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## PROPERTY INSURANCE COMMITTEE

### Prevention Specifications

#### **FIRE EXTINGUISHING SYSTEMS USING LIQUIFIED "HALOCARBON" GASES PLANNING AND INSTALLATION**

*CEA 4045: April 2005 (en)  
EFSAC endorsed*

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# 1 GENERAL

This specification for fire extinguishing systems using halocarbons is created based on CEA specifications for planning and installation for gas extinguishing systems and other national and international guidelines.

The existing draft "Fire extinguishing systems using liquefied halocarbon gases – Planning and installation", CEA GEI 7 N95/2 will be replaced.

## 1.1 Scope

**1.1.1** This specification gives the requirements for design, installation and maintenance of fire extinguishing systems using "halocarbon" gas when used for the protection of buildings, industrial manufacturing plants, and for the extension or modification of existing installations.

This specification details requirements for specified halocarbon gases, see Appendix A1. The gases covered by these rules may be extended in the future<sup>1</sup>. It is not the intention of the specification to indicate approval of any of the extinguishants listed.

Halocarbon gas	Chemical name	More Information	Trade names
HFC 227ea	C <sub>3</sub> F <sub>7</sub> H	Appendix A1, Appendix B1	e.g. FM200
Fk-5-1-12	CF <sub>3</sub> CF <sub>2</sub> C(O)CF(CF <sub>3</sub> ) <sub>2</sub>	Appendix A1, Appendix B2	e.g.: Novec1230

Table 1.1: Halocarbon gases

The specification includes not only requirements for halocarbon gas system installations and associated components but also requirements for buildings and objects to be protected. These rules are in accordance with the current state of the art.

The specification covers objects

- which are listed in clause 2.3 and for which the design concentration is covered by clause 2.3
- for which the design concentration is defined in clause 2.3.2
- whose extinguishing and design concentration is checked by approved test methods. Quantity must be co-ordinated with the inspection body authorized by the insurers. A request for exception must be submitted to this body.

The system shall be planned and installed by an approved installer, according to this specification, using approved, compatible components. Approval is given by an accredited certification body accepted by the Insurers based on CEA standards for components. In the future, CEA component standards are replaced by EN 12094-series.

Due to his qualification the installer must be able to guarantee effective fire protection also in situations not covered by this specification. The appropriate authority shall be consulted with regard to factors not covered by these rules.

This specification covers extinguishing systems for protecting the complete content of a room or enclosed object (total flooding systems). This specification does not cover systems for protection of objects that are not completely enclosed<sup>2</sup>, explosion suppression and inerting systems (see also clause 2.1.1).

**1.1.2** This specification describes the minimum requirements.

<sup>1</sup> To include additional agents, application should be made to CEA..

<sup>2</sup> For protection of electrical and electronic installations the specifications according to CEA 4007 clause 11.5 has to be used.

In this document:

- "shall" indicates a mandatory requirement,
- "should" indicates a recommendation.

**1.1.3** The non-existence of regulations in this specification does not authorise the installer to design without agreement of the appropriate authority.

**1.1.4** Halocarbon gas installations shall comply with this specification and any national legislation<sup>3</sup>.

**1.1.5** Actuation of the installation can be automatic or manual. Installations according to this specification must be actuated automatically. In addition a manual actuation of the installation might be reasonable or necessary.

## **1.2 Aims**

**1.2.1** The function of the installation is to extinguish a fire in the earliest stage of development. It may be necessary to maintain gas concentration for a period of time to prevent reignition.

**1.2.2** The design, installation and approval shall be based on a detailed knowledge of the protected zone, its use and associated alarm organisation.

It is important to consider the fire precautions of the premises as a whole. An installation may be a "stand alone" fire protection system or part of a combination of other fire protection measures.

## **1.3 Definitions**

Alarm device:

Device which emits audible or visual alarm signals.

Authority:

Body having jurisdiction over aspects of the installation, e.g. Insurer, fire brigade, government agencies, authorized inspection body.

Calculation zone:

Zone for which the design quantity of gas required is calculated independently.

Control device:

Device for initiating the discharge process, actuation of the alarm device and any ancillary control equipment.

Deep seated fire:

Fire involving solids subject to smouldering inside the solid combustible material.

Delay device:

Automatic device which delays the release of the gas for a pre-determined period of time (pre-warning time), to permit evacuation of personnel.

Delay time:

A pre-set time period between the triggering of the system and the discharge.

Design concentration:

Minimum concentration for extinguishing agent including safety factors which has to

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<sup>3</sup> See appendix Z

be achieved inside the protected enclosure.

Design quantity:

Quantity of gas to be discharged into the calculation zone.

Discharge time:

Time period from opening the container valves until reaching 95% of the design concentration within the whole flooding zone.

Emergency triggering device:

Manually operated device which can be used to trigger the installation in the event of failure of the normal triggering device.

Emergency stop device:

Manually operated device which prevents the release of gas.

Extinguishing concentration:

Minimum concentration of extinguishing agent required to extinguish the flame of a given fuel under defined experimental conditions excluding any safety factor.

Fire detection device:

Device reacting to the fire characteristics, i.e. smoke, heat or flames.

Fire detector:

Fire detection device complying with EN 54.

Flooding zone:

Zone comprising all calculation zones to be flooded simultaneously with halocarbon gas.

Holding time:

Time from exceeding the design concentration to the time of falling below 85% of the design concentration at 10% and 90% of the maximum room height.

Halocarbon gas:

Extinguishing agent that contains as primary components one or more organic compounds containing one or more of the elements fluorine, chlorine, bromine or iodine. Examples are hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs).

Installation:

Installed halocarbon gas fire extinguishing system.

LOAEL:

Lowest Observable Adverse Effect Level, i.e. the lowest concentration at which an adverse toxicological or physiological effect has been observed.

Local application system:

System designed to protect objects that are **completely** enclosed (see also 2.1.1).

NOAEL:

No Observed Adverse Effect Level, i.e. the highest concentration at which no adverse toxicological or physiological effect has been observed.

Non-electrical disable device (lock-off device):

Mechanical device that prevents the release of gas while maintenance, inspection or service work is being carried out in the protected zone.

Halocarbon gas storage area:

Room or area housing the gas supply container(s).

Pre-warning time:

Time period, to warn endangered personnel, between the start of the warning indication and discharge.

Pressure relief device:

Mechanically operated device, limiting the pressure increase in the area to be protected to a pre-set value.

Release mechanism:

Mechanism that upon actuation by the control device automatically opens the container valve and if fitted, a selector valve, to release the gas.

Selector valve:

Valve in the main feed pipe that directs the gas from the supply container(s) to the appropriate flooding zone.

Surface fire:

Fire involving flammable liquids and solids not subject to smouldering. For these fires the burning is taking place in a zone of mixed fuels (as gas) and air.

Supply quantity:

Total quantity of gas kept available for use within a flooding zone, comprising the design quantity and any supplementary quantity required to compensate for filling variations.

System:

System of components which are approved for correct function and compatibility with one another.

Total flooding system:

Installation to protect the complete contents of an enclosure.

## **1.4 Description of the installation**

- 1.4.1 The block diagram shown in Appendix A2 illustrates the functional interaction between the components which shall (solid lines) or may (dotted lines) be present in an installation.

Halocarbon gas installations, in general, consist of gas containers, valves, fixed pipework with appropriately located nozzles in the protected zone and devices for detecting the fire, alarms, triggering and release.

The gas is stored in pressurized containers at room temperature.

- 1.4.2 Automatic detection and triggering devices or manual triggering devices are used to actuate the system. This may be achieved using any approved method or device which can be used to recognize and indicate the presence of heat, flames or smoke in the protected zone.

- 1.4.3 The control equipment starts alarm devices, if necessary a delay device, and activates the release mechanism of containers and – if available – selector valves.

Automatic triggering and release might be done by mechanical, pneumatic or electrical systems resp. combination of these systems.

- 1.4.4 The installation may be equipped with automatic devices used to switch off machinery and close fire doors and other equipment, the purpose being to build up and to hold the desired gas concentration.

## **1.5 Personnel safety**

- 1.5.1 In any installation where personnel could be endangered, suitable safeguards shall

be provided to ensure prompt evacuation of the zone, and to prevent entry into the zone after discharge and to provide means for prompt rescue of any trapped personnel. Such safety aspects as personnel training, warning signs, alarm and delay devices shall be considered.

For manned areas, a delay device with sufficient delay time for personnel to evacuate the area without undue haste shall be provided to ensure doors are closed before agent release thus property protection objectives are achieved.

- 1.5.2 The halocarbon gas concentration required for effective extinguishing may be dangerous to life.

The following requirements shall be met:

- > provision of exit routes, which shall be kept clear at all times, and provision of adequate direction signs,
- > a flooding zone shall not serve as the only evacuation route for other zones,
- > provision of only outward-opening self-closing doors which shall be openable from the inside even when locked from the outside,
- > provision of alarms that are distinctive and independent from all other alarm signals and that shall operate immediately upon detection of the fire,
- > provision of illuminated signs at entrances to the protected zone, to alert personnel to the danger due to flooding. The illuminated sign shall be maintained until the atmosphere has been made safe. Alternatively the re-entry of personnel should be prevented by locking the doors.
- > provision of warning and instruction signs at entrances to the protected zone,
- > provision of means of ventilating the zones after releasing gas. If not available it shall be guaranteed that such means of ventilation are provided after release (for instance by the fire brigade).
- > vented gases shall not be directed into an occupied area,
- > provision of a non-electrical disable device,
- > provision of any other safeguards that a careful study of each particular situation indicates are necessary.

The following should be considered:

- > provision of self-contained breathing equipment and personnel trained in its use,
- > provision for adding a non-flammable and non-toxic odour to the gas so that hazardous atmospheres may be recognised.

- 1.5.3 Additional safety precautions shall be taken if the gas concentration exceeds LOAEL

Consideration shall be given to the risk of leakage of gas into adjacent zones where hazardous concentrations could be reached.

It shall be taken into account that the final concentration in the flooding zone can be higher than the design concentration (e.g. because of additional quantities).

- 1.5.4 In all cases, national regulations relating to personnel safety shall be observed.

## **1.6 Alarm organisation**

An effective method of alarm organisation shall be provided to:

- > alert appropriate persons,
- > alert the fire brigade,
- > initiate other required measures.

See also clause 5.5.

## 1.7 Application and effectiveness

1.7.1 In order to determine the extent of the protection, a risk analysis shall be carried out.

1.7.2 It may be necessary to maintain gas concentration for a period of time (e.g. until hot surfaces have cooled off) to prevent reignition. Extinguishing agents are limited. After first operation the remaining extinguishing agent is normally triggered manually for a possible re-operation. Therefore, effective installations shall extinguish immediately and finally.

1.7.3 Halocarbon gas can extinguish fires listed in clause 2.3. If used for different risks, Halocarbon gas cannot extinguish fires involving:

- > chemicals containing an oxygen supply, such as cellulose nitrate,
- > mixtures containing oxidizing agents, such as sodium chlorate,
- > chemicals capable of autothermal decomposition, such as some organic peroxides,
- > reactive metals, such as sodium, potassium,
- > solid materials in which fires may quickly become deep seated,
- > installations showing hot surfaces for technical reasons (temperatures higher 150°C).

For special cases, the appropriate authority shall be consulted.

## 1.8 Units

Pressure values not marked as gauge pressure are absolute pressure.  
Dimensions not explicitly specified are SI-units.

## 2 DESIGN OF THE INSTALLATION

### 2.1 Type of installation and structural requirements

2.1.1 This specification covers only total flooding systems and objects that are completely enclosed.

2.1.2 Buildings, rooms and enclosed objects (flooding zones), protected with halocarbon gas total flooding systems shall be of such a nature that the effective gas concentration will be reached and maintained for a sufficient time.

2.1.3 The integrity of the enclosure (walls, ceilings, floors, doors, windows etc.) shall withstand any increase or decrease of pressure during discharge. Pressure relief devices shall be provided in the upper section of a room, to prevent excessive pressure fluctuations in the flooding zone.

*Note: An architect or building consultant should evaluate the strength of the construction (pressure difference).*

Pressure relief devices shall be opened only in the event of design thresholds being reached. They shall close automatically when the pressure differential has dissipated. An example of the calculation method for pressure relief devices is given in appendix A7.

Pressure relief devices shall lead outside the building, but not in the direction of

windows or ventilation systems of other rooms. Personnel safety consideration shall be met.

Pressure relief devices shall meet the requirements according to appendix A8.

- 2.1.4 The construction and location of the enclosure should be in accordance with Appendix A5, taking account of the protection objectives. The enclosure shall be non-combustible or have a fire resistance of at least 30 minutes according to the national rules, so that the enclosure is maintained until the end of the holding time.

Openings shall be closeable with closures meeting the specified criteria. Closure of openings shall be triggered by the extinguishing installation or by the same system that actuates the extinguishing installation.

Requirements listed in appendix A5 might not be sufficient to meet national regulations.

- 2.1.5 Structural parts of the enclosure that do not meet the requirements according to clause 2.1.1 to 2.1.4, shall be rated as non-closeable openings.

- 2.1.6 Non-closeable openings that are supposed in case of fire to lead directly outside the building are not permitted.

- 2.1.7 Non-closeable openings or non-suppressible ventilation to adjacent areas are not permitted.

If, in exceptional cases, non-closeable openings or non-suppressible ventilation are inevitable, the planning shall be done in accordance with the appropriate authority. It shall be proved that both the surface area of all openings, which are supposed to exist in case of fire, and the non-suppressible ventilation will not impair the requested holding time. If this requirement is not met the installation shall be performed as a local application system for not or incompletely enclosed objects using a proper extinguishing agent.

- 2.1.8 If openings are operationally necessary, proper measures shall be taken to guarantee that closure is complete before commencement of the extinguishing agent discharge.

Operationally open fire protection covers shall have reusable locks.

- 2.1.9 Smoke and heat exhaust ventilation systems  
In rooms with gas extinguishing systems, smoke and heat exhaust ventilation systems (SHEVs) shall not open automatically. SHEVs shall be triggered manually. In case of fire, only authorised persons shall trigger the SHEVs. The triggering device must be protected against unauthorised access. If fast temperature rise is assumed (e.g. lacquer production, production and processing of foam, storage of flammable liquids) smoke and heat exhaust ventilators shall be heat-resistant in order to avoid damage before the end of the extinguishing agent discharge (see table in appendix A5).

## 2.2 Extinguishing agent quantity

- 2.2.1 The required gas design quantity must be determined in accordance with the following formula.

$$Q = \rho_{gas} \cdot \frac{DF \cdot C_L}{100 - DF \cdot C_L} \cdot (V_R + k \cdot A_V)$$

the minimum supply quantity is

$$Q_S = FT Q,$$

with the following definitions:

- $C_A$  = DF ·  $C_L$   
 $V_R$  =  $V_V - V_G$   
 $Q$  = design quantity, in kg.  
 $Q_S$  = minimum supply quantity, in kg.  
 $FT$  = factor related to additional quantity for leakage and filling and tapping tolerances,  
 1.1 for <20 containers, otherwise 1.05 for  $\geq 20$  containers<sup>4</sup>.  
 $\rho_{Gas}$  = density of the extinguishing gas, in kg/m<sup>3</sup>.  
 (at a pressure of 1013 mbar<sup>5</sup> and a temperature of 20°C<sup>6</sup>.)  
 $C_A$  = design concentration, in vol% gas (see table 2.1 and 2.2),  
 $C_L$  = extinguishing concentration in vol% gas determined under test conditions specified  
 in Appendices A4 and A9.  
 $DF$  = design (or safety) factor  
 = 1.3 x scaling factor – if the extinguishing concentration is specified by “cup burner”-testing method (appendix A4)<sup>7</sup>,  
 = 1.3 – if the extinguishing concentration is specified by enclosure fire tests (appendix A9)  
  
 $A_V$  = Total surface of the calculation zone including openings  $A_o$ , in m<sup>2</sup>.  
 $V_V$  = Volume of the enclosure or the volume of the object, in m<sup>3</sup>.  
 $V_G$  = Volume of the building structure which can be deducted, in m<sup>3</sup>.  
 $V_R$  = calculated volume in m<sup>3</sup>.  
 $k$  = constant: 0.27 m (this dimension is necessary to get the right dimension in the formula).

The "volume term"  $\rho_{gas} \cdot \frac{DF \cdot C_L}{100 - DF \cdot C_L} \cdot V_R$  comprises the minimum quantity of gas taken as a basis for the formula.

The "surface term"  $\rho_{gas} \cdot \frac{DF \cdot C_L}{100 - DF \cdot C_L} \cdot k \cdot A_V$  comprises the portion of gas that can escape due to leakage from the enclosure.

If  $V_R + k A_V > 1.47V_R$  then the gas quantity calculated according to the following formula can be taken as the upper limit for the design quantity:

$$Q_{max} = \rho_{gas} \cdot \frac{DF \cdot C_L}{100 - DF \cdot C_L} \cdot 1.47 \cdot V_R$$

The factor k in “surface term” can be a lower value if the build-up and holding of gas concentration can be ensured because of the construction of the enclosure and a full flooding test, or equivalent<sup>8</sup> with measurement of the concentration undertaken for confirmation purposes (requirements according to table 2.2) see clause 10.1.6.

The design quantity, however, shall be at least equal to the "volume term" specified in the basic formula:

<sup>4</sup> The number of bottles that are required for storage of design quantity per flooding zone is relevant. The surcharge related to the flooding zone may vary using multi-area installations.

<sup>5</sup> If the environmental pressure is more than 11% (equivalent to ca. 1000m altitude difference) less or more than normal pressure (1013 bar), the density of the corresponding pressure has to be used for calculation of quantity.

<sup>6</sup> If the temperature in the protected room is lower than 10°C, the density at the room temperature shall be used.

<sup>7</sup> See clause 2.3.2

<sup>8</sup> such as the fan test (Appendix A10)

$$Q_{\min} = \rho_{gas} \cdot \frac{DF \cdot C_L}{100 - DF \cdot C_L} \cdot V_R$$

2.2.2 If calculation zones are not separated as described in clause 2.1.4 or separated 5 m as a minimum they shall form one flooding zone.

If closures of openings are actuated by the extinguishing installation, combustible materials shall not be stored or processed within a radius of 2,5 m.

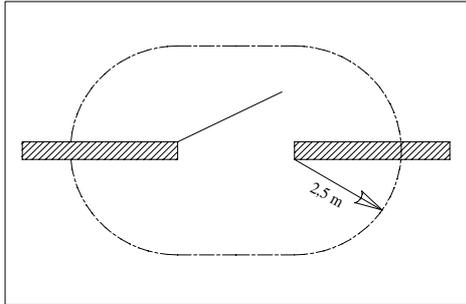


Figure 2.1 Requirements for flooding zones

2.2.3 A maximum of two separate flooding zones may be combined for simultaneous flooding.

2.2.4 The sum of all calculation zone boundary surfaces ( $A_v$ ) shall be used in the formula of clause 2.2.1 in accordance with the following.

- The boundary surface of total flooding installation is the sum of any area of walls, ceilings and floors. This applies to local application systems accordingly.
- The boundary surface between the calculation zones of one flooding zone may be omitted when determining  $A_v$  in the formula specified in clause 2.2.1.

2.2.5 The total supply quantity shall be calculated for the flooding zone with the largest extinguishant demand.

2.2.6 Figure 2.2 shows the maximum quantity per flooding zone.

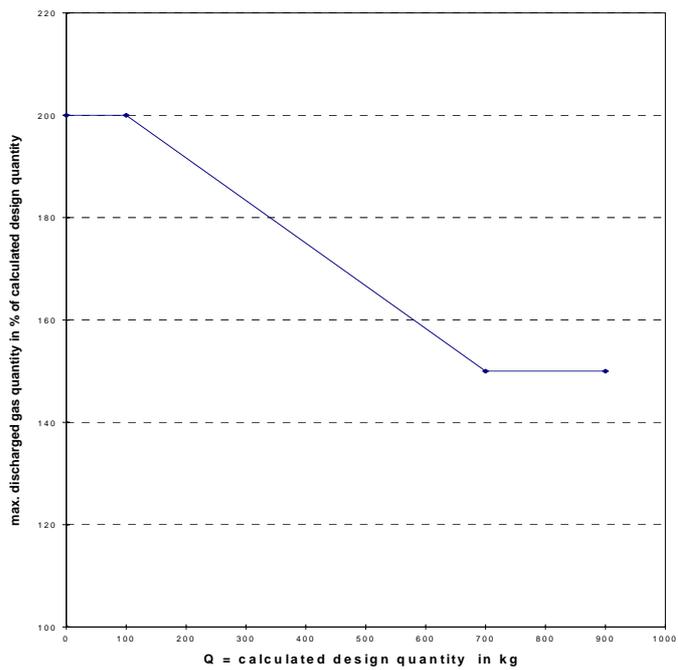


Figure 2.2 Maximum quantity

The maximum quantity according to clause 2.2 may be exceeded in case of cable floors, if this is necessary to meet the requirements of clause 3.4.1 (maximum protection area per nozzle: 30 m<sup>2</sup>).

## 2.3 Design concentration

2.3.1 The numerical values for design concentration given for the flammable materials and special risks listed in Table 2.1 and Table 2.2 are to be inserted in the formula specified in clause 2.2.1 which is used to determine the gas design quantity.

*Note: Detailed information related to table 2.1 and table 2.2 in appendix B.*

If there are different materials in one calculation area, the maximum design concentration shall be used.

Material	HFC 227ea	FK-5-1-12
Acetone	10.1	
Ethyl alcohol	11.9	
Methanol	15.4	
n-heptane	8.8	6.1
Toluene	8.0	

Table 2.1 design concentration for flammable liquids in Vol% agent

special application	HFC 227ea	FK-5-1-12
Computer installations, EDP-rooms, electrical switch and distribution rooms*	8.4	5.8
Cablefloors	8.4	5.8
* Storage or processing of material is not allowed.		
<p><i>Note 1: Appendix A9 shows testing methods for design concentration for plastics (e.g. IT). The maximum of the four determined design concentrations for plastics and cables shall be the basis for design concentration. Due to a lack of test data, according to this new test method, for a transitional period the concentrations for IT-, EDP-risks in table 2.2 are based on 95% of heptane design concentration. This may result in a lower level of protection. Within 3 years after publication of these rules, the standard including table 2.2 will be revised taking into account available results of testing.</i></p> <p><i>Note 2: The concentrations given in table 2.2 may not be sufficient in case of power cables when the power is not shut down and therefore cables and/or equipment are energised during the extinguishment period.</i></p>		

Table 2.2. design concentration for special installations in Vol% agent

2.3.2 The design concentration for hazards not listed\* shall be determined by using the cup burner apparatus described in Appendix A4, by using the room fire test method (see appendix A9) or any other test method giving equivalent results.

The design factor DF of extinguishing concentration depends on the chosen testing method:

$$DF = 1.3 \times \text{scaling factor}$$

If the extinguishing concentration is determined by "cup-burner"-method (appendix A4)

$$DF = 1.3$$

If the extinguishing concentration is determined by "enclosure fire tests" (appendix A9)

If the extinguishing concentration determined by the "cup-burner" -method (appendix 4) is higher than the extinguishing concentration determined using the "enclosure fire tests" (appendix 9), the value from the "cup-burner"-method shall be used as a basis for the determination of the design concentration.

As an indication, a value of 1.2 is given for the scaling factor but in each case the design shall be co-ordinated with the authority.

*Note: if both detailed results from extinguishing tests for flammable liquids according to appendix A9 are available and it is possible to determine the scaling factor from tests according to appendices A4 and A9, the scaling factor will be fixed.*

The design concentration results from the multiplication of the extinguishing concentration and the corresponding design factor.

*Notes: The resultant concentration may be higher than the calculated design concentration and, therefore, consideration should be given to safety of personnel, see clause 1.5.*

## **2.4 Reserve quantity**

A reserve quantity of the same amount as the supply quantity shall be permanently connected for the following conditions:

- > when more than five flooding zones are connected to the installation,
- > if the gas supply quantity cannot be replaced within 36 hours.

A reserve quantity of double the amount of the supply quantity shall be permanently connected, when more than 30 flooding zones are connected to the installation.

## **2.5 Gas storage**

2.5.1 The gas supply quantity and reserve quantity shall be stored in such a way that it is available at all times and cannot be used for other purposes.

2.5.2 For factory-filled containers, the container volumes shall be 140 litres maximum. Only one container size at one pressure and filling density shall be used in an installation. The filling tolerance per bottle shall be +5/-0 % of the nominal value of the extinguishing agent (in kg) and +5/-5% of the nominal value of the pressure cushion (in bar).

2.5.3 The containers shall be installed so that each individual container can be easily mounted and shall be fitted with a check valve to the manifold if there is more than one container.

2.5.4 The quantity of available extinguishant shall be monitored. Any loss in weight or pressure of more than 10% of the extinguishant in any container shall be automatically indicated.

The checking unit shall be easily manageable and ensure that, during the test, no gas leaks from the bottles.

If, by special construction, only a pressure check is necessary to monitor the amount of agent, this special construction must be approved within component or system approval.

2.5.5 All legal and official regulations for pressure containers<sup>9</sup> must be met.

## **2.6 Container marking**

Containers shall be additionally marked with

- the name of the company responsible for the installation,
- the type of gas,

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<sup>9</sup> see appendix Z

- quantity of gas,
- filling density and degree of superpressurization
- specifications for the gas used as pressure cushion.

## 2.7 Gas storage area

2.7.1 The gas storage area should be located in a separate room, which is not exposed to excessive risk of fire and be located as close as possible to the flooding zone

2.7.2 The gas storage area shall be:

- > easily accessible, even in the case of fire,
- > protected against access by unauthorised persons,
- > used for this purpose only, no (flammable) materials shall be stored.
- > normally kept at a temperature between 0°C and 35°C,
- > equipped with ventilation,
- > planned in such a way that maintenance and inspection can be easily carried out,
- > electrically illuminated,
- > if necessary heated.

The components installed in the gas storage room shall be protected against overheating caused by sunlight or other sources.

The gas storage room shall be separated from neighbouring rooms/areas and protected from mechanical and chemical influences.

2.7.3 Operating instructions shall be permanently fixed inside the gas storage area in a visually unobstructed position.

Available in the gas storage area shall be,

- the name of the company responsible for maintenance of the system,
- the year of installation or essential change,
- instructions for use and maintenance and relevant data for the installation.

These instructions shall contain:

- Operating instructions for the gas extinguishing system with scheme of plumbing and control
  - If necessary, the information about the number of weights used for opening the container valves
- General drawing showing the protected areas.

## 2.8 Hydraulic calculation

The nozzles and pipework shall be dimensioned in such a way that the required gas quantity to achieve 95% of design concentration shall be discharged into the flooding zone within the discharge time specified in clause 2.9.

Attention shall be paid to the temperature of the gas container room and the pressure at the discharge nozzle to ensure that a homogenous gas mixture is present within the enclosure. As minimum pressure is dependent upon nozzle design, reference shall, therefore, be made to individual component characteristics.

As a basis for the calculation, the method described in Appendix A6 can be chosen.

Any other method used shall be approved by a certification body accepted by the Insurers.

## 2.9 Discharge time

Referring to table 2.1 and table 2.2 the discharge time shall not exceed 10 seconds and the design concentration at any point within the enclosure shall be achieved.

## 2.10 Holding time

The holding time (difference between design concentration and fall short of 85% of design concentration in the room, i.e. 10% and 90 % of maximum room height) shall be at least 10 minutes. Disadvantageous situations (for instance hot surfaces or deep seated fires) may require longer holding time.

# 3 DISTRIBUTION PIPEWORK

## 3.1 Pipes

3.1.1 Pipes and pipe connections shall be made of metal and be able to withstand the pressures specified in Table 3.1 and any low temperature encountered.

The piping including design and wall thickness shall comply with national regulations. Examples for detailed requirements are given in Appendix A11.

A safety valve shall protect sections of pipe that could be subjected to static head pressure, i.e. closed pipework.

	Service pressure bar	Test pressure bar**	Sort of pipe	Certificate according to EN10204
Pipework between container and selector valve*	as in the container at maximum temperature according to clause 2.7.2	1,5 times service pressure	seamless welding	3.1 B 3.1 B 3.1 B 3.1 B
Pipework downstream of selector valve	as calculated	1,5 times as calculated	seamless welding	2.2 2.2
Fitting downstream of selector valve	as calculated	1,5 times as calculated		2.2
<p>* Safety valves shall ensure that service pressure cannot be increased by leakage from the container valves</p> <p>** leakage test of the pipes shall result from tests of inside pressure with water according to the standard or a useful test without destruction</p>				

**Table 3.1 Pipe quality requirements**

Fittings must be calculated according to table 3.1 for the occurring service pressure. Fittings shall be suitable for lower temperatures (ca. -50°C).

Regarding the nozzle pipe network of gas extinguishing systems, a certificate according to

EN 10204 shall be submitted. This certificate shall confirm that the pipes are designed depending on the occurring service pressure.

Regarding manifolds and distribution pipes, a test certificate of the manufacturer according to EN 10204 shall prove that the pipes are dimensioned for the required service pressure. All used materials and parts shall be listed in the certificate.

Pipework between container and selector valve shall be marked by the manufacturer so that an identification according to the test certificates is possible after installation. Manifolds and distribution pipes may be marked as a kit by an authorised person. A non-ambiguous correlation to the test certificate must be possible.

3.1.2 Flexible pipes and hoses etc. shall only be used where fixed pipes are unsuitable. Flexible pipes and hoses shall be as short as possible.

3.1.3 Pipes smaller than DN8 (nominal diameter 8mm) are not permitted. Pipes smaller than 10 mm have to be galvanised or of stainless steel.

3.1.4 The inside and outside of pipes shall be effectively protected against corrosion if this is necessitated by environmental conditions. To protect sensitive machinery, e.g. computers, from corrosive particles in the pipework, galvanised steel should be used as a minimum. Special-alloy steels and/or suitable surface protection coatings shall be used if the use of pipes and connections made of steel does not provide sufficient corrosion protection.

Pipes in rooms of electrical and electronic risks must be galvanised.

3.1.5 Welding on site shall not be performed for pipes smaller than or equal to DN50, except in factories with approved factory welding methods.

The welding procedure shall be in accordance with national regulations. Fire hazard works are not permitted in areas protected by gas extinguishing systems.

3.1.6 If condensation water can form in the pipework, suitable means shall be provided for drainage. Drainage points shall not be accessible to unauthorised persons.

Drainage points must be

- easy to use (e.g. stop valve with plug)
- easy to maintain
- the installation must be pendulous (leaving from pipeline directly downwards or sideways justified to the lower edge of the pipeline)

If an automatic drainage point is used, it must be approved.

3.1.7 The pipework shall be arranged so that it cannot be damaged by its own weight, temperature fluctuations, vibration, release of gas or other installation inherent influences. All pipework shall be accessible.

3.1.8 The gas installation pipework shall be earthed. If necessary, electrical connections potential equalization conductors (e.g. regarding non-conductive pipe joints) between all pipes shall be provided or the installation shall be earthed at different points (auxiliary equipotential bonding).

*Notes:*

- *In ex-areas the national regulations must be met*
- *Regarding lightning protection, the national regulations must be met.*

3.1.9 Any imbalance of flow division at a tee shall not exceed 1:10. The preferred method of division is horizontal, as vertical division of flow is more likely to cause phase separation of the extinguishing gas.

## **3.2 Pipe supports**

- 3.2.1 The low temperature generated when gas is discharged shall be taken into account when designing pipe supports. Pipe support anchors shall also be able to withstand prevailing static and dynamic loads.

Change in length of pipe due to thermal effects shall be borne in mind.

- 3.2.2 Pipe supports shall be designed so that under extreme load there is no danger of the installation being damaged.

This condition is deemed fulfilled when the supports have been designed and constructed using main and additional load as a basis.

If the temperature rises from +20°C to +200°C, the ultimate tensile strength of the material used shall not be reduced by more than 25%. Combustible materials shall not be used.

Supports that do not conform to the requirements of clauses 3.2.2 to 3.2.6 shall be specially approved.

- 3.2.3 For minimum cross-sectional area of supports see Table 3.2.

In the case of pipe supports which are designed such that the load is distributed over more than one individual cross-sectional area, the sum of the individual cross-sectional areas acting parallel to one another shall be at least 1.5 times the respective minimum cross-sectional area.

Pipe nominal diameter mm	Rated load N	Minimum cross-sectional area of support (mm <sup>2</sup> ) /thread size	Minimum depth for fastening plugs in concrete mm
≤DN50	2000	30 (M8)	30
>DN50 ≤ DN100	3500	50 (M10)	40
>DN100 ≤ DN150	5000	70 (M12)	40
>DN150 ≤ DN200	8500	125 (M16)	50
>DN200 ≤ DN250	10000	150 (M20)	60

**Table 3.2 Supports**

Each individual cross-sectional area shall not be less than 30mm<sup>2</sup>. In determining whether pipe supports have more than one individual cross-sectional area acting parallel to one another, holes for bolts and rivets do not have to be taken into account. Pipe clips and other devices for holding pipe shall completely surround the pipe and be closed.

- 3.2.4 The material from which a pipe support is manufactured shall be at least 3mm thick. If galvanised, a thickness of 2.5mm will suffice. This does not, however, apply to a pipe support made from hot-dip galvanised material, which may have a minimum size of 25mm x 1.5mm for pipes up to DN50 (12mm x 1.5mm, if type approved).
- 3.2.5 In the case of support systems where threaded rod is screwed into a blind hole, provision shall be made at the other end of the threaded rod for adjustment in order to allow the threaded rod to project a minimum of 20mm through the thread.
- 3.2.6 Support brackets for pipes up to DN50 may be attached to a sloping bearing surface. This surface shall not deviate from the horizontal plane by more than 10°. A bracket may only be subjected to vertically acting loads. The clamping screws shall

engage on the sloping support surface.

- 3.2.7 Pipe supports shall not be used for any other purpose and should be attached near joints in the pipe.
- 3.2.8 The required length of fastening plug depends on the type of plug used and on the type of material into which the plug is driven. Plugs shall be made of non-combustible material. The fixing point shall be able to absorb twice the load stated in Table 3.2.

Pipe supports shall connect the pipework directly to the building structure and shall not be used as supports for other objects. Building members, to which primary supports are attached, shall be strong enough to take the load. If not, additional links to load-bearing members shall be created.

Only pipes up to DN50 may be attached to a steel trapezoidal sheet or slabs made of gas concrete or pumice concrete. The appropriate authority shall approve the design. Care shall be taken to ensure that pipework is supported by a load-bearing structure at a maximum of 12m spacing and that the last nozzle is no more than 2m away from such a support.

Fastening plugs in gas concrete or pumice concrete shall be at least 150mm away from the edge of any slab.

- 3.2.9 If, in exceptional cases, it is necessary to fasten pipework to equipment or structural members, it shall be remembered that, in calculating the strength of the fixture for the equipment or structural member, at least double the main load and design load for the pipe given in Table 3.2 shall be used.
- 3.2.10 All pipe runs longer than 1m shall be fixed with supports. The maximum distance between two supports along the pipe shall not exceed the values given in Table 3.3.

Pipe diameter (mm)	Maximum distance between supports (m)
$\leq 25$	2
$> 25 < 50$	3
$\geq 50$	4

**Table 3.3 distance of supports**

- 3.2.11 If, in the case of pipes  $>DN50$ , the 4m spacing cannot be adhered to for building design reasons, the distance may be increased to 6m, if the pipe is provided with double supports.

In this case two independent supports fixed with the building shall be used at each support.

Additional supports are required in cases where greater loads (such as valves) require to be supported.

- 3.2.12 The distance between a support and the last nozzle shall be as short as possible and shall not exceed:
- > 0.1m for pipe with a diameter  $\leq DN25$ ,
  - > 0.25m for pipe with a diameter  $>DN25$ .

### 3.3 Selector valves

- 3.3.1 Selector valves shall be located outside the danger zone resulting from a fire in the flooding zone. No flammables shall be stored in the immediate vicinity of a selector valve.

- 3.3.2 Selector valves shall be arranged so that they will not open when subjected to:
- operating environmental vibration
  - vibration that arises when the valve at the supply container or other selector valves opening.

3.3.3 Automatic actuation of a selector valve shall be powered by static weight and/or pneumatic and/or electrical means. The unit shall be designed in such a way that checking for proper functioning on site can be achieved without discharging gas.

3.3.4 If it is possible to release the extinguishant, even though the mechanism used to automatically open the selector valve has failed, the emergency release mechanism shall not circumvent

- national codes for personnel safety
- the equipment required to prevent damage from excess pressure being exerted by the gas being discharged into the flooding zone.

3.3.5 Selector valves shall open automatically and simultaneously with the opening of a container valve.

3.3.6 Pressure relief devices from safety valves shall discharge gas into the atmosphere away from windows, especially in basements, ventilation openings, etc. In no case shall this constitute a hazard to personnel.

Safety valves have to be assembled vertically.

## **3.4 Nozzles**

3.4.1 Nozzles shall be arranged so that a homogenous mixture of the required gas concentration will be achieved. The maximum protected area per nozzle shall not exceed 30m<sup>2</sup>.

Nozzles shall be sited so as not to affect the even distribution by sublimation of the liquid extinguishing agent on installations or walls. Therefore a minimum distance of 1 m between the nozzle and the barrier shall be kept in direction of the jet.

3.4.2 Nozzles shall be sited so as not to disperse combustible materials when gas is discharged, as this may contribute to the fire hazard.

3.4.3 Nozzles shall be arranged so that the effects of discharge do not damage the components being protected.

- 3.4.4 Nozzles shall be located in the upper area of a flooding zone. If the flooding zone is higher than 5m, special care shall be taken to get an even distribution of gas, e.g. by installing nozzles at intermediate levels.
- 3.4.5 Suitable protective arrangements shall be made in environments where nozzles could be fouled. This protective concept shall be approved by the authority responsible and executed in such a way that it will not adversely affect the discharge of the gas.

In rooms with electrical and electronic risks, the nozzles must be of corrosion-resistant materials.

## **4 DETECTION**

In case of electrical triggering of the gas extinguishing system, an automatic fire detection system must be used for detection. The CEA specifications for fire detection systems must be met.

### **4.1 Type of detectors**

Fire detectors shall be either in accordance with the appropriate part of EN54 or in accordance with the CEA Specifications for detection devices.

Fire detectors may be:

- Electrical detectors (e.g. temperature sensing rod)
- Detectors according to EN 54-7

### **4.2 Criteria of selection of detectors**

In order to determine the most appropriate form of detection for a particular risk, the following points should be considered:

- > fire development in the initial stage,
- > room height,
- > environmental conditions,
- > possibility of false alarms in the protected rooms.

#### **4.2.1 Fire development**

Smoke detectors are preferred when smouldering combustion occurs giving off large amounts of smoke with minimal heat and radiation, e.g. cable fires.

Smoke, heat, ultra-violet or infra-red fire detection devices or combinations of different types of device could be used when combustion causes a rapid fire increase in the initial phase, i.e. high heat output and strong radiation.

If the stored goods are vulnerable to smoke damage, smoke detectors shall be used.

#### **4.2.2 Room height**

The response time of fire detection devices is increased with increasing room height.

The height of ceiling areas smaller than 10% of the complete ceiling area and smaller than the protection zone of one detector shall not be taken in account but shall be considered as one room.

#### **4.2.3 Environmental temperature**

Smoke, ultra-violet and infra-red detectors can be used up to an ambient

temperature of 50°C, if not excluded by type approval.

The response temperature of the heat detectors should be approximately 30°C above ambient temperature.

Heat responding devices incorporating a differential element should not be used when the normal ambient temperature fluctuates.

Fire detection devices can be used down to an ambient temperature of –20°C, provided there is no danger of ice forming and their use is not excluded by type approval.

#### **4.2.4 Air movement**

Smoke detectors can be used up to air speeds of 5m/s or higher if permitted by type approval.

#### **4.2.5 Vibration**

Vibration of fire detection devices mounted on machinery shall be taken into account.

#### **4.2.6 Explosive atmospheres**

Where an explosive atmosphere exists, electrical systems may be unsuitable, due to the potential ignition risk.

#### **4.2.7 Humidity**

Condensation shall not affect the response characteristics of a detection device or cause false alarms.

#### **4.2.8 False alarms**

False alarms caused by environmental influences, i.e. sunlight, heating etc., or mechanical damage, shall be avoided by the appropriate location of the fire detector.

Heat detectors shall not be exposed to solar irradiation. All installations emitting heat, hot air or hot steams shall be taken into account.

Smoke detectors shall be configured in "coincidence-connection". In low rooms with strong air movement, smoke detectors shall be protected by screening plates. Smoke detectors shall not be used in areas where aerosol-concentrations may trigger the detector.

#### **4.2.9 Smoke, dust and other aerosols**

Smoke detectors can give false alarms due to extraneous smoke, dust and other aerosols. Smoke detectors shall, therefore, only be used where the risk of false alarms is minimal. In the case of dust, approved special filters or other measurements can be used.

#### **4.2.10 Optical radiation**

Modulated radiation from sunlight or lighting devices can cause the false alarm of an ultra-violet or infra-red detector. This fact shall be taken in account in the location of such detectors.

### **4.3 Fire detectors: groups and areas**

If smoke detectors are to be used to initiate gas discharge then they shall be configured in "coincidence-connection". This configuration requires that at least two

independent detector alarm outputs from one detector group or two alarms each from one of the two related detector groups are signalled to the detection control and indicating equipment before discharge is initiated.

The area coverage of detectors should be at least one detector per 25m<sup>2</sup> of floor area, when coincidence connection is used, otherwise the system should be in accordance with the CEA fire detection specifications.

For IT-rooms and electric switching and distribution devices applies: IT rooms, cable floors and false ceilings shall be separate fire detection zones.

## **5 CONTROL AND TRIGGERING**

In addition to the following requirements, EN12094-1 and the national regulations for triggering of extinguishing systems (e.g. VdS 2496) and national guidelines for personnel safety shall be met.

### **5.1 Delay device**

5.1.1 The discharge of gas shall be delayed for at least 10 seconds after triggering the installation, in order to warn people in the flooding zone. People must be able to leave the zone without haste.

5.1.2 If the criteria specified in clause 1.5.3 are such that personnel could be endangered, it shall be ensured that gas can only be discharged into the flooding zone if the pre-warning time has elapsed.

Account shall be taken of fault or breakdown of one or more electrical or electronic components caused, for example, by an overload, or any other faults, resulting in premature release of agent.

Note: This can be fulfilled e.g. by a non-electrical delay device. The installer and the user shall take care of the approval of the component for this installation.

The national requirements concerning delay devices must be met.

5.1.3 The pre-warning time must not be longer than necessary to ensure safe evacuation. If the pre-warning time exceeds 30 seconds, the complete fire protection measures need to be reconsidered by the authority responsible.

### **5.2 Manual triggering device**

5.2.1 The gas installation must be equipped with a manual triggering device.

Manual triggering devices should be located outside flooding zones, close to exits.

5.2.2 Manual triggering devices shall be installed at normal operating height, at clearly visible locations and shall be protected against being tripped accidentally. Each device shall be marked to indicate the zone it serves.

In no case shall such devices conflict with the requirements for life safety (pre-warning and delay devices).

### **5.3 Emergency triggering device**

Where a manual emergency triggering device is used, it shall be located near the gas supply container(s) and be protected against being tripped accidentally. Each device shall be marked to indicate the zone it serves.

In no case shall such devices conflict with the requirements for life safety (pre-

warning and delay devices).

## **5.4 Disable device**

5.4.1 Mechanical measures shall be provided to lock-off gas release.

5.4.2 A visual fault indication shall be provided at a continuously manned location or at another clearly visible position whenever the gas supply is locked off.

5.4.3 National regulations on non-electrical disable devices and their use shall be considered.

In multiple-zone systems, a non-electrical disable device shall be provided for each individual flooding zone.

A non-electrical disable device shall not disable the fire detection and alarm functions.

## **5.5 Alarm devices**

5.5.1 The gas installation shall be equipped with at least one alarm device.

In the event that the design criteria in clause 1.5.3 is such that personnel could be endangered, there shall be two completely independent alarm devices, e.g. a pneumatic alarm device powered or triggered by the same source as the delay device and a monitored electrical alarm device, e.g. 24V.

National regulations on alarm devices and their use shall be considered.

5.5.2 An alarm shall be sounded upon triggering.

5.5.3 Audible alarms should be augmented with visual alarm indications.

5.5.4 At the latest by start of the gas release, there shall be a visual indication at the access points to the flooded zone.

5.5.5 When the installation is triggered, an alarm signal shall be transmitted to a location that is continuously manned. Wherever possible, the signals shall also be transmitted to the fire brigade or another alarm receiving centre.

## **5.6 Wiring**

5.6.1 The installation shall comply with national codes, the CEA fire detection specifications and the following requirements.

5.6.2 The relevant standards for wiring shall be considered. The cables shall be protected against operational damage.

The cables shall pass only through flooding zones.

The cables shall be protected and routed so as to keep damage to an absolute minimum in the event of fire. The use of cable which is able to function for 30 min in case of fire (e.g. according to DIN 4102 part 12) is advisable, especially for those cables which are used for triggering of control- and alarm devices.

## **5.7 Control lines**

5.7.1 Pneumatic control lines shall be made of galvanised steel, copper or equivalent corrosion resistant metal. Flexible pipes or hoses etc, shall only be used where fixed pipes are unsuitable.

The strength shall be sufficient for the type of triggering devices used.

- 5.7.2 Pipework shall be arranged so that it cannot be damaged by its own weight, temperature fluctuations, vibration, release of gas or other installation inherent influences. The maximum distance between two supports shall not exceed 2m for steel pipe and 1m for copper pipe.

All pipework shall be accessible.

## **5.8 Control container**

If control containers are used for storage, they shall meet the requirements according to clause 2.6.

Control containers shall have a minimum content of 500 g. The content of the control container shall be monitored. A loss of more than 10 % shall be reported automatically.

## **5.9 Triggering of ancillary equipment**

Ventilation shall be turned off, if the gas concentration is maintained for any length of time.

If operationally possible, the response of the detectors or the triggering of the manual triggering device shall automatically turn off the ventilation. Operating resource must be turned off too.

Functional testing must be possible every time. If operating resource cannot be turned off during operation the gas extinguishing system shall have an operating device (preferably a key switch) turning off the operating resource. The operating status must be marked on a separate display and a location that is continuously manned.

Only authorised persons shall be able to turn off the resource.

## **5.10 Power supply of electrical triggered installations**

For power supply two energy sources are necessary. One energy source shall be the electrical network working without interruption. The other energy source shall be a battery taking power supply automatically and without delay. The energy sources shall be connected with the fire detection and triggering device by a fix connection.

### **5.10.1 Electrical network**

- 5.10.1.1 Power supply from electrical network shall have a separate electrical circuit guaranteeing the non-limited operation of the system and the detection device. The power supply from network shall during normal operation deliver the charging current for the battery.

- 5.10.1.2A separate electrical circuit with a special marked fuse shall be used for power supply. Previous to the fuse there shall be once only fused up to the low-voltage-lateral point of delivery of the electrical network (place of energy input into the building). The electrical circuit of the system must not be interrupted by turning-off of operating resource.

- 5.10.1.3The charging set shall be able to charge the discharged battery within maximum 24 hours automatically reaching 80 % of design capacity. Charging must be finished within 72 hours.

## 5.10.2 capacity of battery

5.10.2.1 The capacity of systems with automatic fault report to a location that is not continuously manned shall ensure the unrestricted power supply within at least 72 hours, when mains supply is disturbed. After 72 hours, all necessary alarm devices for the flooding zone facing the biggest demand of alarm power shall work at least 30 minutes.

5.10.2.2 The capacity for systems with automatic fault report to a location that is continuously manned shall ensure the unrestricted power supply within at least 30 hours, when mains supply is disturbed and if a suitable failure service is within reach all the time. After 30 hours, all necessary alarm devices for the flooding zone facing the biggest demand of alarm power shall work at least 30 minutes.

5.10.2.3 The capacity for systems with automatic fault report to a location that is continuously manned shall ensure the unrestricted power supply within at least 4 hours, when mains supply is disturbed and if a suitable failure service is available all the time. After 4 hours, all necessary alarm devices for the flooding zone facing the biggest demand of alarm power shall work at least 30 minutes. An external auxiliary power supply shall be available and immediately useable. The auxiliary power supply shall deliver power for at least 30 hours.

## 6 INSTALLATION AND TESTING

### 6.1 Installation

6.1.1 The components of a gas system shall be installed in such a way that it is possible to inspect them at any time and without undue difficulty.

Components shall be installed such that mechanical and chemical damage etc. is minimised in the event of a fire.

Fire detectors shall be installed in such a way that they are suitably protected from airborne contaminants.

6.1.2 It is advisable not to route pipework and cables through unprotected zones. If this is not possible, pipework shall, in all cases, be installed and protected in such a way that damage in the event of fire is kept to a minimum.

6.1.3 The inside of pipes shall be cleaned prior to mounting. Pipework shall be carefully purged pneumatically after installation and before fitting nozzles. The purging shall be documented in writing.

6.1.4 Gas extinguishing systems with pneumatic control device shall have a fixed and self-closing test installation in order to connect a test equipment to prove all control functions. The test equipment shall be composed of a coupling counterpart to the test installation, a tube, a manometer, a relief device, and a test container with a shut-off valve. The relief of pilot piping shall be possible in a little while. The filling quantity of the test container shall enable the triggering of the systems five times considering an alarm time of one minute for pneumatic means of alarm. The test container shall not have an immersion tube. Tools for functional testing of the extinguishing system shall be available.

### 6.2 Testing

6.2.1 Pipework which is closed shall be hydrostatically proof-pressure tested to the value indicated in clause 6.2.2.

6.2.2 Pipework should be subjected to 1.5 times the service pressure for a period of 30 to 40 minutes. Not more than 5% loss of pressure shall take place within this period.

The equipment and pipework shall be carefully emptied and dried after proof testing.

A visual inspection will be sufficient for pipework downstream of selector valves. Special attention shall be paid to the correct assembly of threaded connections, bolts and flange bolts.

- 6.2.3 If pipework cannot be subjected to hydrostatic pressure testing, then welded connections can be inspected with the assistance of other methods, e.g. penetration dye inspection, magnetic techniques, x-rays etc.

In case of flange bolts or equivalent approved systems the hydrostatic pressure testing on site may be replaced with a hydrostatic pressure testing of components or pipe segments considering a test pressure according to table 3.1. In these cases a leakage test with gas ( $p_{abs} = 3 \text{ bar}$ ) shall be conducted after installation.

- 6.2.4 Every extinguishing agent container shall be tested for correct filling by weighing and testing by means of a manometer (considering the correction for temperature) before installation. The test shall be included in the quality management system of the installer and documented on a label on each container.

## **7 USE OF THE INSTALLATION**

### **7.1 Instruction and training of personnel**

- 7.1.1 At least two responsible supervisors shall be trained in the use of the system. They shall be responsible for compliance with the directions for use and maintenance and with the legal regulations. They shall be introduced by the installer.

Personnel who work inside a flooding zone or in adjacent zones, shall be thoroughly instructed and trained by a supervisor as to the actions to be taken before, during and after gas is released.

- 7.1.2 Personnel assigned to carry out repair or other work, but who are not generally assigned a work site inside the flooding zone, shall commence such work only after having received written permission (date, time and duration) to do so by the supervisor responsible. Such personnel shall also be given training as described in clause 7.1.1.

### **7.2 Inspection**

- 7.2.1 Regular inspections shall be carried out to ensure that the system functions properly.

The frequency and type of inspections shall depend on the nature of the installation, national legislation and environment etc.

- 7.2.2 Inspections shall be made by personnel specially designated for this work, thoroughly instructed in their duties, with a comprehensive knowledge of the installation.

Daily, weekly and monthly inspections shall be carried out according to the manufacturer's specifications.

#### **7.2.3 Daily inspection**

- > check all installation indications visually.

#### **7.2.4 Weekly inspection**

- > check fire detection system,
- > check quantity of gas, replacing or topping-up if a loss of weight or pressure

in excess of 10% has occurred,

- > check operational position of valves,
- > check power supplies.

### **7.2.5 Monthly inspection**

- > check equipment used to actuate fire doors and hatches and power supplies etc.,
- > check audible and visual alarm devices,
- > check delay device,
- > check nozzles (visual test),
- > check enclosure (visual test),
- > check ancillary equipment.

### **7.3 Log book**

A log book shall be maintained in which the following entries are to be made:

- > results of any inspection,
- > maintenance and repair work undertaken, e.g. reason, nature etc.,
- > Any other event that affects the installation, e.g. fires, unintentional release, deactivation, faults etc.

### **7.4 Other obligations**

**7.4.1** If any changes are made which could have an adverse influence on the effectiveness of the installation (characteristics of fire risk, enclosure, ventilation etc.), the Insurer shall be informed and the installation modified as appropriate.

Any change or extension of the extinguishing system shall be performed by an installer approved for the system concerned.

**7.4.2** If the installation is not functional for more than 24 hours, this shall be reported to the Insurer and/or other authority, as appropriate.

Other fire prevention measures should be carried out immediately.

After any release of the extinguishing system, it shall be controlled and commissioned by the approved installer of this system.

## **8 MAINTENANCE**

To ensure the continued availability of the installation in accordance with the approval, regular maintenance, including periodical inspections, shall be carried out.

Maintenance work shall be conducted in such a manner as to keep the shut-down period to a minimum, both in time and extent. In multizone installations, the zones can be shut down sequentially so as to disable only a small part of the installation at any one time.

Repair work shall start as soon as possible but within 24 hours of any fault being

detected.

Maintenance shall be carried out at least once a year. An approved installer, preferably the company that originally installed the system, shall carry out the maintenance. The installation company shall be approved for the systems to maintain.

## **9 DOCUMENTATION**

The installer shall submit technical documentation, which gives sufficient information to be able to estimate the hazards and the effectiveness of the gas fire extinguishing system as follows:

- > name of the owner and location of the risk,
- > drawings of the protected area on a scale not smaller than 1:100,
- > protected risk,
- > type, arrangement, direction, surface coverage and performance characteristics of the nozzles,
- > type and location of the fire detection, manual and emergency triggering devices,
- > internal diameter and length of pipework,
- > pressure drop data for valves and fittings,
- > calculation of the required gas supply quantity,
- > hydraulic calculations including appropriate isometric drawings etc,
- > location and size of the gas storage area (including filling factor, pressure, and pressure cushion of the extinguishing agent containers and control containers),
- > other information which is necessary for evaluation of the risk and the installation, e.g. pressure test certificate,
- > inspection and maintenance instructions,
- > possible danger to the neighbourhood or danger from the neighbourhood.

## **10 APPROVALS**

**10.1.1** An approval inspection shall be carried out by an inspector accepted by the Insurers to check that the installation is in accordance with this specification.

Before approval inspection, the installer shall submit a certificate of installation to the authority.

The installation should be announced to the authority if possible 4 weeks, at least 2 weeks before beginning by submitting the certificate of installation.

**10.1.2** The gas system shall have been designed, installed and maintained in accordance with these rules by an approved installer.

The approval of the installer shall be given by a certification body accepted by the Insurers according to the appropriate CEA specifications.

**10.1.3** The system shall comprise only components approved by an accredited certification body accepted by the Insurers. The appropriate compatibility of the components shall be certified by a system approval, see list of components in Appendix A3.

**10.1.4** A full discharge test shall be carried out to check that the installation complies with this specification, unless it is possible to use another procedure. The development of gas concentration shall be continuously recorded. The time period, during which the measured concentration value is recorded and logged, shall be not less than ten minutes, or the required holding time, commencing from the time at which the installation was actuated.

During full discharge test the following values shall be taken:

- Duration of flooding
- Automatic measurement and record of the concentration of the extinguishing agent.

Testing points shall be situated at least on the floor and beyond the ceiling (10 % and 90 % of room height). Values shall be recorded in cases, where several zones communicate (e.g.cable floors, or in false ceiling spaces, or in areas with possible delayed build-up of concentration or fastened reduction of concentration e.g. unfavourable room situation, installations)

Every room shall be tested separately, if several zones are protected.

Testing shall be performed under designed conditions of the system, but without fire.

Flooding tests and measurements shall be performed by the authority.

**10.1.5** During approval inspection at least functional tests of the system for each protected zone and a partial flooding test of each protected zone shall be performed.

In case of a partial flooding test (flooding with a subset of the extinguishing agent quantity) it must be certifiable that all nozzles are admitted with gas. Instead of extinguishing agent, a surrogate gas (e.g. coloured gas) can be used.

**10.1.6** According to clause 2.2.1 a full discharge test as described in clause 10.1.4 or equivalent, e.g. fan test, shall be carried out if the value of the "surface term" is lower than  $k$  and the design quantity is lower than  $Q_{max}$  (see 2.2.1).

If the quantity is designed according to clause 2.2.1 without reduction of "surface term" (factor  $k \geq 0.27$  m), a visual control of integrity of the exterior walls of the flooding zone is sufficient.

*Note: Taking the "surface term" into account in case of quantity design results in a higher safety potential. Nevertheless, it is not guaranteed that leakage loss, which affects the holding time, is compensated.*

**10.1.7** If an explosive atmosphere prevails, the earthing of the system shall be proved before functional test. The existence of explosive atmosphere in the flooding zone shall be proved and excluded with suitable test equipment. The owner of the system shall issue the functional test.

If flooding is not possible due to danger of explosion, the reasons shall be noticed in the certificate of installation of the installer.

**10.1.8** The installation and protected risk shall be inspected at least once a year by the authority. On each inspection, a functional test of the system shall be performed.

Both in case of relevant changes of the exterior walls and at least every second year, the density of the exterior walls of the flooding zone shall be controlled, e.g. by

means of a door-fan test<sup>10</sup>.

If the quantity is designed according to clause 2.2.1 without reduction of "surface term" (factor  $k \geq 0.27$  m), a visual control of tightness of the exterior walls of the flooding zone is sufficient.

*Note: Taking the "surface term" into account in case of quantity design results in a higher safety potential. Nevertheless, it is not guaranteed that leakage loss, which affects the holding time, is compensated.*

After every periodic test, a testing report with a list of deficiencies shall be made.

## **11 Monitoring of gas extinguishing systems**

### **11.1 General**

Halocarbon gas extinguishing systems shall be automatically monitored for their availability in the case of:

- systems with more than 500 m<sup>3</sup> of protected volume,
- systems with more than 250 m<sup>3</sup> of protected volume where a delay time is required for life safety aspects,<sup>11</sup>

The following components shall be monitored continuously for their availability and faults (i.e. cases of non-availability) shall be automatically indicated. Their failure or a wrong operating position can prevent the emission of the (correct amount of) extinguishing medium or the functioning of the alarm and delay device in case of triggering, or it can cause an emission into an untriggered extinguishing zone.

Testing of the monitoring system shall always be possible.

The monitoring system shall not affect the correct function of the gas extinguishing system.

### **11.2 Disable and triggering devices and selector valves**

The correct operating position of the following components shall be monitored:

- Non-electrical control devices
- Disable devices
- Selector valves
- Switch devices for main/ reserve supply container
- In the case of mechanical control using wire cables: the position of the triggering device

### **11.3 Agent quantity measurement**

The quantity of available extinguishant and pilot gas shall be monitored. Any loss of more than 10 % of the content of any container shall be indicated.

- all containers of the main supply and of the reserve supply permanently connected to the pipe system
- containers for the supply of the alarm devices and /or pilot containers

### **11.4 Electrical lines**

Electrical lines transmitting alarm and fault signals or signals for the monitoring and control of the installation and alarm devices (monitored first alarm with two independent energy supplies) shall be monitored for line break, short circuit and earth fault. The CEA specifications for fire detection installations shall be taken into account.

Necessary additional controlling signals (e.g. shut-off of ventilation systems, closing of openings of the enclosure) may be transmitted by non-monitored lines.

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<sup>10</sup> Door-fan-tests shall be performed by approved companies (approval for door-fan tests) except the first approval inspection and every third test, which has to be performed by the authority.

<sup>11</sup> There may be aspects of value of the protected risks like consequential losses which need to be considered.

## 11.5 Electrically-operated components

The power supply to electrically-operated components of the extinguishing installation shall be monitored for normal condition and power failure where they cannot be monitored by the fire detection installation.

## 11.6 Monitoring and control lines

### 11.6.1 Monitoring lines

Each monitoring device shall have a separate indicator. A maximum of 60 monitoring devices may be connected to one detection line.

### 11.6.2 Monitoring lines of disable devices

Faults of the disable device shall be indicated if the disable device is in a position that is neither the ready-for service-position (open) nor the blocking position (closed), see 11.2. Independent from that, the actuation of the disable device shall be transmitted and indicated separately.

The disabled condition of the system shall not cause a general fault indication but the disabled condition of the system shall be indicated separately for each flooding zone.

### 11.6.3 Control lines

All electrically controlled components for the release of the installation, operation of selector valves, delay devices and alarm devices shall be connected to lines monitored for line break, short circuit and earth fault.

The devices shall be attached to the control lines so that in the case of a fault indication an unequivocal and quick identification of the components of the installation causing this fault indication is possible.

This is relevant for:

- Triggering devices of pilot containers, container batteries, isolating valves and selector valves,
- electromagnetic locking devices for triggering devices and/or selector valves and
- solenoid valves for controlling the emergency-stop device and / or secondary flooding function.

## 11.7 Storage area

The storage area shall be monitored for the allowable maximum and minimum ambient temperature where a dedicated heating or cooling system is installed.

## 11.8 Fault indication

### 11.8.1 Indication and transmission

Faults of the extinguishing installation shall be indicated visually and audibly at a location of the premises, which is continuously manned. It shall be possible to switch off the audible signal, but the visual signal shall only be switched off if the fault is removed. If the plant does not dispose of a continuously manned location, the fault indication shall be transmitted automatically to an employee of the plant (e.g. by the help of a telephone transmitter).

### 11.8.2 Further indications

The fault indication of the following shall be indicated separately:

- monitoring system of the gas extinguishing system
- other monitoring systems
- fire detection system
- control devices.

Faults of the extinguishing installation and faults of the monitoring installation shall be

indicated separately.

As long as a fire detection signal of the extinguishing installation is present, no fault detection shall be indicated at the monitoring control panel or at the monitoring insertion of the c.i.e. of the fire detection installation.

## **11.9 Power supply of the monitoring installation**

The power supply of the monitoring installation shall be installed according to the CEA specifications for fire detection installations.

## **11.10 Requirements for components of the monitoring installation**

### **11.10.1 Protection class**

The components of the monitoring installation shall fulfil at least the protection class IP 54 (IEC 529 - Degrees of protection provided by enclosures - IP code).

### **11.10.2 Switching way**

In case of valves, the fault indications shall depend on the switching way of the component under monitoring. The switching way is the way from the just still closed to the totally opened position of the valve.

### **11.10.3 Switching way of normally open devices**

The fault indication for valves which are situated in the extinguishant flow and in the pneumatic pilot lines, and the fault indication for other blocking devices which are continuously opened when the extinguishing installation is ready for service, shall be activated at the latest, when the components are closed 20% of the switching way.

### **11.10.4 Switching way of normally closed devices**

In case of valves in the extinguishant flow and in case of valves which are not situated directly in the extinguishant flow and which are closed when the extinguishing installation is ready for service, the fault indication shall be activated immediately when the opening procedure starts.

### **11.10.5 Blocking devices of alarm devices, pressure or pneumatic switches**

In case of blocking devices of alarm devices and pressure or pneumatic switches, the fault indication shall be effective already in intermediate positions.

### **11.10.6 Non-electrical control devices**

Non-electrical control devices shall be monitored. The requirement is fulfilled if the room with the non-electrical control device is only accessible to authorised persons and if opening the door causes a fault indication.

Components may not be monitored if they are automatically reset into their operating position by the triggering energy of the installation itself.

## Appendix A1 Physical properties and toxicity data of the extinguishant

### A.1.1 purity requests

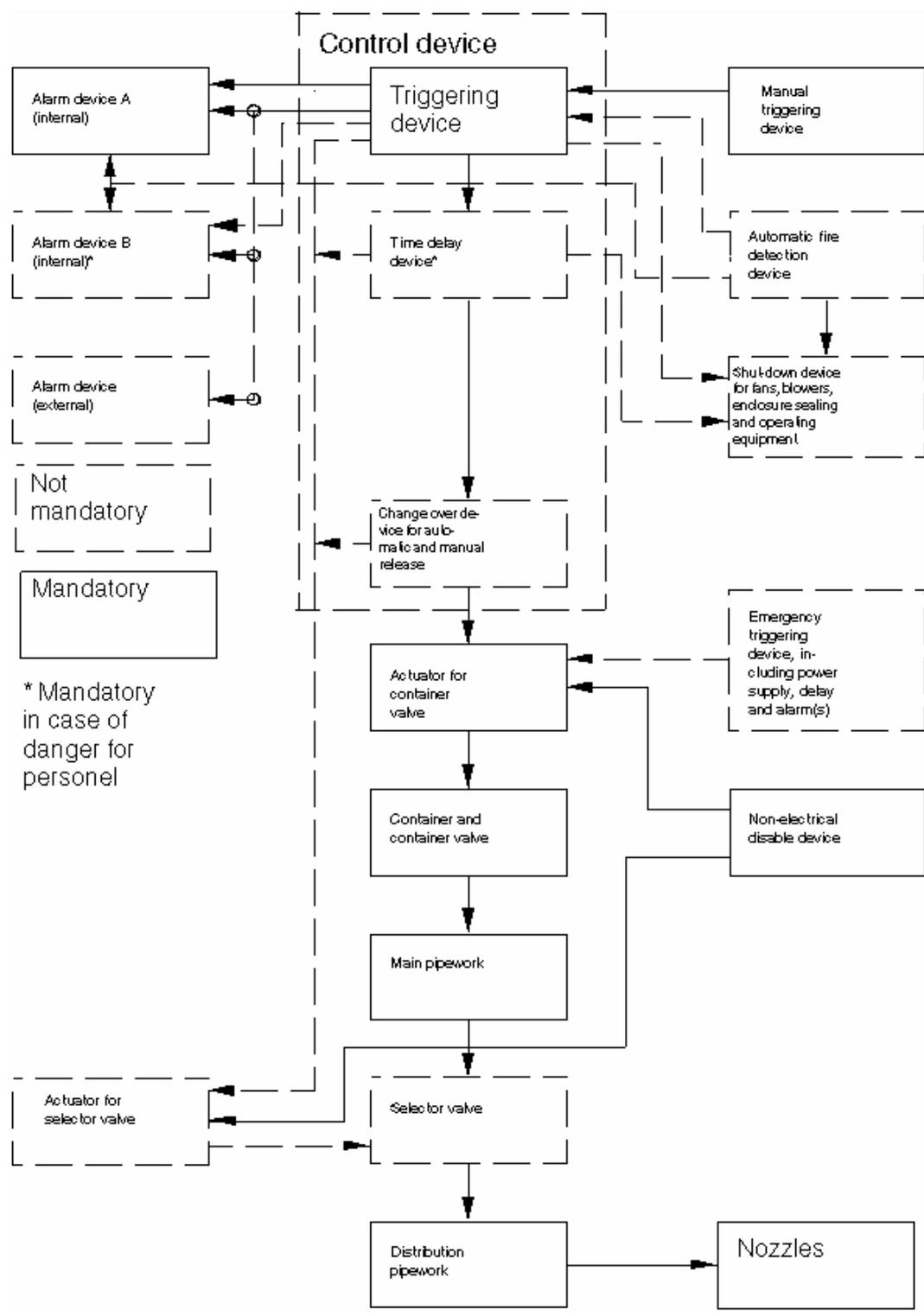
HFC-227 ea: purity: >99.6 mass-%  
 Share of water <10 x 10<sup>-6</sup> mass-%

FK-5-1-12: purity: >99.8 mass-%  
 Share of water <10 x 10<sup>-6</sup> mass-%

### A.1.2 Properties of substance

	<b>HFC 227ea</b>	<b>FK-5-1-12</b>
chemical name	2H-Heptafluoropropane	Dodecafluor-2-methylpentan-3-one
chemical formula	CF <sub>3</sub> CHF <sub>2</sub> CF <sub>3</sub>	CF <sub>3</sub> CF <sub>2</sub> C(O)CF(CF <sub>3</sub> ) <sub>2</sub>
trade name (example)	FM-200	Novec 1230
molecular mass	170 g/mol	316,04 g/mol
boiling point at 1,013 bar (abs.)	-16,4 °C	49,2 °C
freezing point	-131,1 °C	-108,0 °C
critical temperature	101,7 °C	168,7 °C
critical pressure	29,12 bar abs	18,65 bar abs
critical volume	274 cm <sup>3</sup> /mol	494,5 cm <sup>3</sup> /mol
critical density	621 kg/m <sup>3</sup>	639,1 kg/m <sup>3</sup>
vapour pressure at 20°C	3,91 bar abs	0,3263 bar abs
liquid density at 20°C:	1,407 kg/dm <sup>3</sup>	1,615 kg/dm <sup>3</sup>
saturated vapour density at 20°C:	31,176 kg/m <sup>3</sup>	4,3305 kg/m <sup>3</sup>
specific volume of superheated vapour at 1,013 bar and 20°C:	0,1373 m <sup>3</sup> /kg	0,0719 m <sup>3</sup> /kg
density of superheated vapour at 1,013 bar and 20°C:	7,2833 kg/m <sup>3</sup>	13,908 kg/m <sup>3</sup>
heat of vaporization at boiling point	132,6 kJ/kg	88,0 kJ/kg
Toxicity:		
NOAEL	9,0 Vol%	10,0 Vol%
LOAEL	10,5 Vol%	> 10,0 Vol%
Environment:		
ODP	0	0
GWP (conc.: CO <sub>2</sub> , 100 years)	2900	1

# Appendix A2 Block diagram for a halocarbon gas system



## Appendix A3 Components, systems, calculation methods

### A3.1 Components

The following listed components shall be approved:

- 1 Automatic control devices
  - a) electrical control
  - b) non-electrical control
- 2 Manual control devices
- 3 Non-electrical delay devices
- 4 Container valves, assemblies and actuators
- 5 Selector valves and their actuators
- 6 Non-electrical disable devices
- 7 Nozzles
- 8 Hoses and container connecting pipes
- 9 Fire detection devices
- 10 Pressure switches and switch type pressure gauges
- 11 Weighing devices
- 12 Alarm devices
- 13 Check valves
- 14 Safety devices
- 15 Pipe hangers (if not according with this rules)
- 16 Pressure gauges (e.g. manometer)
- 17 Emergency triggering devices
- 18 Automatic drainage points
- 19 Device for adding of odour
- 20 Safety valves

### A3.2 System approval

Systems of gas extinguishing systems shall be approved. All components of gas extinguishing systems shall be approved.

### A3.3 Calculation method

The calculation method of the design of the pipework shall be approved.

## Appendix A4 Testing methods to determine the extinguishing concentration of flammable liquids and gases by means of "cup burner"

### A4.1 Principle

The test procedure for determining the halocarbon gas extinguishing concentration is analogous to the method for determining the CO<sub>2</sub> concentration described in ISO 6183:1990 .

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

The result given is the theoretical minimum halocarbon gas concentration to extinguish the flame. The design concentration is calculated from this figure (see clause A4.5).

### A4.2 Apparatus

The apparatus for these measurements is a cup burner arranged as in Figure A.1.

### A4.3 Test procedure for flammable liquids

**A4.3.1** Place a flammable liquid sample in the fuel reservoir.

**A4.3.2** Adjust the adjustable stand under the fuel reservoir to bring the fuel level in the cup to within 1 mm of the top of the cup.

**A4.3.3** Adjust the electric control circuit to the cup heating element to bring the fuel temperature to 25 °C, or to 5 °C above the open cup flash point of the fuel, whichever is higher.

**A4.3.4** Ignite the fuel by suitable means, preferably electrical, which shall not contaminate the fuel under test.

**A4.3.5** Adjust the air flow rate to 40 l/min.

**A4.3.6** Start the flow of the halocarbon gas and increase it slowly until the flame is extinguished. Record the halocarbon gas flow.

**A4.3.7** Remove approximately 10 ml to 20 ml of fuel from the surface of the cup with a pipette.

**A4.3.8** Repeat steps A4.3.4 through A4.3.6 and average the results.

**A4.3.9** The flame extinguishing concentration C should be determined by means of a measuring instrument to measure the extinguishing gas permanently. The measuring instrument shall be calibrated for the concentration of the mixture of fire extinguishing agent and air.

Alternatively the oxygen concentration of the mixture of air and extinguishing agent below the cup should be measured by means of a permanent oxygen analysis installation. The extinguishing agent concentration shall be calculated as shown in the equation:

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

C.... concentration of the extinguishing gas, in % gas/100

O<sub>2</sub>... concentration of oxygen, in % gas/100

O<sub>2</sub>(air).... concentration of oxygen in the air, in % gas/100

Alternatively calculate the flame extinguishing concentration, C, as a percentage, as shown in the equation.

$$C = \frac{V_F}{40 + V_F} \times 100$$

where V<sub>F</sub> is the halocarbon gas flow, in litres per minute.

**A4.3.10** Increase the fuel temperature to 5 °C below the boiling point of the fuel, or to

200 °C, whichever is lower.

**A4.3.11** Repeat steps A.3.2 and A4.3.4 through A4.3.9.

**A4.3.12** Take the flame extinguishing concentration to be the higher value from the two fuel temperatures.

#### A4.4 Test procedure for flammable gases

**A4.4.1** The apparatus is modified by filling the cup with glasswool and reinserting a rotameter calibrated for the fuel in place of the fuel reservoir of Figure A.1. The rotameter is connected to a source of fuel through an appropriate pressure regulator.

**A4.4.2** Adjust the fuel flow to produce a linear velocity within the cup of 130 mm/s.

**A4.4.3** Perform steps A4.3.3 through A4.3.9.

**A4.4.4** Increase the fuel temperature to 150 °C.

**A4.4.5** Repeat steps A4.3.4 through A4.3.9.

**A4.4.6** Take the flame extinguishing concentration to be the higher value from the two fuel temperatures.

**A4.4.7** If the concentration requirement at the higher temperature exceeds that at the lower temperature by a significant amount, the fuel shall be classified as "temperature-sensitive". The flame extinguishing concentration for temperature-sensitive fuels shall be determined at the maximum temperature existing in the specific protected area.

#### A4.5 Design concentration calculation

Take the design concentration to be the value of the flame extinguishing concentration multiplied by 1.3 scaling factor (see clause 2.3.2).

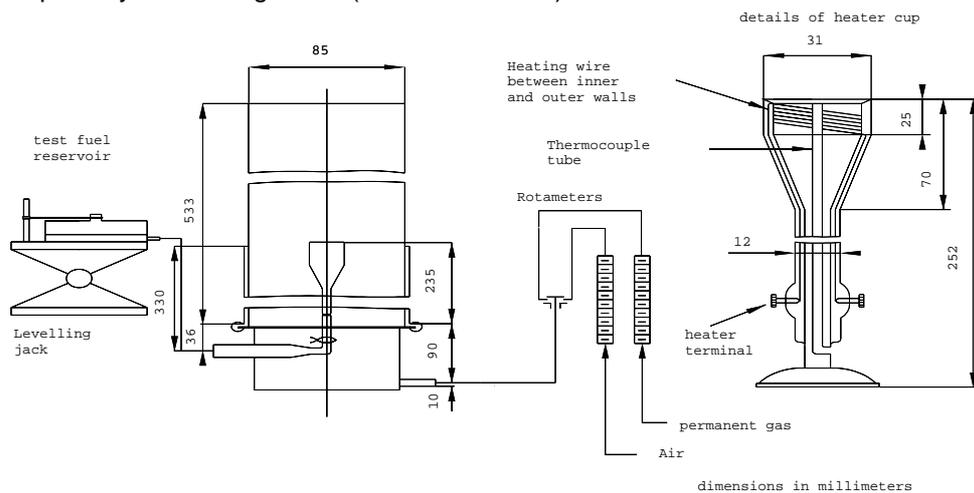


Figure A.1 - Cup burner apparatus

## Appendix A5 Structural construction of the enclosure

	Scope	Protected zone	Requirement	Fulfilled by
1	Buildings or parts of buildings and their contents shall be protected from fires inside and outside	Complete building or part, excluding permissible exceptions (see explanation to A5.3)	Enclosure shall be gas tight* and ensure protection from fires in the neighbourhood	Structural or space separation
2	The contents of a room shall be protected from fires inside and outside	Room	Enclosure (walls, floor and ceiling) shall be gas tight* and ensure protection from fires in the neighbourhood	90 min fire separation according to national rules, if adjoining rooms are not protected by approved extinguishing installations
3	The contents of a room shall be protected from fires inside	Room	Enclosure (walls, floor and ceiling) shall be gas tight*	30 min fire separation according to national rules, or non-combustible material*
4	A closed object shall be protected from fires inside	Closed object	Enclosure (walls, floor and ceiling) shall be gas tight*	30 min fire separation according to national rules, or non-combustible material*

\*see clause 2.1.2

The enclosure shall **always** be sufficient tight until the end of the holding time, that means the structural separation has to fulfil - in addition to the fire resistance requirements – the requirement of a sufficient gas tightness until end of holding time taking into account the possible (e.g. thermal) stresses. Common leakage (e.g. window or door cracks) are tolerable.

**Table A5.1: Aim of protection and structural requirements**

### A5.1 Explanation to Table A5.1

Table A5.1 shows the relationship between the scope of a halocarbon gas installation and the structural requirements. The underlying principle is based on those matters which have to be considered also for the development of a protection concept.

Regarding structural separation national regulations shall be met.

### A5.2 Example

The contents (material value) of a room shall not suffer a total loss.

1	2
Fire breaking inside	Fire breaking outside

#### Protection against 1 (risk from inside):

The protection target is fulfilled by means of a halocarbon gas installation and the gas tightness of the room.

#### Protection against 2 (Risk from outside):

Measures as described above cannot guarantee the fulfilment of the protection target; structural measures are also necessary and shall be valued (assessed) as a function of the risk.

The table details the minimum requirements and under the heading "fulfilled by" describes the methods which may be used basically. These two columns will have to be adapted to the type of internal or external risk.

### A5.3 Permissible exceptions for protection aim 1

- Rooms that are protected by other approved extinguishing installations.
- Wet process rooms cut off by 90 min fire separations meeting national rules. The authorities shall be contacted.

- Lavatories constructed of non-combustible materials and with no combustible storage inside. This exception does not apply to dressing rooms.
- Offices and flats with an maximum area of 150 m<sup>2</sup> cut off by 90 min rated fire walls meeting national rules.
- Staircases with 90 min rated walls that contain no combustible material.
- Lift wells cut off by 90 min rated fire walls.

## Appendix A6 Calculation formula for pipework

### A6.1 General

The following calculation method is suitable for halocarbon agents which are stored liquefied and pressurized with nitrogen. The equations are valid for turbulent flow in the pipe system.

### A6.2 The pressure drop along the pipe system

The pressure drop of a flowing mixture along a pipe with the length  $z$  and the diameter  $D$  is calculated as following

$$\Delta p = \Phi_L^2 \cdot \Delta p_L + \rho_{HOM} \cdot g \cdot z \cdot \sin \gamma \quad (1)$$

with:

$$\Delta p_L = \lambda \cdot \frac{\rho_L}{2} \cdot w_L^2 \cdot \frac{z}{D}$$

$$\Delta p_G = \lambda \cdot \frac{\rho_G}{2} \cdot w_G^2 \cdot \frac{z}{D}$$

$$\Phi_L^2 = 1 + (\Gamma^2 - 1) \cdot \left\{ B(x_L \cdot x_G)^{\frac{2-n}{2}} \cdot x_G^{2-n} \right\}$$

$$\Gamma^2 = \frac{\Delta p_G}{\Delta p_L}$$

$$B = \frac{20 \cdot \Gamma + 2(1 - 2^{1-n})}{\Gamma^2 - 1}$$

$$n = 0,25$$

$\lambda =$  friction coefficient of the single-phase (recommendation for rough pipes: relation of Colebrook)

*Note: The friction coefficient  $\lambda$  in the equation (1) corresponds to the single-phase flow and either it can be taken from pipe specific information or it can be determined experimentally with simple measurements of water pressure drop.*

### A6.3 The local phase change

The halocarbon agent is stored in liquid phase in storage containers with nitrogen for pressurization. During the flow in the pipe system, a pressure drop takes place and nitrogen dissolved in the halocarbon agent becomes gaseous.

As long as the local pressure is higher than the vapour pressure of the halocarbon agent, the agent volatilizes. As soon as the local pressure reaches the vapour pressure of the agent, the agent evaporates.

In each case a two-phase-mixture of gas and fluid flows through the pipes. The gaseous phase consists of gaseous halocarbon agent and nitrogen (2 phase-3 components-mixture).

The fraction of nitrogen in the fluid and the gaseous phase can be calculated from the partial pressure and the local temperature using Henry's law. Henry's law constant for the nitrogen solubility in the halocarbon agent has to be determined by measurements.

### A6.4 The working pressure point in the container

When fire extinguishing systems are engineered, the pressure drop in the pipe system and the nozzle inlet pressure (which is coupled with the pipe system) must be fixed on a

reference value of the container pressure. But, during the expansion process, the pressure in the pipe system falls, so that the choice of a reference pressure seems arbitrary at the moment. Because of the critical rate of flow, the choice of such a reference or so-called "working" pressure point is justified. Thanks to the critical flow phenomenon the mass discharge remains nearly independent of the container pressure during the fluid emitting phase. At the same time, the nozzle inlet pressure shows a nearly linear behaviour during this decisive phase of expansion. Because of these two phenomena, it is acceptable to choose as the so-called working pressure point in the container the pressure when half of the weight of the halocarbon agent has been discharged through the nozzles.

Proceeding from this working pressure point, both the pressure drop in the pipe system and the nozzle flow rate are determined.

The temperature in the container at the working point is determined as a function of the working pressure by measurements:

$$T_0 = T(p_0).$$

*Remark: The working pressure point also depends on the filling density of the container.*

## A6.5 The universal calculation set-up for the nozzle pressure drop

The nozzles for the distribution of the halocarbon agent in protected areas are differently constructed and installed. Simultaneously to the establishment of a calculation method that covers all nozzle designs, also an universal analytical model must be made available, that can cover all nozzle designs.

It can be supposed that the flow homogenises and that no velocity slip between the phases occurs, when the two-phase mixture flows in the nozzle. Consequently, it may be calculated with the homogeneous density  $\rho_H$  and with the (to the density corresponding) homogeneous velocity  $w_H$ .

$$\frac{1}{\rho_H} = \sum_K \frac{x_K}{\rho_K} = \frac{X_L}{\rho_H} + \frac{X_G}{\rho_H}$$

$$w_H = \frac{M_{TOT}^*}{A \cdot \rho_{HOM}}$$

with:

A = cross section of all nozzle orifices (m<sup>2</sup>)

M<sub>TOT</sub><sup>\*</sup> = total mass flow (kg/s)

x<sub>K</sub> = mass fraction of the phase K (-) with x<sub>L</sub> + x<sub>G</sub> = 1

ρ<sub>K</sub> = density of the phase K (kg/m<sup>3</sup>)

The so-called nozzle inlet pressure is set in for the ascertainment of the substance data of the mixture.

The pressure drop of a nozzle can be described by the following term:

$$\Delta p_{nozzle} = k_1 \cdot \text{Re}_{HOM}^{k_2} \cdot n_B^{k_3} \cdot \left( \frac{D_R}{D_B} \right)^{k_4} \cdot w_{HOM}^{k_5} \cdot \rho_{HOM}^{k_6}$$

with:

$$k_5^- = 2 + k_5 \cdot \varepsilon_G \cdot (1 - \varepsilon_G)$$

$$k_6^- = 1 + k_6 \cdot \varepsilon_G \cdot (1 - \varepsilon_G)$$

with:

$$\varepsilon_G = x_G \frac{\rho_{HOM}}{\rho_G}$$

$k_1, k_2, k_3, k_4, k_5, k_6$ : resistance coefficients for one nozzle type

$$Re_H = \frac{w_H \cdot \rho_H \cdot D_B}{\mu_{HOM}} : \text{homogeneous Reynold's number}$$

$$\mu_H = \sum x_K \cdot \mu_K : \text{homogeneous viscosity}$$

$D_B$  = diameter of the nozzle orifice (m)

$D_R$  = diameter of the supply-connection (m)

$\mu_K$  = viscosity of the phase K (kg/ms)

$n_B$  = number of nozzle orifices (-)

### Index of symbols:

A	:	area .....	$m^2$
D	:	diameter .....	m
g	:	acceleration due to gravity .....	$m/s^2$
M	:	mass .....	kg
$M^*$	:	mass flow .....	kg/s
p	:	pressure .....	Pa
T	:	temperature .....	
v	:	specific volume .....	$m^3/kg$
w	:	velocity .....	m/s
x	:	mass transport fraction .....	-
z	:	length .....	m
$\gamma$	:	horizontal angle .....	-
$\varepsilon$	:	room volume fraction .....	-
$\lambda$	:	resistance coefficient of pipe .....	-
$\rho$	:	density .....	$kg/m^3$
$\mu$	:	viscosity .....	Pa s
$\phi$	:	two-phase multiplier .....	-

### Subscripts:

A	:	actual
G	:	gas/vapour
K	:	phase K
B	:	orifice (drill hole)
HOM	:	homogeneous
L	:	liquid
R	:	pipe
0	:	start

## Appendix A7 Pressure relief devices for the protected enclosure

### A7.1 Equation for the calculation of the relief opening for over pressure

$$A = \frac{M_P^* \cdot v_P}{\sqrt{\Delta p \cdot v_{HOM}}} \cdot C_2$$

*Note: this equation is valid for the calculation of pressure relief devices for over pressures.*

### A7.2 Pressure drop through an opening

$$\Delta p = C_1 \cdot \frac{\rho_{HOM}}{2} \cdot w_{HOM}^2 \quad (1)$$

The resistance coefficient  $C_1$  for openings is dependent on the geometry of the opening

and in most cases it is within the following range:

$$0,5 < C_1 < 2,5 .$$

### A7.3 Mass flow through an opening

$$M_{HOM}^* = V_{HOM}^* \cdot \rho_{HOM} \quad (2)$$

### A7.4 Volume flow through an opening

$$V_{HOM}^* = A \cdot w_{HOM} \quad (3)$$

### A7.5 Homogenous mixture density, homogenous specific volume

$$\frac{1}{\rho_{HOM}} = \frac{x_{air}}{\rho_{air}} + \frac{x_P}{\rho_P}$$

$$\rho_{HOM} = \varepsilon_{air} \cdot \rho_{air} + \varepsilon_P \cdot \rho_P$$

$$\frac{1}{\rho_{HOM}} = v_{HOM}$$

**Assumption:** The volume flow of the extinguishing gas  $V_P^*$  is equivalent to the relief

volume flow  $V_{HOM}^*$ :

$$V_P^* = V_{HOM}^* \quad V_P^* = \frac{M_P^*}{\rho_P} .$$

### A7.6 Rearranging for calculating the surface of the relief opening:

(3) rearranged for A:

$$A = \frac{V_{\text{HOM}}^*}{w_{\text{HOM}}}$$

(4)

(2) rearranged for  $V_{\text{HOM}}^*$  :

$$V_{\text{HOM}}^* = \frac{M_{\text{HOM}}^*}{\rho_{\text{HOM}}} = \frac{M_{\text{P}}^*}{\rho_{\text{P}}}$$

(5)

(1) rearranged for  $w_{\text{HOM}}$  :

$$w_{\text{HOM}} = \sqrt{\frac{2 \cdot \Delta p}{C_1 \cdot \rho_{\text{HOM}}}}$$

(6)

(5) and (6) set into (4):

$$A = \frac{\frac{M_{\text{P}}^*}{\rho_{\text{P}}}}{\sqrt{\frac{2 \cdot \Delta p}{C_1 \cdot \rho_{\text{HOM}}}}}$$

(7)

Rearranging and simplifying of equation (7):

$$A = \frac{\frac{M_{\text{P}}^*}{\rho_{\text{P}}}}{\sqrt{\frac{2 \cdot \Delta p}{C_1 \cdot \rho_{\text{HOM}}}}} = \frac{M_{\text{P}}^* \cdot \sqrt{C_1 \cdot \rho_{\text{HOM}}}}{\rho_{\text{P}} \cdot \sqrt{2 \cdot \Delta p}}$$

With the coefficient  $C_2$

$$C_2 = \sqrt{\frac{C_1}{2}}$$

the pressure relief surface is found to be

$$A = \frac{M_{\text{P}}^* \cdot \sqrt{\rho_{\text{HOM}}}}{\rho_{\text{P}} \cdot \sqrt{\Delta p}} \cdot C_2 = \frac{M_{\text{P}}^* \cdot v_{\text{P}}}{\sqrt{\Delta p \cdot v_{\text{HOM}}}} \cdot C_2$$

$C_1$  can be equated with 2 in case of openings with a high flow resistance (e.g. louvers that can move to an angle of 45°). This simplifies the formula, because then  $C_2$  equates with 1.

The results achieved by this method are only valid for normal circumstances, with louvers closed openings in the wall to the outside, not leading the gas flow through ventilation ducts.

**Index of symbols:**

$A$  = opening surface..... m<sup>2</sup>  
 $M^*$  = mass flow .....kg/s  
 $\Delta p$  = allowable pressure increase in the enclosure..... Pa  
 $v$  = specific volume..... m<sup>3</sup>/kg  
 $V^*$  = volume flow ..... m<sup>3</sup>/s  
 $w$  = flow velocity ..... m/s  
 $x$  = mass fraction ..... ≤ 1  
 $\varepsilon$  = volume fraction ..... ≤ 1  
 $\rho$  = density ..... kg/m<sup>3</sup>

**Subscripts:**

$HOM$  = subscript for homogenous mixture

$P$  = subscript for halocarbon gas

**Example**

A total flooding installation brings HFC 227ea with a maximum mass flow of 3 kg/s into a protected volume. The gas quantity was calculated for an extinguishing concentration of 10 % by volume. The enclosure is lightweight constructed and it can be exposed to a maximum over pressure of 100 Pa.

$$A = \frac{M_P^* \cdot v_P}{\sqrt{\Delta p \cdot v_{HOM}}}$$

with

$$M_P^* = 3 \frac{\text{kg}}{\text{s}}$$

$$\Delta p_{\max} = 100 \text{ Pa}$$

$$v_{FM200} = 0,1373 \frac{\text{m}^3}{\text{kg}} \quad \text{at } 20 \text{ }^\circ\text{C}, 1013 \text{ mbar}$$

$$\rho_{\text{gas}} = 7,283 \frac{\text{kg}}{\text{m}^3} \quad \text{at } 20 \text{ }^\circ\text{C}, 1013 \text{ mbar}$$

$$\rho_{HOM} = \varepsilon_{\text{air}} \cdot \rho_{\text{air}} + \varepsilon_{FM200} \cdot \rho_{FM200}$$

$$\rho_{HOM} = (0,9 \cdot 1,20 + 0,1 \cdot 7,283) \frac{\text{kg}}{\text{m}^3} = 1,81 \frac{\text{kg}}{\text{m}^3}$$

at 20 °C, 1013 mbar

$$v_{HOM} = 0,553 \frac{\text{m}^3}{\text{kg}} \quad \text{at } 20 \text{ }^\circ\text{C}, 1013 \text{ mbar}$$

it follows

$$A_{\text{gas}} = \frac{3 \cdot 0,1373}{\sqrt{100 \cdot 0,553}} \text{ m}^2 = 0,055 \text{ m}^2 .$$

## Appendix A8 Requirements for pressure relief devices

To avoid damage on buildings and equipment by an excessively high over- and/or underpressure, provision must be made for pressure relief devices.

The following comments always refer to room protection systems (total flooding systems). For local application purposes the necessity of a pressure relief device for the equipment and/or the surrounding space must be checked in each case. If necessary, the requirements must be applied on a similar basis.

Pressure relief devices must meet the following requirements:

1. Each space within the flooding zone which is structurally segregated must be equipped with its own pressure relief device.
2. The pressure relief device must be sufficiently dimensioned taking into the account the allowable over- and / or underpressure in the room, the maximum mass flow during the flooding process of the extinguishing gas and the type of pressure relief (resistance coefficient of the vent, pressure drop in the duct).

If the pressure relief device is provided in form of a vent aperture in the perimeter of the flooding zone, leading straight into the open, the size of the required aperture can be calculated by means of the formula given in Annex A7 of this standard.

If pressure venting into the open is provided in form of a duct, the pressure drop of the duct must be calculated additionally and must be considered for the dimensioning of the cross sectional surface.

A duct must be suitable for taking up both the pressures and the gas flows.

In case of pressure relief devices that open by the over- and /or underpressure in the room, they shall not begin to open below 20 Pa. This shall be verified (e.g. by using door fan test equipment).

3. To avoid personal and property damage, the fire and extinguishing gases released by the pressure relief device must not result in a hazard outside the extinguishing zone.

For this reason the pressure relief should always directly lead through a vent into the open.

If a duct cannot be avoided, this duct must be sufficiently gas tight, should not be equipped with other outlets and should lead directly into the open. The duct must be designed so as to make sure that during pressure relief the fire is prevented from spreading into other areas and that damage of the duct resulting in a failure can be excluded.

If pressure relief is possible only via the ventilation system in exceptional cases, the ducts must meet the above requirements. Account must be taken of the flow velocities and the possible failure of the shut-off devices.

4. The pressure relief device must close after completed pressure relief.

Preferably the pressure relief device should be equipped with its own power source and should be able to open and close automatically. Pressure relief devices which depend on an external power supply must be triggered directly by the extinguishing system and must be energised by the extinguishing system (preferably with non-electric energy).

If electrically triggered pressure relief devices are used in exceptional cases, the Guidelines for the Triggering of Extinguishing Systems must be observed.

If power supply is not safe in exceptional case, the pressure relief device shall guarantee sufficient pressure relief during the hold time even in case of failure of power supply.

If pressure relief takes place via a vent or a duct directly into the open and if no regulations for fire protection in terms of a fire resistant segregation of the perimeter walls containing the pressure relief vents are to be observed, louvered shutters can be used opening as a result of their own weight or via reset springs at a certain overpressure in the room, i.e. switching into an inclined position and returning to home position after a decrease of the pressure thus closing the aperture.

As an alternative, pressure relief flaps can be used which are opened and closed e.g. by a pressure container which is directly controlled by the extinguishing system.

If requirements in terms of a structural segregation regarding fire resistance must be observed, the pressure relief devices must be designed accordingly.

5. If the extinguishing gas is heavier than air, a geodetic pressure builds up in the lower part of the room which depends on the density ratio of extinguishing gas/air and on the room height. Pressure relief devices which open by overpressure and which are installed in the lower part of the room, can cause the extinguishing gas to escape after the flooding process in particular under the effect of leaks in the upper part of the room. For this reason the pressure required for opening must be higher at the level of the pressure relief vent than the geodetic pressure generated by the extinguishing gas.
6. The pressure relief device must be installed so as to make sure that it is not positioned in the immediate discharge area of the nozzles of the extinguishing system.
7. Pressure relief must not be provided in form of active exhaust suction devices.

## Appendix A9 Testing methods for determination of extinguishing concentration by means of enclosure fire tests

This appendix corresponds to both, a testing method, which has been basis for the research work “extinguishing effects of inert gases” (see the final report CEA GEI7 N125 dated August 1998, appendix D), and a test method for plastic and cable fires worked out within the scope of ISO 14520. The test method for cable fires (A9.6 and A9.7) has been finalised by CEA based on test experiences, within ISO and CEN it is still under discussion.

### A9.1. Principle

A9.1.1 An engineered or pre-engineered extinguishing system unit shall mix and distribute its extinguishant and shall totally flood the enclosure when tested in accordance with this test method.

A9.1.2 When tested as described in Section A9.5 an extinguishing system unit shall extinguish all visible flaming within 30 seconds after the end of extinguishant discharge. When tested as described in Section 4.1 an extinguishing system unit shall extinguish all visible flaming and prevent re-ignition of the fires after an 10 minute soak period (also measured from the end of extinguishant discharge). When tested as described in Sections A9.6 and A9.7 an extinguishing system unit shall “knock-down” the flames within 60 seconds after end of discharge (that means there are only flames allowed at the top edges of the 2 inner sheets) and extinguish all visible flaming within 3 minutes after the end of extinguishant discharge and also prevent re-ignition of the fires after an 10 minute soak period (also measured from the end of extinguishant discharge).

A9.1.3 The tests described herein consider the intended use and extinguishing concentrations for specific fuels.

The tests to be conducted are:

Test objective	Enclosure size	Test fires	Section
extinguishing concentration	≥100m <sup>3</sup> no side less than 4 metres, height: 3,5m to 4,0m	(a) wood crib	A9.4
		(b) heptane pan	A9.5
		(c) polymeric sheet	A9.6
		(i) PMMA (ii) Polypropylene (iii) ABS	
		(d) PVC cable tray	A9.7

### A9.2. Extinguishing system

A9.2.1 For the extinguishing tests described in Sections A9.4, A9.5, A9.6 and A9.7, the agent containers are to be conditioned at 20°C ± 2°C for a minimum period of 16 hours prior to conducting the test. In these tests the jet energy from the nozzles shall not influence the development of the fire. Therefore the nozzle(s) shall direct agent parallel to the test enclosure ceiling.

A9.2.2 For all tests, the extinguishing system has to be arranged and dimensioned with regard the following:

For liquefied extinguishants the time for the discharge of the pre-liquid gas phase plus the two-phase flow shall be 8 -10 seconds.

### A9.3. Extinguishing concentration

A9.3.1 The extinguishing concentration for each test is to be 76.9 % (i.e. 100/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 the ambient temperature of approximately 20°C within the enclosure.

The quantity to reach the concentration within the enclosure can be established using the equations in the specifications.

A9.3.2 A cold discharge test using the same quantity of extinguishant is to be conducted to verify the actual concentration of extinguishant.

For liquefied extinguishants, the agent concentration shall be measured in the cold

discharge test.

#### **A9.4 Wood crib test**

##### **A9.4.1. Test facility**

###### **A9.4.1.1. Construction**

The test enclosure shall meet the following requirements:

a) The test enclosure shall have a minimum volume of 100 m<sup>3</sup>. The height shall be at least 3.5 metres, at maximum 4 m. The floor dimensions shall be at least 4 metres wide by 4 metres long.

b) A means of pressure relief shall be provided.

Recommendation: The pressure vents should have a shape as quadratic as possible.

The ratio of the sides should be at least 0.8. The opening shall be on the longer side wall with its center 0,5m to 1,5 m from the corner. The centre of the opening should be positioned in the upper third of the room height.

c) The temperature in the test enclosure shall be (20 ±5) °C at the beginning of each test and there shall be enough time between the tests so that the enclosure can adapt to this temperature.

###### **A9.4.1.2. Instrumentation**

Sampling and storage of data from the sensors described below shall occur at a rate of at least 4 Hz.

##### **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 level inside the enclosure throughout the duration of the test. The accuracy of the measuring devices shall not be influenced by any of the fire products.

At least three sensors shall be located within the enclosure (Figures A9.1 and A9.2). One sensor shall be located at the equivalent height of the top of the test object from the floor, 0.6 metres to 1 metre away from the test object. The other two sensors shall be located at 0.1 \*H and 0.9\*H with H = height of the enclosure (Figures A9.1 and A9.2)

*Informative note:*

*In addition to the oxygen concentrations there should also be monitoring of the CO<sub>2</sub> concentration. Fire products such as CO, CO<sub>2</sub> etc shall not have any influence on the valuation of the extinguishing capacity of the investigated extinguishing gas.*

##### **Nozzle pressure**

The nozzle pressure during system discharge shall be recorded by a pressure transducer in the pipe work at a distance not greater than 1 metre from the nozzle.

##### **Enclosure temperature**

Temperature sensors shall be located centred 100 mm above the test object and 0.9\*H (H = room height), 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 (Figures A9.1 and A9.2).

*Informative note: It is recommended to use K type thermocouples (Ni-CrNi), diameter 1 mm.*

##### **Nozzle temperature**

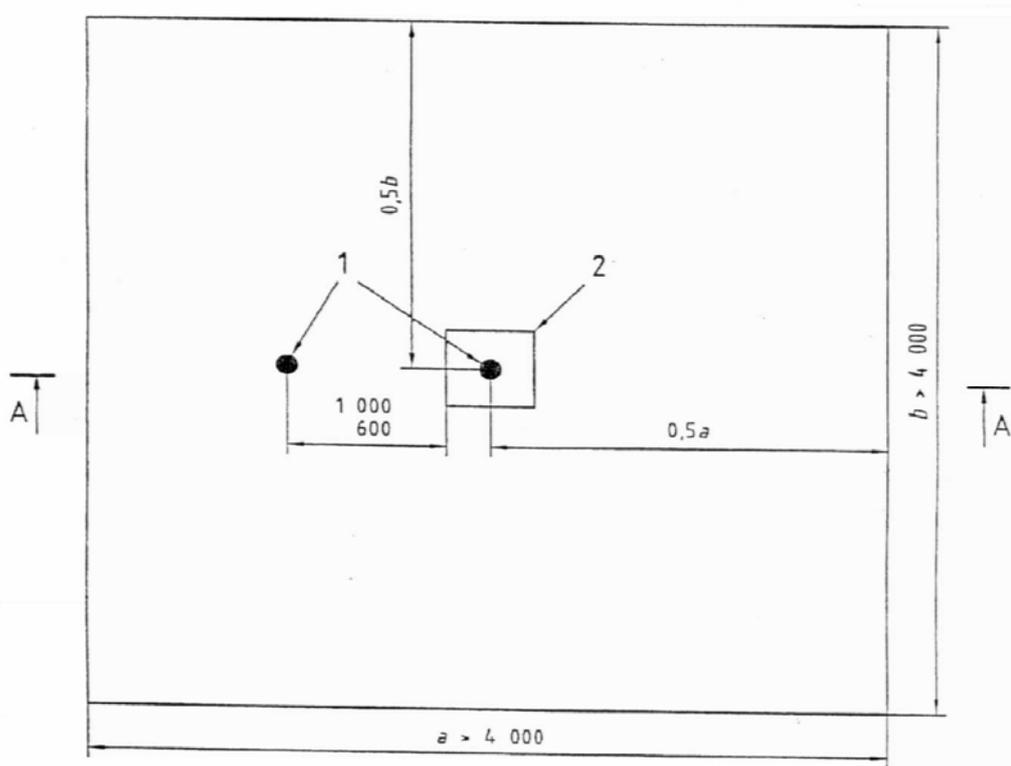
For liquefied extinguishants, the temperature of the liquid jet just outside the nozzle shall be recorded.

##### **Infrared video camera**

For the tests with plastic sheets according to A9.6 and with cable tray according to A9.7, infrared video camera (or equivalent) shall be used to determine the flame out times.

*Informative note: **Video/observations***

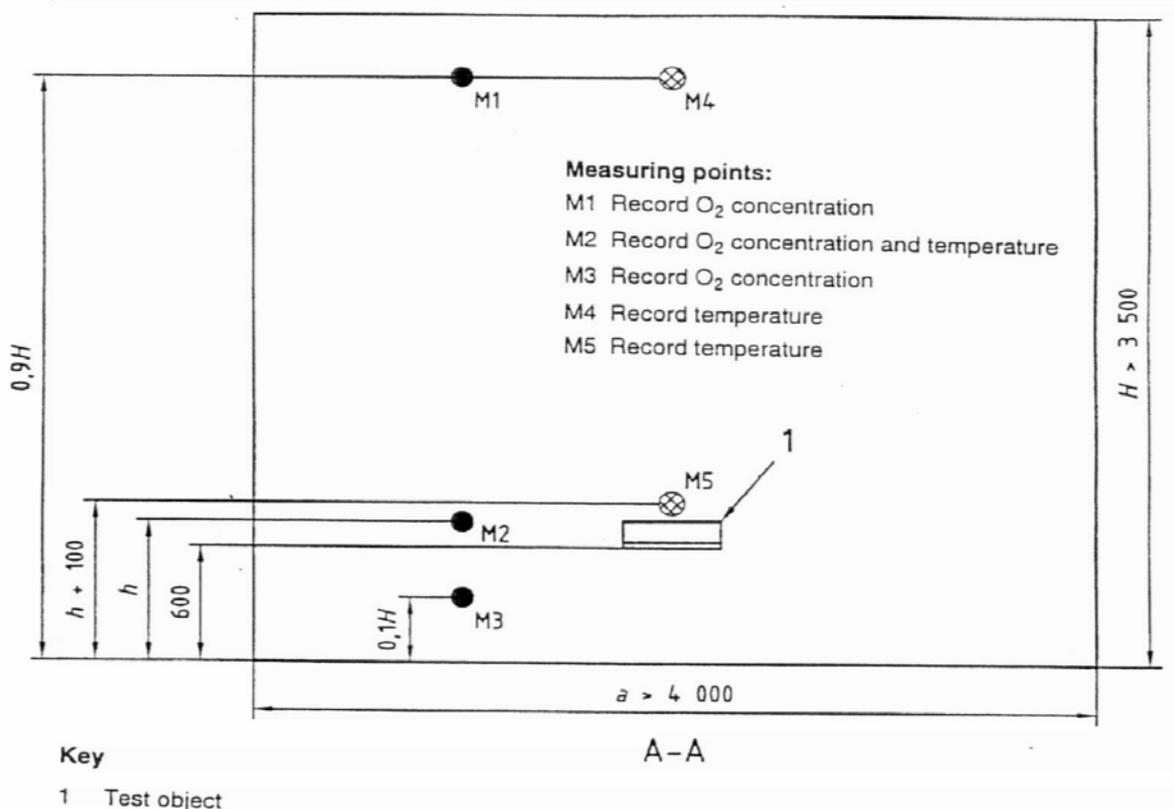
*Cameras, e.g. infrared-cameras, or an alternative means of directly viewing the fire can be provided as an aid to determining flame out times.*



**Figure A.9.1 - Plan view of instrumentation placement for the extinguishing concentration test**

Unit of measurement: mm

Information: 1 measuring point  
2 fire object



**Figure A.9.2 - Side view of instrumentation placement for the extinguishing concentration test**

Unit of measurement: mm

Information: 1 fire object

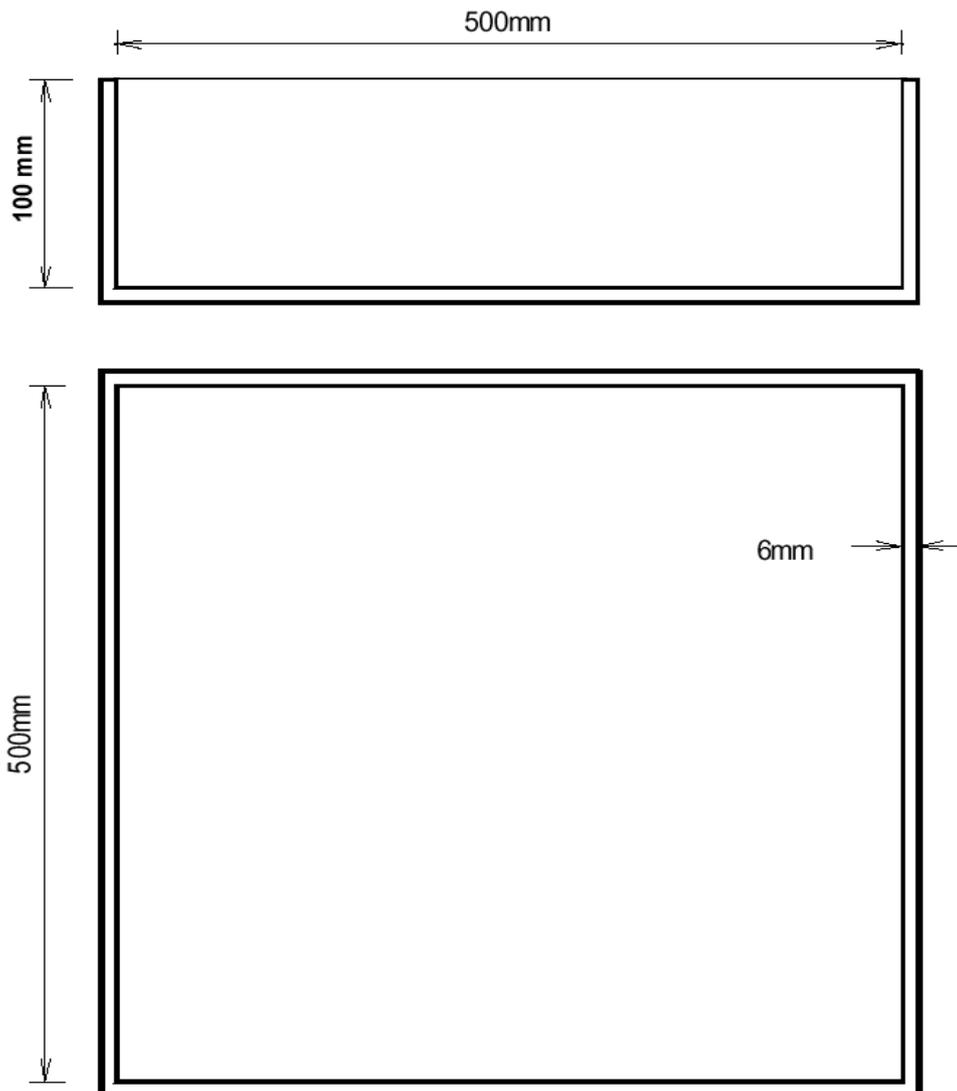
#### A9.4.2. Fuel specification

##### A9.4.2.1. Crib igniter fuel

Ignition of the crib is achieved by burning 1.5 litres of n-heptane (specified in table A9.2) on a 12.5 litre layer of water in a square steel pan 0.25 m<sup>2</sup> in area, 100 mm in height and with a wall thickness of 6 mm (see Figure A9.3).

Specification	Value
Purity	≥ 99 %
Boiling point at 1013 hPa	98.5 °C

**Table A 9.2 specification of n-heptane**



**Figure A9.3 - Pan geometry for Wood crib and Heptane pan fire test**

#### **A9.4.2.2. Fire configuration and placement**

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

The crib shall be pre-burned outside the enclosure on a stand supporting the crib 300 mm above the pan holding the igniter fuel (specified in Section A9.4.1.3.1).

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 with the base of the crib 600 mm above the floor (specified in Section A9.4.1.3.1).

#### **A9.4.3. Test procedure**

Prior to commencing tests the composition of the extinguishing gas shall be analysed. Record the weight and the moisture of the crib prior to the test.

##### **A9.4.3.1. Operation**

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 dimensioned 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<sup>-1</sup>. If necessary, adequate means for protection against wind, etc. may be used. Record the weather conditions including location of pre-burn, air temperature, humidity, and wind speed.

Ignite the heptane and allow the crib to burn freely. The 1.5 litres of heptane will provide a burn time of approximately 3 minutes. After the heptane is exhausted, the crib shall be allowed to burn freely for an additional time of 3 minutes. resulting in a total pre-burn time of 6 minutes (+10/-0s) outside the test enclosure.

Just prior to the end of the pre-burn period, move the crib into the test enclosure and place it on a stand such 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 seconds.

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 vol% lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1.5 vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values). If the start-O<sub>2</sub>-concentration in the fire tests and the cold discharge test is different, this has to be taken into account while comparing the O<sub>2</sub>-concentrations.

From the end of system discharge, the enclosure is to remain sealed for a total of 10 minutes. After the 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) presence and location of burning embers,
- b) whether or not the glowing embers or crib re-ignites; and
- c) weight of the crib after the test.

If necessary, amend the extinguishant concentration and repeat the experimental programme until 3 successive, successful extinguishments are achieved.

##### **A9.4.3.2. Results recording**

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

- a) The calculated discharge time of 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-liquefied extinguishants the time from opening the container valve(s) to cutting off the discharge. The discharge time for liquefied extinguishants has to be determined by nozzle pressure, nozzle temperature or combination of both.
- c) The time required to achieve extinguishment, in seconds. This time shall be determined by visual observation or other suitable means.
- d) The total mass of extinguishant discharged into the test enclosure.

e) The soaking time (time from the end of system discharge until the opening of the test enclosure)

f) Recording the temperature profile of the wood crib, using the infrared camera, is recommended.

#### **A9.4.4. Determination of design extinguishant concentration**

The laboratory extinguishant concentration is that concentration which achieves satisfactory extinguishment of the fire over 3 successive tests (no re-ignition or existence of burning embers after 10 minutes after end of discharge). The design concentration is the laboratory concentration multiplied by an appropriate 'safety factor'.

### **A9.5 Heptane pan test**

#### **A9.5.1 Test facility**

##### **A9.5.1.1 .Construction**

Construction of the enclosure is as described in Section A9.4.1.1.

##### **A9.5.1.2.Instrumentation**

Instrumentation of the enclosure is as described in Section A9.4.1.2.

#### **A9.5.2. Fuel specification**

##### **A9.5.2.1.Heptane**

The heptane has to be n-heptane having the characteristics according to Section A9.4.2.1.

##### **A9.5.2.2. Fire configuration and placement**

The fire will be a square steel pan of 0.25 m<sup>2</sup>, 100 mm high with a wall thickness of 6 mm as specified in Section A9.4.2.1. The test pan is to contain 12.5 litres of heptane. The resulting heptane surface is then 50 mm below the top of the pan.

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

*Note: The following requirements regarding additional 8 test cans shall ensure that the main test object has been extinguished by the agent concentration and not by blowing out effects. The number of test cans can be reduced due to symmetrical reasons (symmetry of the test enclosure, nozzle arrangement and nozzle jets). The additional test cans are not necessary if by other means it is ensured that the fire has not been blown out (e.g. extinguishment after end of discharge). or due to symmetry of the room*

In addition to the main test object, 8 test cans filled with n-heptane shall be positioned in the upper and lower corners of the test room.

The test cans shall have the following dimensions:

inner diameter of 80 mm to 82 mm,

wall thickness of 5 mm to 6 mm,

height of 100 mm to 110 mm.

They shall be filled with heptane up to a height of 50 mm to 55 mm.

The bottom of the cans is to be positioned 400 mm to 500 mm below the ceiling for the 4 upper test cans, 400 mm to 500 mm above the bottom for the lower test cans. The distance from the walls shall be 50 mm to 55 mm to each of the 2 nearest side walls.

The test cans shall be protected from direct jet by baffles. The vertical baffles form together with the walls of the test room a rectangular form around each test can. The baffles are positioned in a horizontal distance of 150 to 155 mm from the cans and they are tightly connected with the walls. The height of the baffles is 200 mm to 205 mm, their bottom line goes 0 mm to 5 mm lower than the bottom of the test cans.

The construction of test cans and baffles shall not be closed on top or bottom side.

#### **A9.5.3. Test procedure**

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

##### **A9.5.3.1.Operation**

The heptane is to be ignited and allowed to burn for 30 seconds. The heptane in the test cans should be ignited automatically at the same time or at least directly before the main pan.

After 30 seconds all openings are to be closed and the extinguishing system is to 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 vol% lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1.5

vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values). If the start-O<sub>2</sub>-concentration in the fire tests and the cold discharge test is different, this has to be taken into account while comparing the O<sub>2</sub>-concentrations.

The test is only positive if the main test object is extinguished at the same time as the test cans are extinguished or later.

If necessary, amend the extinguishant concentration and repeat the experimental programme until 3 successive, successful extinguishments are achieved.

#### **A9.5.3.2. Results recording**

Results are to be recorded as specified in Section A9.4.3.2 with the exception of notes e) and f).

#### **A9.5.4. Determination of design extinguishant concentration**

The laboratory extinguishant concentration is that concentration which achieves satisfactory extinguishment of the fire over 3 successive tests (no flaming 30 seconds after the end of extinguishant discharge). The design concentration is the laboratory concentration multiplied by an appropriate 'safety factor'.

### **A9.6 Polymeric sheet fire test**

#### **A9.6.1. Test facility**

##### **A9.6.1.1 .Construction**

Construction of the enclosure is as described in Section A9.4.1.1.

##### **A9.6.1.2. Instrumentation**

Instrumentation of the enclosure is as described in Section A9.4.1.2.

#### **A9.6.2. Fuel specification**

##### **A9.6.2.1. Igniter fuel**

The ignition source is a heptane pan (constructed of 2 mm thick mild or stainless steel) with inside to inside dimensions of 51 mm x 112 mm and 21 mm deep centred below the bottom of the plastic sheets (see Figure A9.4). The 51 mm side of the pan is orientated parallel to the sheets of polymeric fuel. The pan is filled with 6.0 ml of n-heptane (specified in A9.4.2.1) on a water base of 40 ml.

##### **A9.6.2.2. Polymeric fuel**

Tests are to be conducted with three plastic fuels:

- Polymethylmethacrylate (PMMA);
- Polypropylene (PP),
- Acrylonitrile-butadiene-styrene polymer (ABS).

Plastic properties are given in Table A9.3.

25 kW/m <sup>2</sup> Exposure in Cone Calorimeter – ASTM E 13554								
					180 Second Average		Effective	
		Density	Ignition Time		Heat Release Rate		Heat of Combustion	
Fuel	Colour	g/cm <sup>3</sup>	sec	Tolerance	kW/m <sup>2</sup>	Tolerance	MJ/kg	Tolerance
PMMA	Black	1.19	77	±30%	286	25%	23.3	±25%
Polypropylene	Natural (White)	0.905	91	±30%	225	25%	39.6	±25%
ABS	Natural (Cream)	1.04	115	±30%	484	25%	29.1	±25%

**Table A9.3 - Plastic properties**

##### **A9.6.2.3. Polymeric fuel array**

The polymeric fuel array consists of 4 sheets of polymer, which are cut to 405mm ± 5mm high by 200mm ± 5mm wide. The thickness of the sheets shall be as follows:

- Polymethylmethacrylate (PMMA) – 10.0 ± 1.0mm,
- Polypropylene (PP) – 10.0 ± 1.0mm
- Acrylonitrile-butadiene-styrene polymer (ABS) – 10.0 ± 1.0mm.

Sheets are spaced and located as per Figure A9.4 and A9.5. The bottom of the fuel array is located 203 mm from the floor. The fuel sheets shall be mechanically fixed at the required spacing. The sheets of plastic shall not significantly bend during the test. This can be reached e.g. by supporting each sheet on both vertical sides at 3 different heights.

The fuel array shall be located centrally within the enclosure.

#### **A9.6.2.4. Fuel shield**

A fuel shield consisting of a metal frame with sheet metal on the top and two sides shall be provided around the fuel array as indicated in Figure A9.4. The fuel shield is 380 mm wide, 850 mm high and 610 mm deep. The 610 mm (wide) x 850 mm (high) sides and the 610 mm x 380 mm top are metal sheet. The two remaining sides and bottom are open.

The metal sheet shall be aluminium with a wall thickness of 2 to 3 mm.

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

#### **A9.6.2.5. External baffles**

External baffles are constructed as shown in Figure A9.6 and are located around the exterior of the fuel shield. The baffles are placed 90 mm above the floor. The top baffle is rotated 45° with respect to the bottom baffle.

#### **A9.6.3. Test procedure**

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

Record the weight of the plastic sheets prior to the test.

##### **A9.6.3.1. Operation**

The heptane is ignited and allowed to burn completely. 210 seconds after ignition of the heptane, all openings are to be closed and the extinguishing system is to be manually actuated.

At the time of actuation of the system, the amount of oxygen within the enclosure at the level of the fuel shall not be more than 0,5 vol% lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1.5 vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values). If the start-O<sub>2</sub>-concentration in the fire tests and the cold discharge test is different, this has to be taken into account while comparing the O<sub>2</sub>-concentrations.

The enclosure is to remain sealed for a total of 10 minutes from end of discharge. After the soak period, ventilate 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) presence and location of burning fuel;
- b) whether or not the fire re-ignites; and
- c) weight of the fire structure after the test.

If necessary, amend the extinguishant concentration and repeat the experimental programme until 3 successive, successful extinguishments are achieved.

##### **A9.6.3.2. Results recording**

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

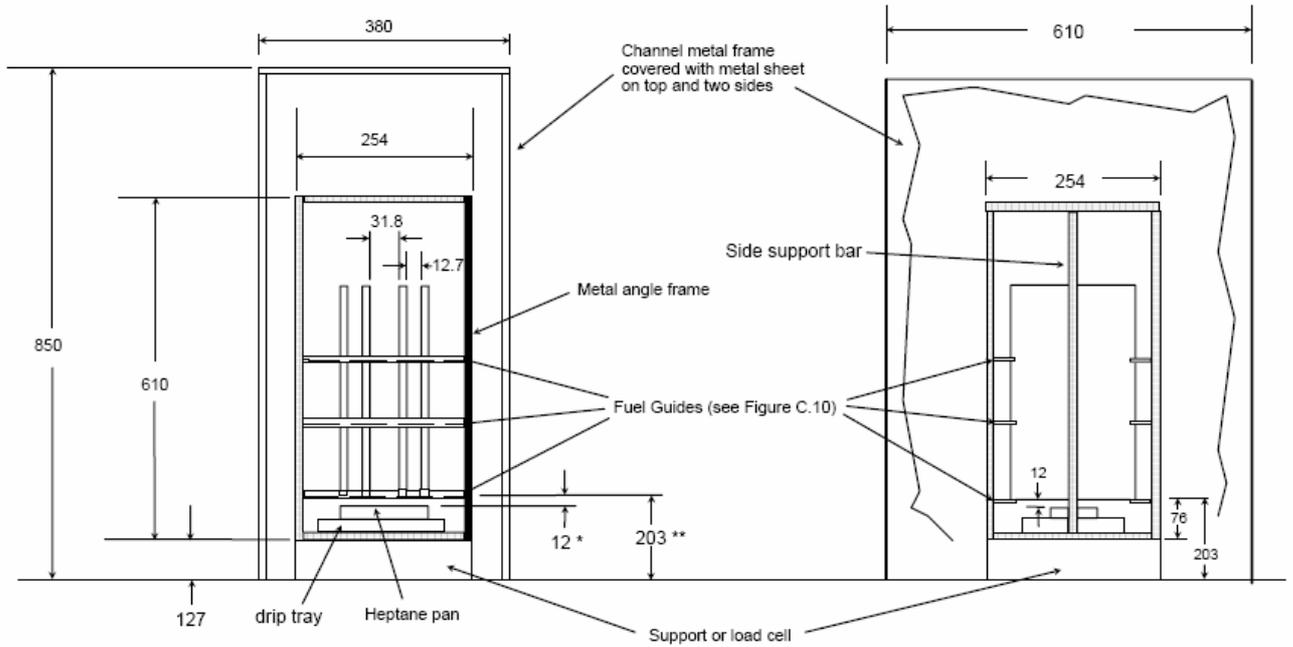
- a) The calculated discharge time of extinguishant, i.e. the time needed to reach 95% of the laboratory extinguishant concentration, in seconds.
- b) The effective discharge time, i.e. for liquefied extinguishants the time of the pre-liquid gas phase plus the time of the two phase flow; for non-liquefied extinguishants the time from opening the container valve(s) to cutting off the discharge. The discharge time for liquefied extinguishants has to be determined by nozzle pressure, nozzle temperature or combination of both.
- c) The time to achieve "knock down" of the flames, that means the time when there are only flames at the top edges of the 2 inner plastic sheets, in seconds. This time shall be determined by visual observation or other suitable means.
- d) The time required to achieve extinguishment, in seconds. This time shall be determined by visual observation or other suitable means.
- e) The total mass of extinguishant discharged into the test enclosure.
- f) The soaking time (time from the end of system discharge until the opening of the test enclosure).

#### **A9.6.4. Determination of design extinguishant concentration**

The laboratory extinguishant concentration for each fuel is that concentration which

achieves satisfactory extinguishment of the fire over 3 successive tests (only flames at the top edges of the 2 inner plastic sheets at 60 seconds after end of discharge, no flaming 180 seconds after end of discharge and no re-ignition after 10 minutes from end of discharge).

The design concentration is the highest of the laboratory concentrations for the three fuels (see A9.6.2.2) multiplied by an appropriate 'safety factor', if the three laboratory concentrations are higher than the laboratory concentration according to A9.7.4.



All dimensions in mm

\* top of ignition pan to bottom of plastic sheets

\*\* floor to bottom of plastic sheets

Figure A9.4 - Polymeric sheet fire

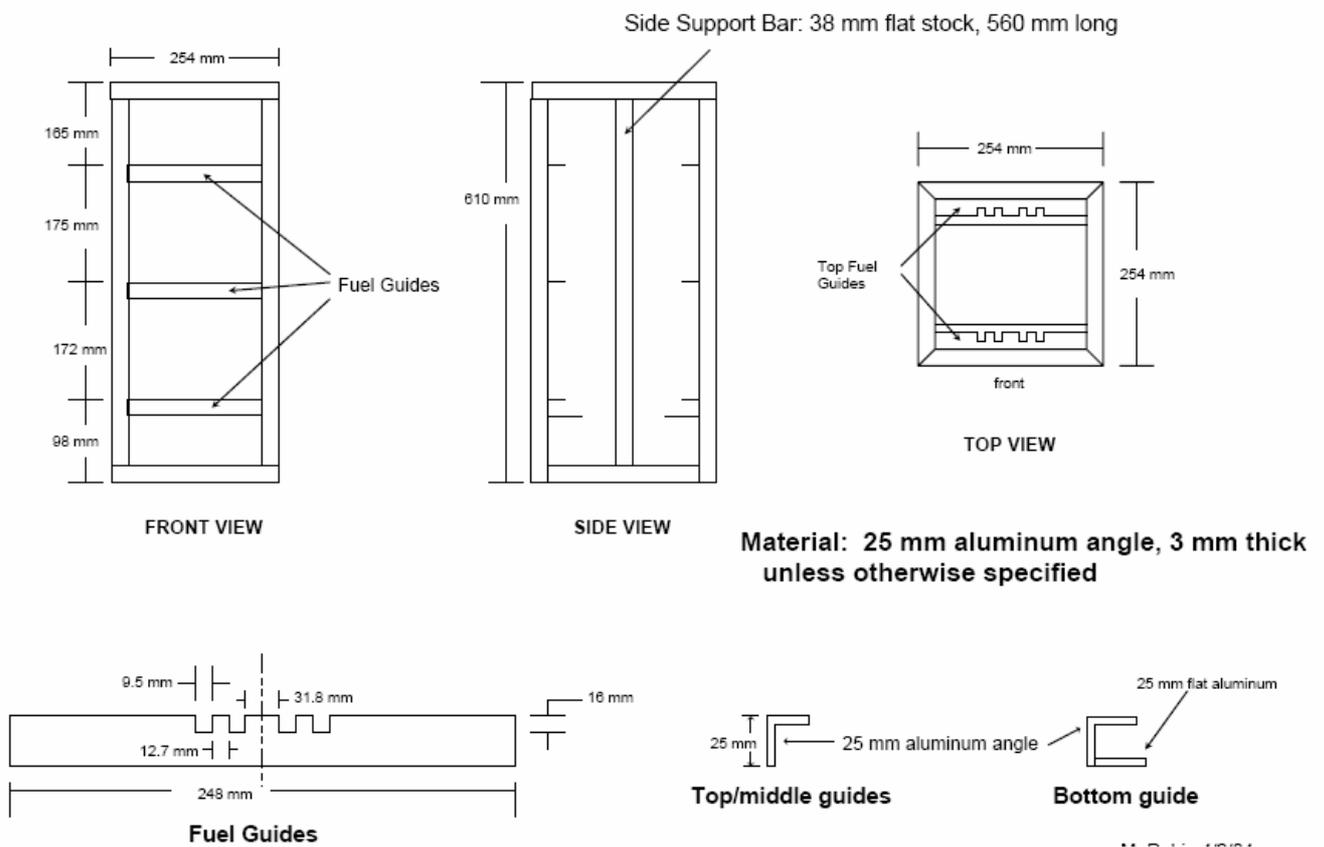
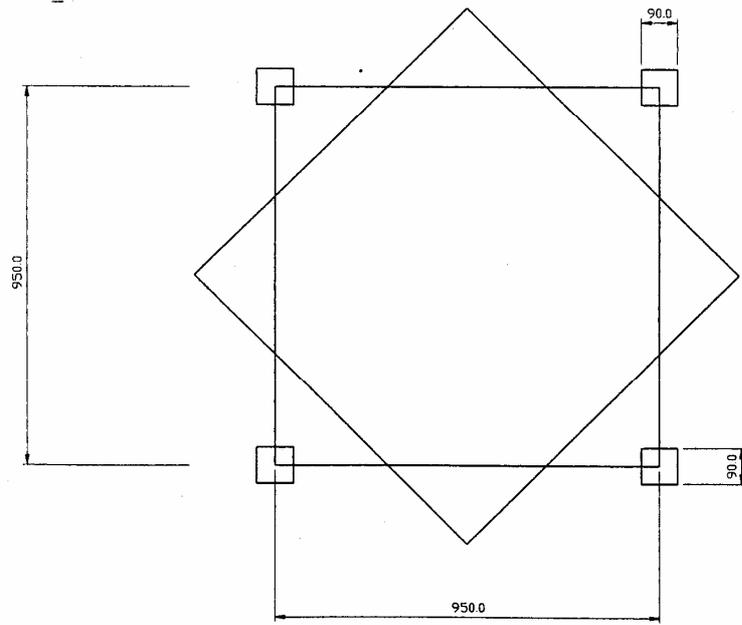
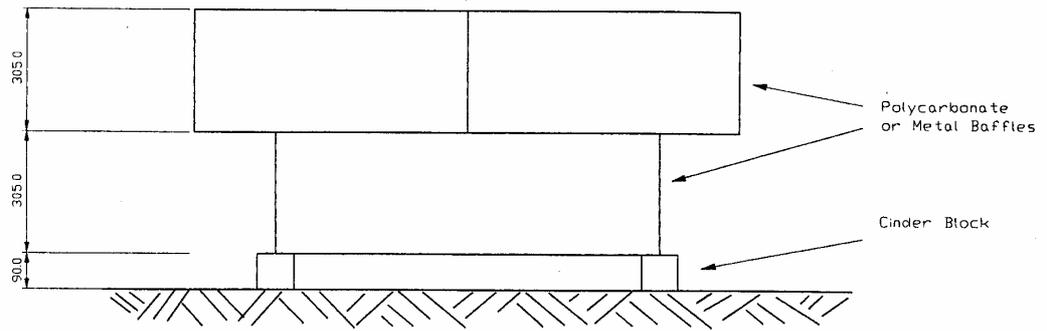


Figure A9.5 - Polymeric sheet fire – fuel guides



**Figure A9.6 - Polymeric fire baffle arrangement**

## A9.7 PVC Cable tray fire test

**Note: Test method described in A9.7 is still under development.**

### A9.7.1. Test facility

#### A9.7.1.1. Construction

Construction of the enclosure is as described in Section A9.4.1.1.

#### A9.7.1.2. Instrumentation

Instrumentation of the enclosure is as described in Section A9.4.1.2.

### A9.7.2. Fuel specification

#### A9.7.2.1. Igniter fuel

The ignition source is a heptane pan (2 mm thick stainless steel) with inside to inside dimensions of 200 mm by 200 mm and 20 mm deep centred 75 mm below the lowest cable tray (see Figure A9.7). The pan shall be placed on a flat surface at the required height. The pan is filled with 65 ml of n-heptane (specified in A9.4.2.1) without a water layer.

#### A9.7.2.2. PVC Cables

The test shall use Surface Wiring cable conforming to BS6004. The PVC casing houses two insulated conductors and an exposed earth continuity conductor

Component properties of the wire are given in Table A9.2.

Cable Part	Weight (g/m)	Mass %
External sheathing	75	32.6
Internal sheathing	35	15,2
Internal copper wire	100	43.5
Copper core	20	8.7

**Table A9.2 - Properties of PVC cable for cable tray fire test**

#### A9.7.2.3. Cable tray details

The test shall use tray according to the specifications in fig. A9.8 and A9.9.

Component properties of the tray are given in Table A9.3.

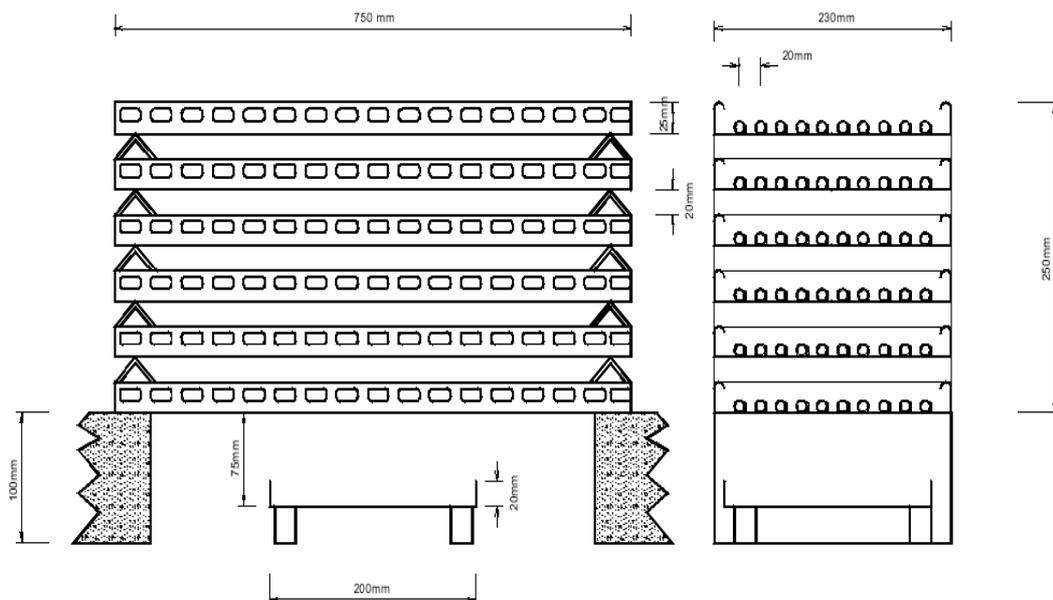
#### A9.7.2.4. Fuel configuration and placement

The cable array consists of 6 cable tray layers, each with 10 evenly spaced cables on it. Dimensions and arrangement of the cables are as described in Table A9.3 and Figure A9.7. The bottom of the fuel array is located 100 mm from the floor

The fuel array shall be located centrally within the enclosure.

Test Parameter	Measurement
Cable tray length	750mm
Cable tray width	225 mm
Cable length	650mm
Number of cables per layer	10
Cable separation (distance between centres)	20 mm
Cable tray porosity	20.3%
Cable tray thickness	1 mm
Cable tray separation	20mm
Starter fuel (heptane) quantity	100ml
Height of fire above base of starter fuel tray	75mm

**Table A9.3 • Specification of the PVC cable tray fire**



**Figure A9.7 - PVC cable tray fire**

### **A9.7.3. Test procedure**

Prior to commencing tests the composition of the extinguishing gas shall be analysed. Record the weight of the cables prior to the test.

#### **A9.7.3.1. Operation**

The heptane is ignited and allowed to burn completely. 195 seconds after ignition of the heptane, all openings are to be closed and the extinguishing system is to be manually actuated.

*Note: At that time the heat release rate of the cable array is between 20 and 25 kW.*

At the time of actuation of the system, the amount of oxygen within the enclosure at the level of the fuel shall not be more than 0.5 vol% lower than the normal atmospheric oxygen concentration. During the test, the oxygen concentration shall not change more than 1.5 vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values). If the start-O<sub>2</sub>-concentration in the fire tests and the cold discharge test is different, this has to be taken into account while comparing the O<sub>2</sub>-concentrations.

The enclosure is to remain sealed for a total of 10 minutes after end of discharge. After the 10 minute soak period, ventilate 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) presence and location of burning fuel,
- b) whether or not the cables re-ignite; and
- c) weight of the cables after the test.

If necessary, amend the extinguishant concentration and repeat the experimental programme until 3 successive, successful extinguishments are achieved.

#### **A9.7.3.2. Results recording**

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

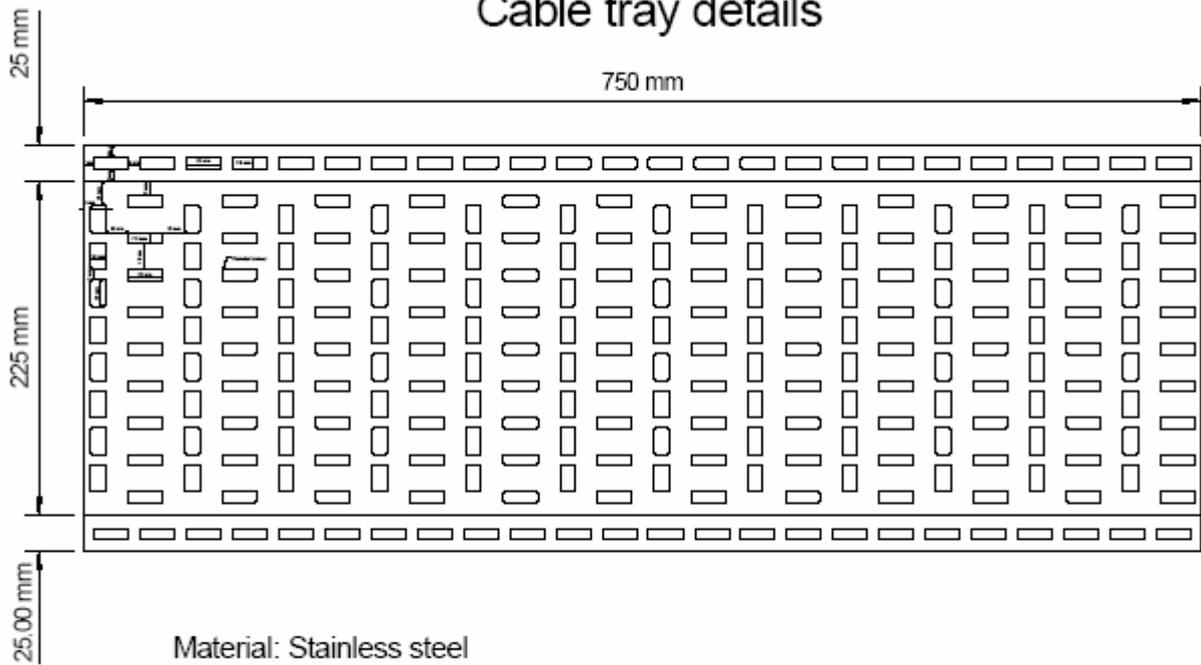
- a) The calculated discharge time of extinguishant, i.e. the time needed to reach 95% of the laboratory extinguishant concentration, in seconds.
- b) The effective discharge time, i.e. for liquefied extinguishants the time of the pre-liquid gas phase plus the time of the two phase flow; for non-liquefied extinguishants the time from opening the container valve(s) to cutting off the discharge. The discharge time for liquefied extinguishants has to be determined by nozzle pressure, nozzle temperature or combination of both.
- c) The time required to achieve extinguishment, in seconds. This time shall be determined by visual observation or other suitable means.
- d) The total mass of extinguishant discharged into the test enclosure.
- e) The soaking time (time from the end of system discharge until the opening of the test enclosure).

#### **A9.7.4. Determination of design extinguishant concentration**

The laboratory extinguishant concentration is that concentration which achieves satisfactory extinguishment of the fire over 3 successive tests (no flaming 60 seconds after end of discharge and no re-ignition after 10 minutes from end of discharge).

The design concentration is the laboratory concentration multiplied by an appropriate 'safety factor', if the laboratory concentration is higher than the three laboratory concentrations according to A9.6.4.

## Cable tray details



Material: Stainless steel  
Thickness: 1 mm  
Quantity required: 12 lengths  
The 25 mm side flanges will need bending 90 degrees to upright

Figure A9.8 – Cable tray details

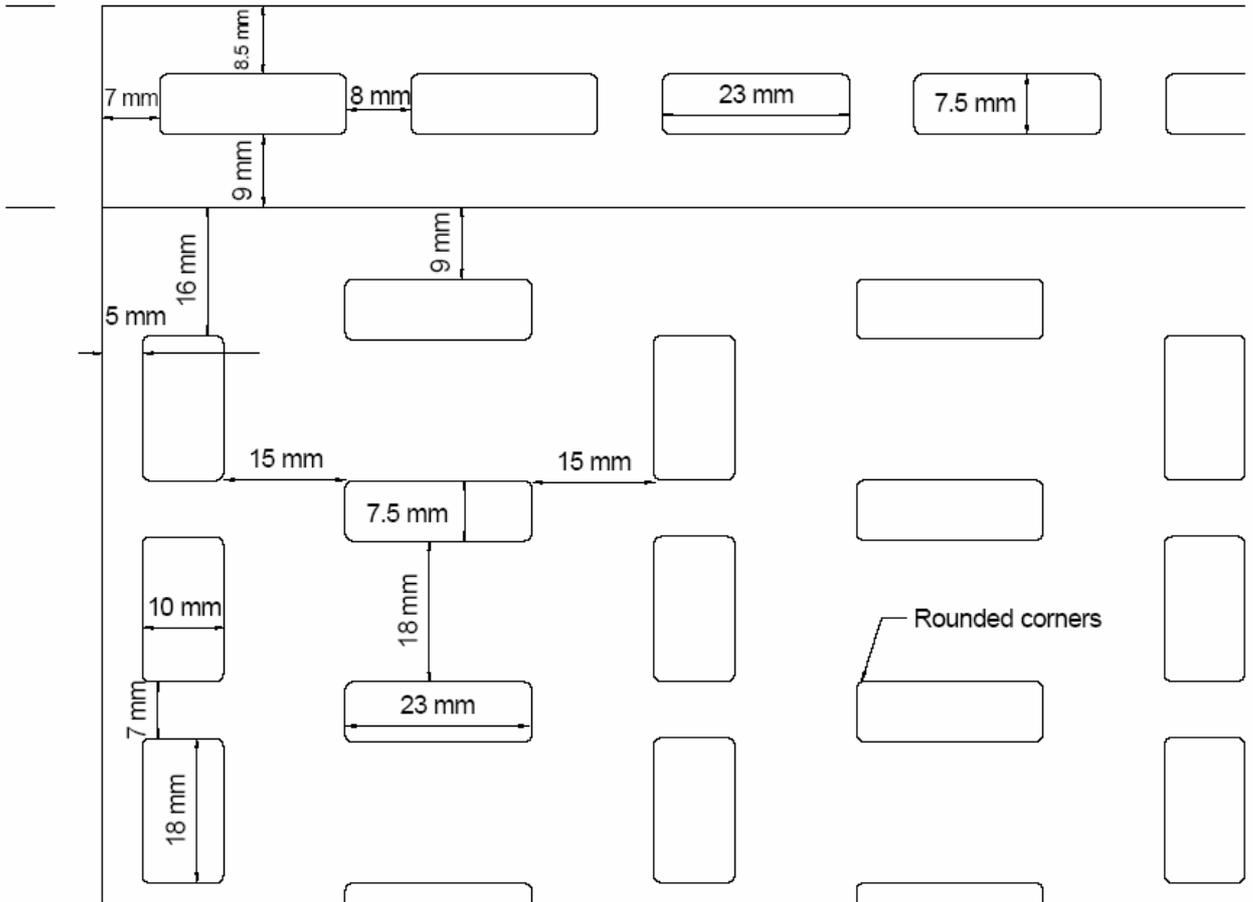


Figure A9.9 – Cable tray details - zoom

## Appendix A10 Door fan test for determination of hold time

### A10.1 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 testing.

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

This procedure is only suitable providing:

- a) An adequate return air path exists (ref: A10.2.4.2 & A10.2.7.1.3)
- b) The fan unit(s) can develop an enclosure pressure of 25Pa (this is a function of the size of the enclosure, its integrity, and the number and capacities of the fans – ref: A10.2.2.1 & A10.2.7.4.3)

The calculation procedures used are based upon heavier than air extinguishants. If extinguishants are lighter than air the calculation procedures and pass/fail criteria may need to be modified. The Hold Time calculation model, for enclosures without mixing, assumes that the enclosure has a constant cross sectional area with horizontal upper and lower boundaries. Expert advice must be sought on the possible use of this model to provide a Hold Time prediction for enclosures of other shapes.

### A10.2 Test for determination of predicted hold time

#### A10.2.1 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 equivalent 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 respectively either from or into an infinitely large space.
- d) That the system is at a temperature of 20°C, and atmospheric pressure is 1,013 bar absolute.

#### A10.2.2 Apparatus

**A10.2.2.1 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.

**A10.2.2.2 Two pressure measuring devices**, one to measure enclosure differential pressure and one to measure fan flow pressure. In addition, one pressure measuring device shall be used suitable for measuring the atmospheric pressure.

**A10.2.2.3 Flexible tubing**, for connecting the pressure measuring devices.

**A10.2.2.4 Chemical smoke pencils and/or smoke generator.**

**A10.2.2.5 Two thermometers**, to measure ambient temperatures.

**A10.2.2.6 Signs reading “DO NOT OPEN – PRESSURE TEST IN PROGRESS” and “DO NOT CLOSE – PRESSURE TEST IN PROGRESS”**

*NOTE 53 Additional apparatus, such as measuring tapes, ladders, tools to remove floor and ceiling tiles,*

*computer or other calculating device, camera, may be necessary or convenient.*

### **A10.2.3 Calibration and accuracy of apparatus**

#### **A10.2.3.1 Fan unit**

Calibrate the fan unit at the intervals and by the method recommended by the manufacturer. Keep records and where appropriate calibration certificates. The flow rate shall be accurate to +/- 5% of the measured value.

#### **A10.2.3.2 Pressure measuring devices**

The pressure measuring devices shall be accurate to +/- 1Pa and shall be calibrated periodically. Records shall be maintained and where appropriate calibration certificates.

The pressure measuring device for determination of the flow rate through the fan may have other accuracies as long as A10.2.3.1 is fulfilled.

If inclined manometers are used, change the fluid according to manufacturer's recommendation. Level and zero inclined manometers before each test.

The pressure measuring device for the atmospheric pressure shall be accurate to  $\pm 100$ Pa.

#### **A10.2.3.3 Temperature measuring devices**

Temperature measuring devices must be accurate to +/- 1°C.

### **A10.2.4 Preliminary preparation**

**A10.2.4.1** Obtain a description of air-handling equipment and extinguishant extraction systems, serving the enclosure and its surroundings, from the user.

**A10.2.4.2** 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) visually obvious leaks in the door and other openings, that are chosen for the installation of the fan unit

**A10.2.4.3 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; for example, removal of floor or ceiling tiles, shutdown of air handling systems, holding doors open and/or shut.

### **A10.2.5 Evaluation of enclosure**

#### **A10.2.5.1 General**

Obtain or prepare a sketch plan showing the enclosure and its surroundings, the size and location of door and other openings through which air will flow during the test, and the location of any ducts penetrating the enclosure, and any dampers in the ducts. Show the status (i.e. whether open, closed, on, off during the Hold Time) of each door, hatch, damper and other significant items (e.g. fans), and which access opening(s) is(are) to be used for the fan unit.

Show size and location of floor and sink drains.

### **A10.2.5.2 Mixture during Hold time**

Test enclosures with permanent mixing are rooms without an interface due to e.g. recirculating air-handling. During Hold time there is a uniform extinguishing gas concentration in the enclosure.

Test enclosures without permanent mixing are rooms without a significant, mechanically or thermally caused mixture during Hold time.

If it is not sure, whether there is a test enclosure with or without permanent mixing, calculation shall be done for both situations (according to clause A10.2.8.6 and A10.2.8.7). The lower value shall be used.

### **A10.2.6 Measurement of enclosure**

#### **A10.2.6.1 Standard Enclosures without mixing**

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

- a) The overall height of the protected enclosure,  $H_o$
- b) Determine the required protected height (H) (see clause 2.10).
- c) The gross volume of the protected enclosure,  $V_g$

#### **A10.2.6.2 Enclosures with irregular boundaries without mixing**

For enclosures with irregular boundaries, without mixing, it is not possible to give general guidance. Contact the authority.

#### **A10.2.6.3 Enclosures with mixing**

The height from the lowest point within the enclosure to the highest point within the enclosure must be used as the overall height of the enclosure ( $H_o$ ). The volume of the enclosure shall be recorded.

#### **A10.2.6.4 Opening for installation of the fan unit**

If there is significant leakage in the door or another opening, where the fan unit shall be installed, this leakage shall be measured and recorded.

### **A10.2.7 Test procedure**

#### **A10.2.7.1 Preparation**

**A10.2.7.1.1** Advise supervisory personnel in the area of the test.

**A10.2.7.1.2** Remove papers and objects likely to be disturbed by the air stream from the fan.

**A10.2.7.1.3** Block open sufficient doors outside the enclosure envelope to provide an adequate return path for air between the fan unit and the enclosure boundaries while correcting any breach of any requirements of the facility, including requirements for security, fire protection and environmental boundaries.

**A10.2.7.1.4** Using the sketch plan (see A10.2.5) set the enclosure air-handling equipment and extinguishant extraction systems to the state they would be in during the Hold Time, except that—

- a) recirculating air-handling equipment without fresh air make-up which does not give a bias pressure across the enclosure boundary or otherwise preclude accurate testing, and which would be shutdown 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.

**A10.2.7.1.5** Post the appropriate signs on doors (see A10.2.2.6).

**A10.2.7.1.6** Open doors and remove floor or ceiling tiles within the extinguishant protected portions of the enclosure envelope so that the extinguishant protected volume is treated as one space. Do not remove false ceiling tiles if the volume above the false ceiling is not protected with extinguishant.

*Caution: Suitable measurements shall prevent danger due to removing floors*

**A10.2.7.1.7** Set all doors and windows and other openings in the enclosure envelope to the state they would be during the Hold Time. Tightening measures only for door fan testing are not allowed. Locking of parts of the enclosure is only allowed if it is verified that these parts do not move below 20 Pa or column pressure whichever is higher.

**A10.2.7.1.8** Check that liquid traps in the floor and sink drains are sealed with liquid, if this is normal condition.

**A10.2.7.1.9** Record the conditions (enclosure, surroundings, and services) during the fan test.

### **A10.2.7.2 Setting up the door fan unit**

**A10.2.7.2.1.** 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.

**A10.2.7.2.2** 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 10s.

Release the pressure and zero the devices.

**A10.2.7.2.3.** 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.

**A10.2.7.2.4** Use the fan(s) to raise or lower the pressure of the enclosure by the highest possible and safe pressure. Check all dampers with smoke and ensure that they are closed properly. Check doors and hatches and ensure correct closure. Inspect the wall perimeter (above and below any false ceiling) and the floor slab for any major leaks and note their size and location.

**A10.2.7.2.5** Ensure that there will be no pressure differential between the area of the fan outside the enclosure, and along the return air paths around the boundary of the enclosure under test. This may be done visually or by pressure measurement.

### **A10.2.7.3 Measurement of Bias Pressure $P_{bt}$ during fan testing**

**A10.2.7.3.1.**  $P_{bt}$  is used to correct for the measured pressure differential (inside/outside) the enclosure in order to calculate the enclosure leakage characteristics.

**A10.2.7.3.2.** Seal the fan unit and, without the fan(s) operating, observe the enclosure differential pressure-measuring device which may take up to 30 s.

Record the static pressure ( $P_{bt}$ ) and its direction at the time of the door fan test. If the absolute value of  $P_{bt}$  is more than 3 Pa (i.e.  $|P_{bt}| > 3$  Pa),  $P_{bt}$  shall be reduced before continuing the leakage test.

**A10.2.7.3.3.** Make every effort to reduce the static pressure  $P_{bt}$  by shutting down air handling equipment even though it can operate during a discharge.

If a subfloor pressurisation airhandler cannot be shut down for the test and leaks exist in the subfloor, these leaks cannot be accurately measured. During the test as many floor tiles as possible should be lifted to reduce the amount of subfloor pressurisation. If not possible, every effort should be made to reduce subfloor leaks to insignificance.

*Caution: Suitable measurements shall prevent danger due to removing floors*

**A10.2.7.3.4.** 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 accurate fan tests can be carried out.

### **A10.2.7.4 Measurement of leakage rate**

**A10.2.7.4.1** Measure the air temperature inside the enclosure  $T_e$ , and measure the air temperature outside the enclosure  $T_o$ , at several points. If the location of leaks is not known, use the average value; otherwise, use the average value weighted according to the known location of the leaks. Verify the temperatures at the end of the test.

**A10.2.7.4.2** Unseal the fan inlet or outlet and connect the fan flow pressure measuring device.

**A10.2.7.4.3** 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 (for at least 30s) and record the pressure differential i.e.  $(P_f + P_{bt})$ . 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. At each pressure difference, measure the air flow and pressure difference across the enclosure/fan boundary. After the fan and instrumentation have stabilised, the average over an interval equal to, or greater than, 10 s should be used if fluctuations are observed. If stable readings cannot be obtained at 10 Pa then only go down to the lowest pressure at which stable readings can be obtained.

**A10.2.7.4.4** Use the fan unit to pressurize the enclosure and repeat the procedure of A10.2.7.4.3. Again record values of  $(P_f + P_{bt})$ , which will be positive.

**A10.2.7.4.5** Repeat the zero flow pressure difference (bias pressure  $P_{bt}$ ) measurement. If the reading differs from the initial zero flow pressure difference reading by more than 1Pa, repeat the test.

### **A10.2.7.5 Field Calibration Check**

**A10.2.7.5.1** Calculate the enclosures' equivalent leakage area (average of pressurization and depressurization) at a convenient reference pressure differential, using equations (E.17) and (E.19). The reference pressure differential should be within and in the middle of the testing enclosure pressure differential according to clause A10.2.7.4.3.

**A10.2.7.5.2** In a sheet of rigid material, less than 3 mm thick and free of any penetrations, cut a sharp-edged circular or square calibration check orifice. The area of the orifice must be large enough to cause an easily measurable increase in the enclosure's leakage rate, but not so large that a different range of the fan unit must be used to measure the increased flow. A geometrical area about 50 % of the enclosure's equivalent leakage area is likely to be suitable. Install the sheet in an unused fan unit port if possible. Otherwise, install the sheet in some other convenient enclosure opening but consider that this will modify the enclosure's leakage characteristic and reduce the accuracy of the field calibration check.

**A10.2.7.5.3** Seal the fan unit and orifice, repeat the zero flow pressure difference (bias pressure  $P_{bt}$ ) measurement (A10.2.7.3) and record the value of  $P_{bt}$ .

The orifice will be opened and the measurement of the leakage rate repeated (A10.2.7.4).

**A10.2.7.5.4** The equivalent leakage area of the test enclosure with test orifices (average of pressurization and depressurization) will be calculated by means of the equation E 17 and E 19 considering the reference pressure differential used in A10.2.7.5.1.

**A10.2.7.5.5** The measured equivalent leakage area of the calibration check orifice (average of pressurization and depressurization) is defined as the equivalent leakage area of the test enclosure with test orifices minus the equivalent leakage area of only the test enclosure.

**A10.2.7.5.6** Field calibration is acceptable if the measured equivalent leakage area of the orifice is within +/- 10 % of its geometrical area. If the difference is greater than 10 %, the fan unit should be recalibrated.

### **A10.2.7.6 Measurement of Bias Pressure $P_{bh}$ under Hold Time conditions**

$P_{bh}$  is the Bias Pressure under Hold Time conditions that is used in the calculation of the Hold Time.

Set the enclosure, its surroundings, and services, to the conditions that would apply during the Hold Time – using the information from A10.2.5.

Measure  $P_{bh}$  – the pressure difference across as many boundaries of the enclosure as possible.

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 ( $P_{bh}$ ).  $P_{bh}$  is negative, if the enclosure pressure is minor to the neighbored area.

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.

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.

## A10.2.8 Calculation

### A10.2.8.1 Symbols

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

$A_e$ .....effective leakage area	( m <sup>2</sup> )
$c$ ..... design concentration of extinguishant in air for the enclosure	( % V/V)
$c_{min}$ minimum concentration of extinguishant in air for the protected part of the enclosure at the end of Hold Time – not less than the extinguishing concentration	( % V/V) the
$F$ lower leakage fraction, effective area of lower leaks divided by effective area of all leaks	dimensionless
$g_n$ .....gravitational acceleration (= 9,81)	( m/sec <sup>2</sup> )
$H$ required protected height – this is the minimum required height of $C_{min}$ at the end of the Hold Time	( m)
$H_o$ .....overall height of enclosure	( m)
$H_e$ .....height of equivalent sharp interface	( m)
$k_0$ .....actual leakage area discharge coefficient (see equation E1)	dimensionless
$k_1$ .....leakage characteristic (see equation (E 11))	( m <sup>3</sup> /(s.Pa <sup>n</sup> ))
$k_2$ .....correlation constant (see equation (E12))	( kg <sup>n</sup> .m <sup>3(1-n)</sup> /(s.Pa <sup>n</sup> ))
$k_3$ .....simplifying constant (see equation (E13))	( m/s <sup>2</sup> )
$k_4$ .....simplifying constant (see equation (E14))	( Pa.m <sup>3</sup> /kg)
$n$ ..... leakage characteristic (see equation (E10))	dimensionless
$P_f$ .....differential pressure produced by the fan	( Pa)
$P_{ref}$ differential pressure produced by the fan, used as reference pressure for calculation of $A_e$	(Pa)
$P_{mi}$ initial extinguishant/air column pressure	( Pa)
$P_{mf}$ final extinguishant/air column pressure.....	( Pa)
$P_{bt}$ bias pressure at the time of the fan test	( Pa)
$P_{bh}$ bias pressure during the Hold Time.....	( Pa)
$P_c$ atmospheric pressure during fan calibration.....	( Pa)
$P_t$ atmospheric pressure during door fan test.....	( Pa)
$Q_f$ ....measured air flow rate through fan	( m <sup>3</sup> /s)
$Q_{ref}$ air flow rate through fan at $P_{ref}$ , used for calculation of $A_e$	(Pa)
$Q_l$ air flow rate, temperature and pressure corrected to reference conditions (20°C, 1.013 bar atmospheric pressure)	( m <sup>3</sup> /s)

$T_e$ .....air temperature inside enclosure	( °C)
$T_o$ .....air temperature outside enclosure	( °C)
$T_c$ .....atmospheric temperature during calibration of fan unit...	.....( °C)
$t$ .....predicted hold time	( s)
$V_g$ enclosure gross volume	( m <sup>3</sup> )
$\rho_a$ .....air density (1,205 at 20°C and 1,013 bar)	( kg/m <sup>3</sup> )
$\rho_{mf}$ extinguishant/air mixture density at the minimum concentration $C_{min}$ 20°C and 1,013 bar atmospheric pressure.....	( kg/m <sup>3</sup> )
$\rho_{mi}$ extinguishant/air mixture density at design concentration $c$ , 20°C and 1,013 bar atmospheric pressure .....	( kg/m <sup>3</sup> )
$\rho_m$ extinguishant/air mixture density at 20°C and 1.013 bar atmospheric pressure	( kg/m <sup>3</sup> )
$\rho_e$ .....extinguishant density at 20°C and 1.013 bar atmospheric pressure	( kg/m <sup>3</sup> )

### A10.2.8.2 Air flow rates

From the measured values of  $(P_f + P_{bt})$  and  $P_{bt}$  calculate the values of  $P_f$  and, using the fan calibration data (see A10.2.3.1), the corresponding air flows  $Q_f$  through the fan.

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

$$|Q_f| = k_1 |P_f|^n \quad (E1)$$

The leakage coefficients  $k_0$  and  $n$  and the correlation coefficients ( $r$  or  $r^2$ ) will be determined by means of the method of least squares for adaptation to the test data:

$$\ln |Q_f| = \ln k_0 + n \ln |P_f|$$

Check that the correlation coefficients of each set are not less than  $r = 0.99$  ( $r^2 = 0.98$ ). The two sets will almost always have different values of  $k_1$  and  $n$ .

If the correlation coefficient is too less:

- check the fluctuating bias pressure
- check, if e.g. dampers, hatches are moveable
- repeat the door-fan test.

The corrected values of  $k_0$  shall be calculated by means of equations E2 and E3 and named  $k_1$ .

for depressurization

$$k_1 = k_0 \left( \frac{P_c(T_e + 273)}{P_f(T_c + 273)} \right)^{1/2} \left( \frac{T_o + 273}{T_e + 273} \right) \left( \frac{P_f(20 + 273)}{1.013(T_o + 273)} \right)^n \quad (E2)$$

for pressurization

$$k_1 = k_0 \left( \frac{P_c(T_o + 273)}{P_f(T_c + 273)} \right)^{1/2} \left( \frac{T_e + 273}{T_o + 273} \right) \left( \frac{P_f(20 + 273)}{1.013(T_e + 273)} \right)^n \quad (E3)$$

Note: Equations (E2) and (E3) correct the flow rates for the effects of temperature and pressure differences on air density, assuming that:

- the flowmeter is of the usual type, which gives a pressure signal proportional to the air density and the square of the volume flow rate.
- Considering a defined pressure difference the air flow (between outside and inside enclosure) is reverse proportional to  $n$ th square of the air density.

The effects of humidity and viscosity are ignored.

### A10.2.8.3 Column pressure

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

$$\rho_{mi} = \frac{\rho_e C}{100} + \frac{\rho_a(100 - C)}{100} \quad (E4)$$

For enclosures with mixing, calculate the density of the extinguishant/air mixture at 20°C at the minimum concentration  $C_{min}$  using the equation:

$$\rho_{mf} = \frac{\rho_e(C_{min})}{100} + \frac{\rho_a(100 - C_{min})}{100} \quad (E5)$$

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

$$P_{mi} = g_n H_o (\rho_{mi} - \rho_a) \quad (E6)$$

Calculate the final column pressure by means of the following equation, if  $P_{bh}$  is negative, and check, whether  $P_{mf}$  is more than the absolute value of  $P_{bh}$ . If not, the equations for calculating the Hold time are not suitable (because the leakage differential pressure causes reverse flow).

Calculate the corresponding final column pressure  $P_{mf}$  as follows:

For enclosures without mixing:

$$P_{mf} = g_n H (\rho_{mi} - \rho_a) \quad (E7)$$

With:

$$H_e = H_o - (H_o - H)(C/2C_{min}) \quad (E8)$$

For enclosures with mixing:

$$P_{mf} = g_n H_o (\rho_{mf} - \rho_a) \quad (E9)$$

### A10.2.8.4 Leakage characteristics

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

Calculate the average values ( i.e. of the pressurisation and depressurisation data) of

$Q_l = k_1 |P_f|^n$   
for values of  $P_f$  equal to  $P_{mi}$ , and for  $P_f$  equal to 0.5  $P_{mi}$ . These are  $Q_{lm}$  and  $Q_{lm/2}$  respectively:

$$n = \frac{\ln Q_{lm} - \ln Q_{lm/2}}{\ln 2} \quad (E10)$$

$$k_1 = \exp \left( \frac{(\ln Q_{lm/2})(\ln P_{mi}) - (\ln Q_{lm})(\ln P_{mi} - \ln 2)}{\ln 2} \right) \frac{(ELA + \text{leakage orifice})}{(ELA)} \quad (E11)$$

with:

ELA measured equivalent leakage area of enclosure (A10.2.7) using E17 and E19.  
Leakage orifice according to A10.2.6.4

### A10.2.8.5 Correlation constant

Calculate the correlation constant  $k_2$  using the equation:

$$k_2 = k_1 \left[ \frac{\rho_a}{2} \right]^n \quad (E12)$$

Calculate the simplifying constant  $k_3$  using the equation:

$$k_3 = \frac{2 g_n (\rho_{mi} - \rho_a)}{\rho_{mi} + \rho_a \left( \frac{F}{1-F} \right)^{1/n}} \quad (E10)$$

$$\rho_{mi} + \rho_a \left( \frac{F}{1-F} \right)^{1/n}$$

Calculate the simplifying constant  $k_4$  using the equation:

$$k_4 = \frac{2 P_{bh}}{\rho_{mi} + \rho_a \left( \frac{F}{1-F} \right)^{1/n}} \quad (E11)$$

#### A10.2.8.6 Predicted hold time: enclosures without mixing

For enclosures without mixing, the predicted hold time  $t$  for the extinguishant concentration at height  $H$  to fall from the design concentration  $c$  to the minimum  $c_{min}$  may be calculated by assuming the extinguishant distribution in the enclosure, and calculating the hold time for an equivalent sharp interface which would give the same column pressure and rate of loss of extinguishant as the actual extinguishant distribution.

If the enclosure is a standard enclosure and  $c_{min}$  is greater than or equal to  $0.5c$ , assume that the extinguishant concentration at any particular instant equals the design concentration from the lower boundary of the enclosure up to a certain height, and above this decreases linearly with increasing height to zero at the upper boundary of the enclosure. Calculate the height  $H_e$  of the equivalent sharp interface using the equation E8.

Considering  $F=0.5$  the predicted hold time is:

$$t = \frac{V_g}{H_o} \frac{(k_3 H_o + k_4)^{(1-n)} - (k_3 H_e + k_4)^{(1-n)}}{(1-n) k_2 F k_3} \quad (E15)$$

If  $c_{min} < 0.5 C$  calculate hold time according to E15 using  $H$  instead of  $H_e$ .

#### A10.2.8.7 Predicted Hold Time: enclosures with mixing

For enclosures with mixing, assume  $F = 0,5$  and calculate the predicted hold time  $t$  for the extinguishant concentration in the enclosure to fall from the design concentration to the minimum concentration  $C_{min}$  (see 2.10) using the equation:

$$t = \frac{V_g}{F k_2} \int_{\rho_{mf}}^{\rho_{mi}} \left[ \frac{2 g_n H_o (\rho_m - \rho_a)^{(n+1)/n} + 2 P_{bh} (\rho_m - \rho_a)^{1/n}}{\rho_m + \rho_a \left( \frac{F}{1-F} \right)^{1/n}} \right]^{-n} d\rho_m \quad (E16)$$

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

### A10.3 Treatment of enclosures with predicted minimum hold times less than the recommended value

#### A10.3.1 General

If the predicted minimum hold time, calculated in accordance with A10.2, is less than as recommended in part 2.10 of this standard then A10.3.2 to A10.3.5 shall be implemented in sequence.

#### A10.3.2 Leakage area

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

$$A_e = \frac{Q_{ref} (\rho_a)^{1/2}}{(2 P_{ref})} = k_1 P_{ref}^{-1/2} \left( \frac{\rho_a}{2} \right)^{1/2} \quad (E17)$$

At 20° C and 1.013 bar, equation E17 reduces to:

$$A_e = 0.7762 k_1 P_{ref}^{n-1/2} \quad (E18)$$

The equivalent leakage area (ELA) may be calculated as:

$$ELA = A_e / 0.61 \quad (E19)$$

The ELA is used for fan calibration checks and for identification of actual leaks. It is the area of a circular sharp edged orifice which has the same value of  $A_e$  as the actual leakage area  $A_l$ .

### **A10.3.3 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 hold time, after new fan test measurements in accordance with A10.2.7.4, is not less than the minimum recommended value, no further action is necessary.

### **A10.3.4 Quantification and location of leaks**

#### **A10.3.4.1 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. In an enclosure without bias pressure the 'neutral plane' (between inflow and outflow) can be taken as the mid height of the enclosure. For the purpose of this assessment, lower leaks are assumed to be those below the neutral plane, and upper leaks are those above it.

The fan test does not show the location of the leaks or the value of the lower leakage fraction  $F$ . In section A10.2 it is assumed that the value of  $F$  is 0.5, all the lower leaks are in the base of the enclosure and all the upper leaks are in the top of the enclosure. This is the worst case and gives the minimum value for hold time.

If some lower leaks are above the base of the enclosure or if some upper leaks are below the top of the enclosure, the hold time will 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.

#### **A10.3.4.2 Second calculation of hold time**

Make a second calculation of the hold time using equations (E12),(E13),(E14) and (E15) or equation (E16), as appropriate, assuming  $F = 0,15$ . If this value is more than the recommended minimum (see 2.10) then make an estimate of the actual value of  $F$  using the method in A10.3.4.3.

#### **A10.3.4.3 Method of estimating $F$**

Temporarily seal upper leaks, such as dampers, that can be traced using smoke. Repeat the fan test and calculate the reduced effective leakage area  $A_e$  using (E17 and E19).

Remove the sealing from upper leaks and seal lower leaks, that can be traced using smoke. Repeat the fan test and calculate the reduced effective leakage area  $A_e$  using (E17 and E19).

The area of the temporarily sealed upper leaks can thus be quantified and the remaining open area treated as 50% upper leaks and 50% lower leaks. Calculate the new value of  $F$  (with:  $ELA_1$  = value of original ELA-measurement).

$$F=0.5 (ELA_1 + ELA_2 - ELA_3)/(ELA_1) \quad (E20)$$

#### **A10.3.5 Final calculation of hold time**

Using the value of  $F$  determined as in A10.3.4.3, which should not be more than 0,5 or less than 0,15, recalculate the hold time using equations (E12),(E13),(E14) and (E15) or equation (E16) as appropriate.

## **A10.4 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, minimum concentration, and the extinguishant to be used;
- 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 hold time and whether or not the value complies with the recommendation of clause 2.10.
- h) the information on the arrangement and status of the enclosure, surroundings and services as specified in A10.2.5 and A10.2.7.1.4.
- i) the current calibration data for the fan unit and the pressure measuring devices, corresponding certificates if available, and the results of the field calibration check;
- j) the test results, including a record of the test measurements and any appropriate calculations.
- k) size and location of leaks, if identified.

## Appendix A11 Example for design of pipes and pipe connections

	Service pressure Bar	Test pressure bar**	Sort of pipe	standard	material	quality	Certificate according to EN10204
Pipework between container and selector valve*	as in the container at maximum temperature according to clause 2.7.2	1,5 times service pressure	seamless welding	DIN 1629 ***, DIN 17175 DIN 1626 ***, DIN 17177	St 37.0 St 35.8 St 37.0 St 37.8	III  III	3.1 B 3.1 B 3.1 B 3.1 B
Pipework downstream of selector valve	as calculated	1,5 times as calculated	seamless welding	DIN 1629 ***  DIN 1626 ***	St 37.0 St 37.0		2.2 2.2
Fitting downstream of selector valve****	as calculated	1,5 times as calculated		DIN EN 10242	EN-GJMW-400-5 (acc. EN 1560)		2.2
<p>* Safety valves shall ensure that service pressure cannot be increased by leakage from the container valves</p> <p>** leakage test of the pipes shall result from tests of inside pressure with water according to the standard or a useful test without destruction</p> <p>*** Pipes according to DIN 1629 and DIN 1626 maximum 160 bar service pressure.</p> <p>**** if high-class fittings are used, mark shall be clear. "Red spot" or mark "D" is not necessary.</p>							

**Table 3.1 Pipe quality requirements**

A11.1 For design of pipes the AD-leaflets W4 – Pipes of non-alloy and alloy steels – and W 10 – materials for deep temperatures , iron materials – shall be noticed. Only pipes according to table 3.1 shall be used.

Tube sheet thickness shall be designed according DIN 2413 section I in consideration of AD-leaflet W 10. Measurements shall meet DIN 2448/DIN 2458, pipes shall have minimum normal tube sheet thickness.

Pipes according to DIN 2448 and DIN 2458 with normal tube sheet thickness shall not be used as tubes. Tubes require larger thicknesses.

Pipes according to DIN2391 and DIN 2393 may be used.

Fittings shall be marked by a red spot and the letter D.

A11.2 The gas installation pipework shall be earthed. If necessary, electrical connections Potential equalization conductors (e.g. regarding non-conductive pipe joints) between all pipes shall be provided or the installation shall be earthed at different points (auxiliary equipotential bonding).

Pipework have to be connected with the main equipotential bonding according to DIN VDE 0100, part 410 clause 413.1.2.1. The equipotential bonding has to be dimensioned in accordance with DIN VDE 0100, part 540. The cross section of the potential equalization conductor has to be at least as large as half of the cross section of the biggest protective grounding, at least 6 mm<sup>2</sup> Cu or equal conductance. Beyond that in Ex-areas an auxiliary equipotential bonding is needed according to DIN VDE 0165, clause 6.3. This equipotential bonding has to meet the requirements according to DIN VDE 0100, part 410, clause 413.1.2.2. The minimum cross section of the potential equalization conductors shall meet DIN VDE 0100, part 540, clause 9, at least 2,5 mm<sup>2</sup> Cu (if mechanically protected) or 4 mm<sup>2</sup> without mechanical protection.

*Notes:*

- *In ex-areas the national regulations have to be met*
- *Regarding lightning protection the national regulations have to be met.*

A11.3 Marking shall be in accordance with DIN 2403.

## Appendix B1 Extinguishing and design concentrations for HFC227ea

Fuel	C <sub>L</sub> Extinguishing concentration in Vol% HFC227ea		C <sub>D</sub> Design concentration in Vol% HFC227ea
	cup burner <sup>12</sup>	enclosure <sup>13</sup>	
Acetone	6.5	-	10.1
Ethanol	7.6	-	11.9
n-Heptane	6.6	6.8	8.8
Methanol	9.9	-	15.4
Toluene	5.1	-	8.0

**Table B1.1: flammable liquids**

Source of data: VdS

Extinguishing concentration: for Cup Burner determined on basis of measured oxygen concentrations, for room tests determined on basis of agent quantity, rounded on first decimal.

Design concentration: determined from the extinguishing concentration by use of appropriate design factor, rounded on first decimal.

Special equipment	C <sub>L</sub> Extinguishing concentration in Vol% HFC227ea	C <sub>D</sub> Design concentration in Vol% HFC227ea
Computer installations, EDP-rooms, electrical switch and distribution rooms <sup>1)</sup>		8,4 <sup>2)</sup>
Cable floors <sup>1)</sup>		8,4 <sup>2)</sup>
<sup>1)</sup> storage or processing of materials is not allowed. <sup>2)</sup> Note: corresponding to 95 % of design concentration of n-heptane. In appendix A9 testing methods for determining the extinguishing concentration for plastic objects (e.g. IT-rooms) are explained. If results of practical tests are available, the design concentrations in table B1.2 will be changed: extinguishing concentration is the maximum of four determined extinguishing concentrations of plastics and cables..		
<b>Table B1.2: Special equipment</b>		

Fuel	C <sub>L</sub> Extinguishing concentration in Vol% HFC227ea	C <sub>D</sub> Design concentration in Vol% HFC227ea
Wood crib	5,9 <sup>1)</sup>	<sup>2)</sup>
<sup>1)</sup> according to appendix A9. <sup>2)</sup> At this time there is no application foreseen. If in an exceptional case the extinguishing concentration shall be taken as basis for the design of an extinguishing installation, this is only allowed after agreement of the appropriate authority..		

<sup>12</sup> according to appendix A4

<sup>13</sup> according to appendix A9

<b>Table B1.3: Solid fuels</b>
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Source of data: VdS

Design concentration: determined from the extinguishing concentration by use of appropriate design factor, rounded on first decimal.

## Appendix B2 Extinguishing and design concentrations for FK-5-1-12

Material	C <sub>L</sub> Extinguishing concentration in Vol% FK-5-1-12		C <sub>D</sub> Design concentration in Vol% FK-5-1-12
	"cup burner" <sup>14</sup>	Enclosure <sup>15</sup>	
Acetone		-	
Ethanol		-	
n-Heptane	4.5 <sup>1)</sup>	4.7 <sup>2)</sup>	6.1
Methanol		-	
Toluene		-	

**Table B2.1: flammable liquids**

Source of data: <sup>1)</sup> CNPP, <sup>2)</sup> VdS

Extinguishing concentration: for Cup Burner determined on basis of measured oxygen concentrations, for room tests determined on basis of agent quantity, rounded on first decimal.

Design concentration: determined from the extinguishing concentration by use of appropriate design factor, rounded on first decimal.

Special equipment	C <sub>L</sub> Extinguishing concentration in Vol% FK-5-1-12	C <sub>D</sub> Design concentration in Vol% FK-5-1-12
Computer installations, EDP-rooms, electrical switch and distribution rooms <sup>1)</sup>		5,8 <sup>2)</sup>
Cable floors <sup>1)</sup>		5,8 <sup>2)</sup>
<sup>1)</sup> storage or processing of materials is not allowed. <sup>2)</sup> Note: corresponding to 95 % of design concentration of n-heptane. In appendix A9 testing methods for determining the extinguishing concentration for plastic objects (e.g. IT-rooms) are explained. If results of practical tests are available, the design concentrations in table B1.2 will be changed: extinguishing concentration is the maximum of four determined extinguishing concentrations of plastics and cables..		

**Table B2.2: Special equipment**

Fuel	C <sub>L</sub> Extinguishing concentration in Vol% FK-5-1-12	C <sub>D</sub> Design concentration in Vol% FK-5-1-12
Wood crib	3,5 <sup>1)</sup>	<sup>2)</sup>
PP	4,0 <sup>1)</sup>	<sup>2)</sup>
ABS	4,0 <sup>1)</sup>	<sup>2)</sup>
PMMA	4,1 <sup>1)</sup>	<sup>2)</sup>
<sup>1)</sup> according to appendix A9. <sup>2)</sup> At this time there is no application foreseen. If in an exceptional case the extinguishing concentration		

<sup>14</sup> according to appendix A4

<sup>15</sup> according to appendix A9

shall be taken as basis for the design of an extinguishing installation, this is only allowed after agreement of the appropriate authority..

**Table B2.3: Solid fuels**

Source of data: VdS

Design concentration: determined from the extinguishing concentration by use of appropriate design factor, rounded on first decimal.