protected enclosure, H_o;

b) the height of the highest hazard in the enclosure, H;

c) the gross volume of the protected enclosure, V_g.

E.2.7 Test procedure

E.2.7.1 Preparation for test

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 turbulence 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 leaks, 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 all air-handling equipment and extinguishant-extraction systems to the state they would be in at the time of extinguishant system discharge, except for the following:

a) recirculating air-handling equipment without fresh air make-up which does not give a bias pressure across the enclosure boundary or otherwise preclude accurate testing, and which would be 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) recirculating air-handling equipment which would continue to operate on extinguishant discharge should be shut down if it creates excessive bias pressure.

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.

E.2.7.1.7 Close all doors and windows in the enclosure envelope.

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

E.2.7.2 Setting up 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 air-flow 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. 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 by approximately 15 Pa. Check all dampers with smoke and ensure that they are closing properly. Check doors and hatches and ensure correct closure. Inspect the wall perimeter (above and below any false floor) and the floor slab for any major leaks and note their size and location.

E.2.7.3 Measurement of bias pressure

E.2.7.3.1 Seal the fan unit inlet or outlet and, without the fans(s) operating, observe the enclosure differential pressure-measuring device for at least 30 s.

E.2.7.3.2 If a bias pressure is indicated, use smoke to detect the consequent air flow and its direction. If the existence of a bias pressure is confirmed, record the pressure-measuring device reading as the bias pressure (P_b).

E.2.7.3.3 If the enclosure is large, or if the bias pressure is largely caused by wind or stack effects, repeat the measurement at one or more different access openings. Record all the values measured and use the largest positive value (or if only negative values are recorded, the value closest to zero) as the bias pressure.

A bias pressure as low as 0,5 Pa can affect the accuracy of the test result. If the bias pressure has a numerical value greater than 25 % of the extinguishant/air column pressure, then the hold time is likely to be low and the enclosure may not hold the specified extinguishant concentration. The source of the excessive bias pressure should be identified and, if possible, permanently reduced.

In the event of fluctuating bias pressures (such as those created by wind effects), it may not be possible to achieve the necessary correlation accuracy in the fan test results. These fluctuating pressures may need to be eliminated before an accurate fan test can be carried out.

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.

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

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 the value of ($P_f + P_b$), which will be positive.

E.2.8 Calculations

E.2.8.1 Symbols

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

A_e	effective leakage area	(m^2)
A_l	actual lower leakage area below height H	(m^2)
A_t	actual total leakage area	(m^2)
c	design concentration of extinguishant in air for the enclosure	(%)
c_{min}	minimum concentration of extinguishant in air for the enclosure	(%)
F	lower leakage fraction, effective area of lower leaks divided by effective area of all leaks	(dimensionless)
g_n	gravitational acceleration (= 9,81)	(m/s^2)

H	height of highest hazard	(m)
H_o	overall height of enclosure	(m)
k_0	actual leakage area discharge coefficient (= 0,61 to 1,0)	(dimensionless)
k_1	leakage characteristic [see equation (E.8)]	$(m^3/(s \cdot Pa^n))$
k_2	correlation constant [see equation (E.9)]	$[kg^n \cdot m^{3(1-n)}/(s \cdot Pa^n)]$
k_3	simplifying constant [see equation (E.10)]	(m/s^2)
k_4	simplifying constant [see equation (E.11)]	$(Pa \cdot m^3/kg)$
n	leakage characteristic [see equation (E.7)]	(dimensionless)
P_f	differential pressure produced by the fan	(Pa)
P_m	extinguishant/air column pressure	(Pa)
P_b	bias pressure	(Pa)
Q	air flow rate	(m^3/s)
Q_f	measured air flow rate through fan	(m^3/s)
Q_l	air flow rate, temperature corrected	(m^3/s)
Q_{lm}	mean value of Q_l at $P_f = P_m$	(m^3/s)
$Q_{lm/2}$	mean value of Q_l at $P_f = \frac{1}{2} P_m$	(m^3/s)
T_e	air temperature inside enclosure	(°C)
T_o	air temperature outside enclosure	(°C)
t	predicted minimum hold time	(s)
V_g	gross volume of enclosure	(m^3)
ρ_a	air density (1,205 at 20 °C and 1,013 bar)	(kg/m^3)
ρ_{mf}	extinguishant/air mixture density at 80 % of the minimum design concentration at 20 °C and 1,013 bar atmospheric pressure	(kg/m^3)
ρ_{mi}	extinguishant/air mixture density at design concentration, at 20 °C and 1,013 bar atmospheric pressure	(kg/m^3)
ρ_m	density of extinguishant/air mixture	(kg/m^3)
ρ_e	density of superheated extinguishant	(kg/m^3)

E.2.8.2 Air flow rates

From the measured values of ($P_f + P_b$) and P_b, calculate the values of P_f and, using the fan calibration data (see E.2.2.1), the corresponding air flows Q_f through the fan. Calculate the corrected air flow rates using equations (E.1) and (E.2), as appropriate:

For depressurization

$$Q_l = Q_f \left(\frac{T_o + 273}{T_e + 273} \right) \tag{E.1}$$

For pressurization

$$Q_l = Q_f \left(\frac{T_e + 273}{T_o + 273} \right) \tag{E.2}$$

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

$$|Q_l| = k_1 \, |P_f|^n \tag{E.3}$$

and check that the correlation coefficients of each set are not less than 0,99 using the least-squares method. The two sets will almost always have different values of k_1 and n.

E.2.8.3 Density of extinguishant/air mixture

Calculate the density of the extinguishant/air mixture at 20 °C at the design concentration using the equation:

$$\rho_{mi} = \frac{\rho_e \, c}{100} + \frac{\rho_a (100 - c)}{100} \tag{E.4}$$

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

$$\rho_{mf} = \frac{\rho_e \, (0{,}8c_{min})}{100} + \frac{\rho_a \, (100 - 0{,}8c_{min})}{100} \tag{E.5}$$

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

$$P_m = g_n H_o (\rho_{mi} - \rho_a) \tag{E.6}$$

E.2.8.4 Leakage characteristics

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

Calculate the average values (i.e. of the pressurization and depressurization data) of Q_{lm} and $Q_{lm/2}$ respectively:

$$n = \frac{\ln Q_{lm} - \ln Q_{lm/2}}{\ln 2} \tag{E.7}$$

$$k_1 = \exp \frac{(\ln Q_{lm})(\ln \rho_{lm}) - (\ln Q_{lm/2})(\ln \rho_m - \ln 2)}{\ln 2} \tag{E.8}$$

E.2.8.5 Correlation constant

Calculate the correlation constant k_2 using the equation:

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

Calculate the simplifying constant k_3 using the equation:

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

Calculate the simplifying constant k_4 using the equation:

$$k_4 = \frac{P_b}{\rho_{mi} + \rho_a \left(\frac{F}{1-F}\right) 1/n} \tag{E.11}$$

E.2.8.6 Predicted hold time: Enclosures without mixing

For enclosures without mixing, assume $F = 0,5$ and calculate the predicted minimum hold time t for the extinguishant/air interface to fall to height H, using the equation:

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

E.2.8.7 Predicted hold time: Enclosures with mixing

For enclosures with mixing, assume F = 0,5 and calculate the predicted minimum hold time t for the extinguishing concentration in the enclosure to fall from the design concentration to 80% of the minimum design concentration (see 11.2) using the equation:

$$t = \frac{V_g}{Fk_2} \int_{\rho_{mf}}^{\rho_{mi}} \left(\frac{2g_n \ H_o \ (\rho_m - \rho_a)^{(n+1)/n} + 2P_b \ (\rho_m - \rho_a)^{1/n}}{\rho_m + \rho_a \left(\frac{F}{1-F}\right)^{1/n}} \right)^{-n} \mathrm{d}\rho_m \tag{E.13}$$

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

E.2.9 Test report

Prepare a written report containing the following information:

a) the enclosure leak flow characteristics (i.e. the average values of k_1, and n);

b) the design concentration of extinguishant;

c) the gross volume of the enclosure;

d) the quantity of extinguishant provided;

e) the height of the enclosure;

f) the height of the highest hazard;

g) the predicted minimum hold time and whether or not the value complies with the recommendation of 7.8.2 c), i.e. whether it is less than 10 min or the higher necessary value, as appropriate.

h) the sketch plan used in the evaluation of the enclosure as specified in 7.4;

i) the current calibration data for the fan unit and the pressure-measuring devices, and, if available, corresponding certificates;

j) the test results, including a record of the test measurements and any appropriate computer printout.

E.3 Treatment of enclosures with predicted minimum hold times less than the recommended value

E.3.1 General

If the predicted minimum hold time, calculated in accordance with E.2.8.6 or E.2.8.7, is less than as recommended in 7.8.2, then E.3.2 and E.3.3 shall be implemented in sequence.

E.3.2 Estimation of leakage area

To illustrate the scale of the problem calculate the effective leakage area, A_{e} from the equation:

$$A_{\mathrm{e}} = \frac{Q_{\mathrm{l}}}{P_{\mathrm{f}}^{n}} \left(\frac{\rho_{\mathrm{a}}}{2}\right)^{n} = k_1 \left(\frac{\rho_{\mathrm{a}}}{2}\right)^{n} \qquad \text{(E.14)}$$

It is usually not possible to measure A_{e} or k_0 (which will be between 0,61 and 1,00, depending on the geometry of the leakage paths).

E.3.3 Improved sealing of the enclosure

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

E.3.4 Quantification and location of leaks

E.3.4.1 General

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

The fan test does not show the location of the leaks or the value of the lower leakage fraction F. In E.2.8.6 and E.2.8.7 it is assumed that the value of F is 0,5, with all the lower leaks in the base of the enclosure and that all the upper leaks (equal in area to the lower leaks) are in the top of the enclosure. This is the worst case and gives the minimum value for the hold time.

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

The hold time will also be underestimated if F is not 0,5 and the effect of this can be calculated.

E.3.4.2 Second calculation of hold time

Make a second calculation of the hold time using equations (E.10), (E.11) and (E.12) or equation (E.13), as appropriate, assuming F = 0,15. If this value is more than the recommended minimum [see 7.8.2 c)] then make an estimate of the actual value of F using one or both of the methods of E.3.4.3.

E.3.4.3 Methods of estimating F

E.3.4.3.1 First method

Temporarily seal known or suspected leaks, such as large dampers, or suspended ceilings or raised floors using for example plastics sheet and sealing tape, and carry out additional fan tests. Calculate the effective leakage area from equation (E.14) and compare with the original value (see E.3.2) and estimate F for the original condition.

E.3.4.3.2 Second method

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

E.3.5 Final calculation of hold time

Using the value of F estimated as in E.3.4.3, which should not be more than 0,5 or less than 0,15, recalculate the hold time using equations (E.10), (E.11) and (E.12) or equation (E.13) as appropriate.

Annex F
(informative)

System performance verification

A suitable procedure for verification of the system is as follows.

a) **Every 3 months:** Test and service all electrical detection and alarm systems as recommended in the appropriate national standards.

b) **Every 6 months:** Perform the following checks and inspections.

   1) Externally examine pipework to determine its condition. Replace or pressure test and repair as necessary pipework showing corrosion or mechanical damage.

   2) Check all control valves for correct manual function and automatic valves additionally for correct automatic function.

   3) Externally examine containers for signs of damage or unauthorized modification, and for damage to system hoses.

   4) Check pressure gauges of extinguishing containers, liquefied gas should be within 10 % and non-liquefied gases within 5 % of correct charge pressure. Replace or refill any showing a greater loss.

   5) For liquefied gases, check weigh or use a liquid level indicator to verify correct content of containers. Replace or refill any showing a loss of more than 5 %.

c) **Every 12 months**

Carry out a check of enclosure integrity using the method given in annex E. If the measured aggregate area of leakage has increased from that measured during installation which would adversely affect system performance, carry out work to reduce the leakage.

d) **As required by statutory regulations**, but otherwise when convenient, remove the containers and pressure test when necessary.

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