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Condensed aerosol fire extinguishing systems — Requirements and test methods for components and system design, installation and maintenance — General requirements

Systèmes d'extinction d'incendie utilisant des aérosols — Exigences et méthodes d'essai pour la conception des composants et des systèmes, l'installation et l'entretien — Exigences générales

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

ISO 15779 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 8, *Gaseous media and firefighting systems using gas*.

Introduction

Firefighting systems covered in this International Standard are designed to provide a supply of condensed aerosol extinguishing medium for the extinction of fire.

Several different methods of supplying condensed aerosol extinguishant to, and applying it at, the required point of discharge for fire extinction have been developed in recent years, and there is a need for dissemination of information on established systems and methods. This International Standard has been prepared to meet this need.

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

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

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

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

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

It is essential that firefighting equipment be carefully maintained to ensure instant readiness when required.

Routine maintenance is liable to be overlooked or given insufficient attention by the owner of the system. It is, however, neglected at peril to the lives of occupants of the premises and at the risk of crippling financial loss. The importance of maintenance cannot be too highly emphasized. Installation and maintenance should only be carried out by qualified personnel.

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

Annex D deals with the tests for determination of the extinguishing application density and system performance and they are designed in such a way to allow individual installers to use his or her system and carry out all of the extinguishing tests. The tests presented in Annex D have been established to evaluate application densities suitable for the protection of Class A fires with wood crib fire tests and plastic fuel hazards such as may be encountered in information technology, telecommunications and process control facilities, as well as Class B fires with heptane pan and heptane can test fires in an enclosure of 100 m^3.

Condensed aerosol fire extinguishing systems — Requirements and test methods for components and system design, installation and maintenance — General requirements

1 Scope

This International Standard specifies requirements and test methods for components and gives recommendations for the design, installation, testing, maintenance and safety of condensed aerosol firefighting systems in buildings, plants or other structures, and the characteristics of the extinguishants and types of fire for which they are a suitable extinguishing medium. It covers total flooding systems primarily related to buildings, plant and other specific applications, utilizing electrically non-conducting condensed aerosol fire extinguishants for which there are sufficient data currently available to enable validation of performance characteristics by an appropriate independent authority.

Local applications of condensed aerosol extinguishing systems are not covered by this International Standard. Any local applications require a pre-engineered and pre-designed system which has been tested and approved for a specific application by a relevant authority.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3941, *Classification of fires*

EN 60068-2-6, *Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)*

EN 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db and guidance: Damp heat, cyclic (12h + 12h cycle)*

3 Terms and definitions

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

3.1
aerosol extinguishing agent
condensed aerosol
extinguishing medium consisting of finely divided solid particles, generally in the order of magnitude of microns in diameter suspended in gas generated and distributed by a combustion process of a solid aerosol-forming compound

3.2
aerosol generator
non-pressurized container which, when activated, generates a condensed aerosol extinguishing agent

NOTE The pressurized container system includes the mounting bracket(s).

3.3
aggressive environment
environment including the following or as defined by the appropriate authority:

a) exterior situations exposed to the sun, ultraviolet radiation, wind, rain, or salt spray;

b) corrosive atmospheres;

c) abnormally dusty or moisture-laden atmospheres;

d) extreme temperatures;

e) vibrations and shocks

3.4
approved
acceptable to a relevant authority

NOTE In determining the acceptability of installations or procedures, equipment or materials, the authority may base acceptance on compliance with the appropriate standards.

3.5
authority
organization, office, or individual responsible for approving equipment, installations or procedures

3.6
automatic
performing a function without the necessity of intentional human intervention

3.7
automatic/manual switch
means of converting the system from automatic to manual actuation

3.8
electrical clearance
unobstructed air distance between the aerosol generator components and unenclosed or uninsulated live electrical components not at ground potential

3.9
thermal clearance
air distance between a condensed aerosol generator and any structure or components sensitive to the temperature developed by the generator

3.10
competent person
designated person, suitably trained, qualified by knowledge and practical experience and with the necessary instructions, to enable the required tests and examinations to be carried out

3.11
coolant
heat-absorbing medium or process

3.12
design application density
extinguishing application density of extinguishant, including a safety factor, required for system design purposes

NOTE 1 The design application density may also be referred to as the design factor.

NOTE 2 Measured in g/m^3.

3.13
discharge time
time from the generator activation until the end of its discharge/extinguishing application density

NOTE Measured in g/m^3.

3.14
extinguishant
condensed aerosol extinguishing agent

3.15
extinguishing application density
effective minimum mass of discharged extinguishant per unit of enclosure volume required to extinguish fire involving a specific fuel under defined experimental conditions, using a specific aerosol generator type and size, excluding any safety factor

NOTE Measured in g/m^3.

3.16
family of condensed aerosol generators
range of generators designed with the same solid compound, the same kind of cooling device, discharge outlet, ignition device, layout and internal/external architecture (varying of mass of solid compound)

3.17
effective mass
mass of discharged extinguishant required to achieve the design application density within the protected volume within the specified discharge time

3.18
hold time
period of time during which an extinguishant is required to maintain at least the extinguishing application density to maintain even distribution throughout protected volume

3.19
hot work
grinding, welding, thermal or oxygen cutting or heating and other related heat-producing or spark-producing operations

3.20
ignition device
device which is able to ignite the solid aerosol-forming compound

3.21
inspection
visual examination to give reasonable assurance that the extinguishing system is fully charged and operable and has not been activated or tampered with, and that there is no obvious physical damage or condition to prevent operation

3.22
location drawing
layout diagram of protected volume clearly indicating the as-installed location of all aerosol generators, controls, maintenance isolate switch (lock-off devices), and associated components of the systems

3.23
lock-off device
lockable manual shut-off device that prevents the electrical actuation of aerosol generators

NOTE 1 The lock-off device may be in the form of a lockable system isolate switch.

NOTE 2 The actuation of this device provides an indication of system isolation.

NOTE 3 The intent is to prevent the discharge of agent into the hazard area when the lock-off device is activated.

3.24
lowest observed adverse effect level
LOAEL
lowest agent factor at which an adverse toxicological or physiological effect has been observed

3.25
listed
systems or components that are included in a list published by a listing authority organization

3.26
listing organization
internationally recognized fire protection system or components test and certification organization

NOTE Examples of these organizations are: Factory Mutual (FM); Underwriters Laboratories (UL/ULC); Loss Prevention Certification Board (LPCB); VdS Schadenverhütung; All-Russia Scientific Research Institute for Fire Protection (VNIIPO).

3.27
maintenance
thorough check to give maximum assurance that the extinguishing system will operate as intended

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

3.28
manual
requiring intentional intervention to accomplish a function

3.29
manufacturer
entity that is responsible for the design, manufacturing, packaging and quality assurance of a device before it is placed on the market

3.30
mass median aerodynamic diameter
MMAD
particle size and distribution of any aerosol statistically, based on the weight and size of the particle, along with the geometric standard deviation

NOTE Fifty percent of the particles by weight will be smaller than the median diameter and fifty percent of the particles will be larger (US EPA Health Effects Test Guidelines OPPTS 870.1300 Acute Inhalation Toxicity, August 1998).

3.31
monitoring
supervision of the operating integrity of an electrical, mechanical, pneumatic or hydraulic control feature of a system

3.32
no observed adverse effect level
NOAEL
highest agent factor at which no adverse toxicological or physiological effect has been observed

3.33
normally occupied area
area that is occupied by persons, under normal circumstances

3.34
particulate concentration
concentration of the solid fraction of the aerosol in the protected space after system discharge at the design application density

NOTE 1 Measured in g/m^3.

NOTE 2 This information is necessary to assess the potential health effects of accidental exposure to the agent in occupied spaces, and the potential degree of visibility obscuration.

3.35
release
physical discharge or emission of aerosol as a consequence of the aerosol generator's actuation

3.36
safety factor
multiplier of the extinguishing application density to determine the aerosol design application density

3.37
solid aerosol-forming compound
mixture of oxidant, combustible component and technical admixtures producing fire extinguishing aerosol upon ignition

3.38
supplier
entity that is responsible for the product and is able to ensure that its quality is ensured

3.39
system isolate switch
manually operated switch located at each entrance to the protected area, electrically supervised and secured from unauthorized use which prevents the automatic or manual electrical activation of the condensed aerosol generators by electrically opening the released circuit

3.40
total flooding system
firefighting system arranged to discharge extinguishant into an enclosed space to achieve the appropriate design application density factor

3.41
unoccupiable area
area which cannot be occupied due to dimensional or other physical constraint requiring intentional intervention to accomplish a function

NOTE Examples of unoccupiable areas are shallow voids or cabinets.

3.42
user
entity whom the system is designed for, and who is responsible for operation and to ensure the consistency of performance as described by the supplier and to follow the legal regulations

4 Use and limitations

4.1 General

This International Standard sets out requirements for the design, installation, service and maintenance of aerosol systems used as fire extinguishing media for total flooding applications. This International Standard also covers performance requirements and methods of testing for aerosol generators or storage containers and associated components. The design, installation, service and maintenance of aerosol fire-extinguishing systems shall be performed by those competent in fire extinguishing system technology.

4.2 Aerosol agent description

4.2.1 Condensed aerosol

Condensed aerosol consists of finely divided solid particles typically based on alkali metal salts and gases typically comprised of nitrogen, carbon dioxide and water vapour.

Condensed aerosol is not stored in a container. It is self-generated by a combustion process of a solid aerosol-forming compound contained in a non-pressurized canister, an aerosol generator. Aerosol generators also contain an actuation device(s) designed to ignite the aerosol-forming compound and may have various cooling arrangements to cool the aerosol prior to its release into a protected area.

The aerosol generating combustion process provides sufficient energy for a rapid discharge and efficient distribution of the aerosol. No propelling gas is required for the aerosol delivery. An aerosol generator has one or more discharge outlets and is normally placed inside the protected risk area. No piping is required.

4.2.2 Physical characteristics

Aerosols are electrically non-conductive gas-like media, which are suspended in the air in the protected volume.

Being a suspension of fine solid particles in a gaseous medium, the aerosol is not a clean agent. Following actuation of an aerosol generator there is a period of time during which the aerosol remains suspended within the enclosure; if the enclosure is not ventilated, the aerosol suspension will eventually settle down, forming a dust-like residue, normally in a very small quantity.

4.2.3 Extinguishing mechanism

Aerosols extinguish fires by:

a) chemical interference by removing the reactive free radicals;

b) physically cooling the seat of the fire; or

c) reducing the concentration of oxygen by introducing inert gas.

Generally, an aerosol generator will primarily use two of the three mechanisms.

For aerosol generators that produce particulates, the chemical and cooling mechanisms take place mainly on the surface of the solid aerosol particles, and therefore, the finer the particles, the more effective the extinguishing mechanism.

For aerosol generators that produce inert gas and water vapour, these inert gases displace air, reducing the amount of oxygen available for combustion. The combustion is then cooled to the point of extinguishment as heat is transferred to the water.

4.3 Application

Aerosol extinguishants are recognized as suitable for suppression of Class A and Class B fires.

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

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

a) electrical and electronic hazards;

b) telecommunications facilities;

c) flammable and combustible liquids and gases.

Where aerosol generators are used in a potentially explosive application, the suitability of the generator to the atmosphere for the determined life shall be assessed. Thus, aerosol generators shall be constructed such that they do not cause fire or explosion when actuated. Aerosol generators may be used in hazardous areas subject to the manufacturer obtaining the specific listings and approvals for such areas from the appropriate authorities having jurisdiction.

CAUTION — Aerosol extinguishing systems are intended for the types of fire for which they are a suitable extinguishing medium. The end user should consider the potential adverse effects of aerosol extinguishing agent discharge residue on sensitive equipment and other objects.

4.4 Limitation of use

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

a) chemicals containing their own supply of oxygen, such as cellulose nitrate;

b) mixtures containing oxidizing materials, such as sodium chlorate or sodium nitrate;

c) chemicals capable of undergoing autothermal decomposition, such as some organic peroxides;

d) reactive metals (such as sodium, potassium, magnesium, titanium and zirconium), reactive hydrides, or metal amides, some of which may react violently with some aerosol extinguishants;

e) oxidizing agents such as nitric oxides and fluorine;

f) pyrophoric materials such as white phosphorous or metallo-organic compounds.

The above list may not be exhaustive.

4.5 Electrostatic discharge

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

4.6 Potentially explosive atmosphere

Under certain conditions, the potential for explosive atmospheres may exist. Areas where such potential may exist are classified as hazardous. Condensed aerosols may be used in hazardous areas subject to the manufacturer obtaining the specific listings and approvals for such areas from the appropriate authorities.

4.7 Temperature limitations

All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation.

Devices shall normally be designed to function properly from –20 °C to +75 °C, or marked to indicate temperature limitations, or in accordance with manufacturers' specifications which shall be marked on the name-plate, or (where there is no name-plate) in the manufacturer's instruction manual.

For condensed aerosols, special care shall be taken to determine the maximum ambient temperature at which the aerosol generator can be installed, without risk of actuation by temperature itself.

Condensed aerosol generators shall not be employed at less than the minimum thermal clearance distances specified in the manufacturer's instruction manual.

4.8 Compatibility with other extinguishants

Mixing of extinguishants in the same container shall be permitted only if the system is approved for use with such a mixture. Systems employing the simultaneous discharge of aerosols and other extinguishants to protect the same enclosed space shall not be permitted.

4.9 Environmental

When selecting an extinguishing system or agent to protect a hazard area, the effects of the agent on the environment shall be considered.

5 Safety

5.1 General

Any hazard to personnel created by the actuation and discharge of the condensed aerosol extinguishing system shall be considered in the design of the system with reference to the hazards associated with particular aerosol extinguishants. When selecting an aerosol extinguishant, careful consideration should be given to independent occupational health and safety data.

Potential hazards of aerosol extinguishing systems include noise, reduced visibility, high or low temperature, turbulence, potential toxicity, and skin or eye irritation to persons in the protected space and other areas where the aerosol may migrate. For additional information see Annex B.

Determination for use of an agent in spaces that are normally occupied, normally unoccupied, or unoccupiable shall be based on an evaluation of the adverse effects(s) caused due to accidental exposure to the agent. Potential adverse health effects shall be assessed for the particulate concentration, the size of the particulates (i.e. the mass median aerodynamic diameter), and the concentration of gases expected after actuation of the aerosol extinguishing system at the concentration design density.

In any proposed use of condensed aerosol where there is a possibility that people may enter the protected enclosure or be close to the protected risk, suitable safeguards such as personnel training, warning signs, pre-discharge alarms and system isolate switches shall be provided. Means of ventilation after fire should be readily available.

Unnecessary exposure to a condensed aerosol shall be avoided.

Following the use of a condensed aerosol, personnel should not enter the protected area until it has been thoroughly ventilated. Venting of the post-fire atmosphere should be to an open-air area, where possible, to prevent the inadvertent exposure of personnel to any combustion products of the fire and aerosol-generating reaction. In case of fire involving unknown products it is imperative to check the concentration of carbon monoxide and other potentially toxic gases before entering the premises.

Following a system discharge, the aerosol that has settled should be removed in accordance with the manufacturer's recommendations. Protective clothing including gloves and goggles should be worn. A respirator or mask may be required.

Adherence to this International Standard does not remove the user's statutory responsibility to comply with the appropriate safety regulations.

In order to assess the potential human health effects manufacturers should conduct the toxicity testing for use. This requires direct toxicity assessment on the aerosol after discharge of the system at the maximum design factor.

5.2 Toxicity

5.2.1 General

No fire suppression extinguishant shall be used which is carcinogenic, mutagenic or teratogenic at the design concentration density expected during use.

5.2.2 Condensed aerosols

Condensed aerosol extinguishing systems for normally occupied areas are permitted where the aerosol particulate concentration does not exceed the adverse effect level as determined by a scientifically accepted technique (see Annex B). Any gases produced as a result of the aerosol-forming reaction shall not exceed the appropriate excursion limit for the critical toxic effect.

When activated, condensed aerosol generators may produce toxic levels of gases such as carbon monoxide, nitrogen oxides and ammonia, which are typical by-products of the aerosol generating reaction. Actual concentrations of these by-products depend on the chemical compositions of the solid aerosol-forming compound and coolant, engineering design of the aerosol generators and conditions of the enclosure under protection. Maximum allowable exposure to a design factor of the aerosol under conditions of a sealed enclosure shall be provided for each agent by its manufacturer. Any possible adverse effects on humans that may be experienced at the indicated allowable exposures should be described. The information shall be supported by the appropriate test results on chemical composition of the aerosol and its short-term "acute" adverse effects. The results shall be endorsed by an independent testing laboratory having an appropriate authority.

5.3 Reduced visibility

5.3.1 General

All aerosol extinguishing agents reduce visibility, some more than others. Annex B contains guidance in assessing visibility levels for aerosol extinguishing agents.

5.3.2 Safety precautions

Safety precautions such as personnel training, goggles, audio devices, floor mounted directional lighting, evacuation plans and exit drills shall be included in the operational plan for the occupancy.

5.4 Turbulence

Turbulence caused by high-velocity discharge from the condensed aerosol generator may be enough to dislodge substantial objects directly in its path, such as ceiling tiles and light fittings. Therefore, tiles and light fittings should be properly secured. Aerosol discharge may also cause enough general turbulence to move unsecured paper and light objects.

5.5 Thermal hazards

5.5.1 Minimum thermal clearance

Condensed aerosol generators shall not be employed at less than the minimum thermal clearance as specified in the listing of the product.

For locations where personnel may be situated, the minimum thermal clearance shall refer to the temperature not exceeding 75 °C.

For locations where combustible materials or equipment may be situated, the minimum thermal clearance shall refer to the temperature not exceeding 200 °C.

For locations where non-combustible materials or equipment may be situated, the minimum thermal clearance shall refer to the temperature not exceeding 400 °C.

5.5.2 Removal of discharged generators

Protective gloves shall be worn when removing discharged condensed aerosol generators immediately after discharge.

5.5.3 Hot work

As open flame or prolonged exposure to temperatures exceeding 400°C may cause activation of the condensed aerosol generators, they shall be removed from a protected area prior to any hot work being carried out within their vicinity.

5.5.4 Casing temperatures for condensed aerosol generators

The manufacturer shall indicate the maximum temperature of the condensed aerosol generator casing during system discharge.

5.6 Safety precautions

5.6.1 General

In any proposed use of aerosol where people may enter the protected enclosure or be close to the protected risk, suitable safeguards such as personnel training, warning signs, pre-discharge alarms and system isolate switches shall be provided. Means of ventilation after fire should be readily available.

5.6.2 Specific requirements

The following general safety aspects shall apply for areas protected by the aerosol systems and which are capable of being occupied:

a) Time delay devices:

   1) a pre-discharge alarm shall be incorporated with a time delay sufficient to allow evacuation of personnel prior to discharge;

   2) time delay devices shall be used only for evacuation of personnel or to prepare the hazard area for discharge;

   3) in the event of failure of the pre-discharge alarm and time delay, means should be provided to limit exposure to agents approved for use in normally occupied areas to no longer than five minutes. The effect of reduced visibility on egress time shall be considered.

b) Exit routes, which shall be kept clear at all times, and emergency lighting and adequate direction signs to minimize travel distances for areas which may be occupied.

c) Outward-swinging self-closing doors which can be opened from the inside, including when locked from the outside.

d) Continuous visual and audible alarms at entrances and designated exits inside the protected area and continuous visual alarm outside the protected area which operate until the protected area has been made safe.

e) Appropriate warning and instruction signs.

f) Where required, pre-discharge alarms within such areas that are distinctive from all other alarm signals that will operate immediately upon detection of the fire.

g) Means for prompt natural or forced-draft ventilation of such areas after any discharge of extinguishant. Care should be taken to completely dissipate hazardous atmospheres and not just move them to other locations.

h) Instructions and drills for all personnel within or in the vicinity of protected areas, including maintenance or construction personnel who may be brought into the area, to ensure they take proper action when the system operates. Personnel shall not re-enter the enclosure until it has been verified as being safe to do so.

In addition to the above requirements, is it recommended that a self-contained breathing apparatus be supplied and personnel trained in its use.

5.7 Electrical hazards

Where exposed electrical conductors are present, electrical clearances no smaller than those given in Table 1 shall be provided, where practicable, between the electrical conductors and all parts of the system that may be approached during maintenance. Where these clearances cannot be achieved, warning notices shall be provided and a safe system of maintenance work shall be adopted.

The system should be so arranged that all normal operations can be carried out safely by the operator.

Table 1 — Required electrical clearances to enable operation, inspection, cleaning, repairs, painting and normal maintenance work to be carried out

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

[a] Measured from position of the feet.

[b] The term “insulator” includes all forms of insulating supports, such as pedestal and suspension insulators, bushings, cable sealing ends and the insulating supports of certain types of circuit breaker.

5.8 Electrical earthing

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

5.9 Electrostatic discharge

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

6 Extinguishant

6.1 General

This clause sets out the requirements for the extinguishant concentrations. In the future, additional parts of this International Standard may be developed covering different types of extinguishing systems.

6.2 Design application density requirements

6.2.1 Fire classification

For fire classifications, see ISO 3941.

6.2.2 Class B fire

The minimum Class B design application density for each extinguishant shall be a demonstrated minimum extinguishing application density for each Class B fuel multiplied by a safety factor of 1,3. The minimum extinguishing application density used shall be that demonstrated by the minimum extinguishing application density fire test (D.6.2 pan fire test).

Procedures using heptane in the fire extinguishment/area coverage fire test procedure are detailed in D.6.1 and D.6.2. For hazards involving multiple fuels, the value for the fuel requiring the greatest design application density shall be used.

6.2.2.1 Minimum Class B design application density

The minimum design application density for Class B fires shall be the highest (extinguishing) application density derived from n-heptane pan test (D.6.2) and generator distribution tests (D.5.1 and D.5.2) multiplied by a 1,3 safety factor (see 7.3.1).

6.2.3 Class A solid burning surface fire

The minimum extinguishing application density for Class A surface fires shall be determined by test using the fire test procedure described in D.6.3 (Polymeric sheet fire tests) and D.6.4 (Class A compatible wood crib test). The minimum design application density for Class A surface fires shall be the highest extinguishing concentration density determined from the results of four test scenarios times a safety factor of 1,3.

6.2.3.1 Minimum Class A solid surface burning design application density

The minimum design application density for Class A fires solid surface burning design application density shall be the highest (extinguishing) application density derived from the wood crib test (D.6.1), polymeric sheet tests (D.6.3) and the Class A compatible wood crib test (D.6.4). This application would be adjusted to account for the generator distribution by multiplying by the ratio of the n-heptane pan application density to the distribution test application density. A safety factor of 1,3 would also be applied (see 7.3.1).

6.2.4 EDP (electronic data processing) rooms, telecommunication and electronic risks

It is recognized that the wood crib and polymeric sheet Class A fire tests may not adequately indicate extinguishing concentrations suitable for the protection of certain plastic fuel hazards (e.g. electrical and electronic type hazards involving grouped power or data cables such as computer and control room under-floor voids, telecommunication facilities, etc.). An extinguishing concentration not less than that determined in accordance with 6.2.3, or not less than that determined from the heptane fire test described in D.6.2, whichever is the greater, should be used under certain conditions. These conditions may include:

a) cable bundles greater than 100 mm in diameter;

b) cable trays with a fill density greater than 20 % of the tray cross-section;

c) horizontal or vertical stacks of cable trays (closer than 250 mm);

d) equipment energized during the extinguishment period where the collective power consumption exceeds 5 kW.

NOTE Where electrical equipment shut down is delayed, higher concentrations, longer hold times, or other fire protection systems can be considered.

6.2.4.1 Minimum EDP rooms telecommunication and electronic risks application density

The minimum design application density for EDP rooms telecommunication and electronic risks design application density shall be the highest (extinguishing) application density derived from polymeric sheet test (D.6.3) and the Class A compatible wood crib test (D.6.4). This application would be adjusted to account for the generator distribution by multiplying by the ratio of the n-heptane pan application density to the distribution test application density. A safety factor of 1,3 would also be applied.

6.3 Aerosol generator performance requirements

6.3.1 General

This clause sets out requirements for the aerosol generator container's performance.

6.3.2 Distribution coverage

6.3.2.1 Condensed aerosol generators

The maximum area coverage and the maximum and minimum protected area height limitations for each condensed aerosol generator unit size shall be determined by the fire extinguishment/area coverage fire test procedure as described in D.5.1 and D.5.2.

6.3.3 Effective discharge

Discharge time shall be specified by the manufacturer and shall not exceed 90 s.

Aerosol containers and released aerosols shall not cause fire or explosion during actuation and discharge. The minimum thermal clearances from the condensed aerosol generator's discharge outlet(s) for 75 °C, 200 °C and 400 °C shall be specified in the product listing. Refer to 7.5.2 for requirements on minimum thermal clearances.

Parameters of the aerosol discharge shall be verified by the test procedure as described in Annex C.

6.3.4 Ambient temperature and humidity operation range

Aerosol containers shall be operable for the total service live period within temperature and humidity range specified by the manufacturer and listed by approval agencies.

The temperature operation range shall be verified by the accelerated aging test procedure as described in Annex C. The humidity operation range shall be verified by the temperature and humidity operation range tests as described in Annex C.

6.3.5 Service life

The service life period includes the storage and installation life period for the product. Aerosol containers shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation. The service life of aerosol containers for typical applications shall be specified by the manufacturer and listed by approval agencies.

The specified service life shall be verified by the accelerated aging test procedure as described in Annex C.

6.3.6 Vibration and shock resistance

The aerosol container and its mounting bracket shall withstand the vibration and shock resistance tests as described in Annex C.

6.3.7 Corrosion

The aerosol container and its mounting bracket shall withstand the corrosion test as described in Annex C.

6.3.8 Impact

The packaged condensed aerosol generator shall not be a disposal hazard after the impact (drop test) as described in Annex C.

6.3.9 Actuation element

The technical characteristics and actuation processes shall be specified by the manufacturer for all types of actuation devices incorporated in the aerosol container.

6.3.10 Exposure to fire

Aerosol containers intended for installation inside the protected enclosure shall be tested for reliability of operation and effectiveness of the discharge under the heat exposure conditions by the test procedure as described in Annex C.

6.4 Marking

Manufacturers shall put a permanent name-plate or other permanent marking specifying the following on each aerosol container:

a) extinguishant trade name;

b) manufacturer;

c) date of manufacture;

d) serial number;

e) mass of aerosol forming compound.

For condensed aerosols, installers shall attach a durable metallic tag to each aerosol generator indicating the installation date, and the expiration date. Installation life (from installation to expiration date) for condensed aerosol generators depends on the specific application and the installation environment (based on expected conditions of operation, e.g. temperature and humidity).

7 Specifications, plans and approvals

7.1 Specifications

Specifications for condensed aerosol fire extinguishing systems shall be prepared under the supervision of a person fully experienced in the design of aerosol extinguishing systems and, where appropriate, with the advice of the authority. The specifications shall include all pertinent items necessary for the proper design of the system such as the designation of the authority, variances from the standard to be permitted by the authority, design criteria, system sequence of operations, the type and extent of the acceptance testing to be performed after installation of the system, owner training requirements and working documents as defined in A.2. The specification shall also include mounting parts for the generator.

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

7.2 Enclosure

7.2.1 Venting and structural strength

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

A calculation method or formula to estimate a minimum vent area shall be provided by a systems manufacturer. Type and location of pressure relief vents shall ensure maximum possible containment of the agent during and after its discharge.

7.2.2 Loss of extinguishant to adjacent hazards

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

7.2.3 Forced-air ventilating systems

Forced-air ventilating systems shall be shut down or closed automatically where their continued operation would adversely affect the performance of the fire-extinguishing system or result in propagation of the fire. Ventilation systems necessary to ensure safety are not required to be shut down upon system activation. An extended extinguishant discharge shall be provided to maintain the design concentration for the required duration of protection. The volumes of both ventilated air and the ventilation system ductwork shall be considered as part of the total hazard volume when determining extinguishant quantities. All services within the protected enclosure (e.g. fuel and power supplies, heating appliances, paint spraying) that are likely to impair the performance of the extinguishing system shall be shut down prior to, or simultaneously with, the discharge of the extinguishant.

7.2.4 Venting requirements

When an aerosol is discharged into a closed volume, a significant overpressure may be developed due to the amount of gases generated and the effects of increased temperature on the atmosphere.

Later, the combined volume of aerosol and air will become greater than the initial room volume. The final result will increase the pressure or will exhaust the excess volume through vent openings. The air temperature is increased during the discharge but will return to normal levels as heat is adsorbed from solid surfaces in the room.

The designer/installer shall provide reliable calculations for venting requirements for each system if applicable.

7.3 Total flooding quantity

7.3.1 General

The effective mass of aerosol in the system shall be at least sufficient for the largest single hazard or group of hazards that are to be protected against simultaneously.

The mass of extinguishant required to achieve the design application density shall be calculated from Equation (1):

$$m = \rho \times V \quad (1)$$

where

m is the total flooding quantity, in g;

ρ is design application density, in g/m^3 (may need to be adjusted to compensate for any special conditions that would adversely affect the extinguishing efficiency, see 7.4);

V is protected volume, in m^3 (may include adjacent connected hazards or work areas).

The design application density is to be specified by the manufacturer in the design manual.

In addition to these calculated total flooding quantities, additional quantities of extinguishant may be required by national standards to compensate for any special conditions that would adversely affect the extinguishing efficiency or, if required, by the physical characteristics of the extinguishant.

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

7.3.2 Safety factor

The safety factor of 1,3 relates to the increase of 30 % from the extinguishing application density to the design application density, which results in additional quantity of extinguishant. Circumstances which may not be adequately covered by this factor (although in some cases they are covered by other requirements in this

International Standard) and which may need allowance for additional extinguishant (i.e. more than 30 %) are included but not limited to the following:

a) Where leakage occurs from a non-tight enclosure.

b) Where leakage occurs due to doors being opened during or immediately after discharge. This should be covered by operational protocols for individual risks.

c) Where excessive leakage occurs from an enclosure due to expansion of the extinguishant.

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

WARNING — The additional extinguishant required to compensate for one of the above-mentioned circumstances may increase potential inhalation toxicity of the aerosol. Care should be taken to prevent any possibility of exposure by personnel to the high initial concentration of the aerosol.

7.4 Design application density adjustment

7.4.1 Effects of altitude

The design calculations of the extinguishant shall be adjusted to compensate for ambient pressures that vary by more than 11 % (equivalent to approximately 1 000 m of elevation change) from standard sea level pressure (101 300 Pa absolute). The ambient pressure is affected by changes in altitude, pressurization or depressurization of the protected enclosure, and weather-related barometric pressure changes.

7.4.2 Effects of temperature

Temperature, as with altitude, has no effect on condensed aerosol design factor calculations, but it affects the extinguishants spatial distribution.

At elevated temperatures, aerosol expands to a greater specific volume. A system designed for standard conditions will therefore develop, at the same design factor, a higher distribution at elevated temperatures. Reduction in quantity of extinguishant is, however, not recommended, as it may result in lower extinguishant performance.

At lower temperatures, aerosol may expand to a lesser specific volume. This may result in lower coverage compared to that achieved under standard temperature conditions. The likelihood of this should be low due to a high velocity and the elevated temperature of aerosol being released.

At temperatures below zero, the quantity indicated at room temperature shall be increased to compensate for a lower coverage. Design factor determined at room temperature shall be multiplied by a correction factor determined by the manufacturer and included in the design manual.

7.4.3 Effects of ventilation

All ventilation systems should be shut down prior to the actuation of the condensed aerosol system.

However, the possibility of aerosol discharge into an enclosure that is ventilated should also be considered. In such enclosures, some extinguishant will be lost with the ventilating air. Assuming that ventilation must continue during and after discharge, a greater amount of extinguishant is required to develop a given design factor.

Also, to maintain the design factor at a given level requires continuous extinguishant discharge for the duration of the holding period.

The designer/installer shall provide reliable calculations for each system if applicable.

7.4.4 Compensation for leakage through enclosure openings

The designer/installer shall provide reliable calculations for the design application density necessary to compensate for any leakage through unclosable openings.

7.5 Unit size and quantity of aerosol generators

7.5.1 Maximum or minimum protected height limitations

The selected unit sizes shall comply with the maximum distance and area coverage and maximum or minimum protected height limitations as specified for each unit. The maximum and minimum height and coverage distance for each unit size of the aerosol generators are determined by area coverage fire tests as described in Annex D.

7.5.2 Minimum thermal clearance

The selected unit sizes shall be appropriate for the protected area in terms of the minimum thermal clearance from the discharge outlets. If the protected area is congested or contains temperature-sensitive equipment, it would be appropriate to select several smaller units that require less minimum clearance although one large unit may be adequate in terms of achieving the required design quantity.

The following general criteria should apply:

— for locations where personnel may be situated, the minimum thermal clearance shall refer to a temperature not exceeding 75 °C;

— for locations where combustible materials or equipment may be situated, the minimum thermal clearance shall refer to a temperature not exceeding 200 °C;

— for locations where non-combustible equipment may be situated, the minimum thermal clearance shall refer to a temperature not exceeding 400 °C.

7.5.3 Several smaller units versus few large units

In some applications such as cable ducts and trenches, several smaller units of the same family evenly spread along the protected enclosure would provide better distribution and faster achievement of the minimum design density throughout the area although one large unit may fulfill the agent quantity requirement.

7.5.4 Mounting locations

Certain protected enclosures may have very specific permissible mounting locations. This may influence the quantity and size of the units selected.

7.5.5 Quantity of aerosol generators

7.5.5.1 General

Quantity of aerosol generator’s units needed to protect a room may be increased in order not to exceed maximum coverage distance.

7.5.5.2 Same unit size

$$n = \left[\frac{m}{m_{\mathrm{g}}} \right] \qquad (2)$$

where

n is the rounded-up integer number of aerosol generators of one size;

m is the design application density, in grams;

m_{g} is the effective mass of aerosol in one generator, in grams.

7.5.5.3 Different unit size

If different sizes of aerosol generators should be selected, the total mass of extinguishant shall be not less than the design quantity. If the different sizes have different design application densities, this has to be taken into account.

The height of the protected enclosure shall not exceed the maximum height limitation listed for the smallest unit size selected, unless uniformity of the aerosol distribution for the greater height has been proved by a discharge test.

7.5.6 Multiple generator systems

In case of the need of more than one aerosol generator to protect a volume, generators of the same family shall be used.

7.6 Operating conditions

In-service operating conditions, such as temperature, humidity and vibration, shall be within ranges specified by the manufacturer and as listed by a listing authority for a specific aerosol extinguishant (see also 6.4).

7.7 Duration of protection

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

It is essential to determine the likely period during which the extinguishing concentration will be maintained within the protected enclosure. This is known as the hold time.

Due to the specific characteristics of the extinction process of condensed aerosols that primarily produce particulates, no method is known to evaluate the hold time in real installations, other than real discharge which is not practical. For this reason, a specific test is required for each aerosol formulation to determine the maximum leakage area to volume ratio that provides for the minimum hold time declared by the manufacturer. For condensed aerosols that produce particulates participating in the extinction process, the approach for determining hold time is detailed in Annex D. For condensed aerosols that produce only gases (i.e. do not generate particulates participating in the extinction process), an alternative approach detailed in Annex E of ISO 14520-1:2006 may be used, based on the density of the mixture of gases produced.

The leakage area for a specific room can be determined as the ELA value obtained with the door fan test described in Annex E of ISO 14520-1:2006 . The details of the test to determine the area/volume ratio are given in D.7.

To ensure the protection is adequate in terms of hold time, the following comparison must be fulfilled:

$$\frac{ELA}{Vroom} \leq \text{leakage area to volume ratio (D.7).}$$

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

As the application density of a condensed aerosol cannot be measured directly by a gas analysis technique, other physical properties proportional to the application density, such as optical transmittance, could be measured providing the adequate calibration between such property and the design application density can be effected. The measuring technique, procedure and calibration method shall be listed or approved by an appropriate authority.

7.8 System discharge

7.8.1 Discharge time

The discharge time shall not exceed 90 s from the actuation or as otherwise accepted by the authorities.

7.8.2 Effectiveness of discharge

The system design shall be such that:

a) the design concentration is achieved in all parts of enclosure;

b) the discharge does not cause fire or explosion;

c) the discharge does not unduly splash flammable liquids.

7.8.3 Thermal clearance

In order to minimize the potential heat damage to the enclosure or its contents during discharge of the condensed aerosol generators, minimum thermal clearance from the discharge outlet(s) shall be observed as specified for the selected size of the condensed aerosol generator and as appropriate for the protected contents. Consideration shall also be given to the maximum casing temperature in relation to the heat sensitivity of the mounting and adjacent surfaces.

7.8.4 Extended discharge

Where an extended discharge is necessary, the duration shall be sufficient to maintain the design density concentration for the required hold time.

7.9 Detection, actuation and control systems

7.9.1 General

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

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

Unless otherwise specified in a national standard, 72 h minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control and actuation requirements of the system.

7.9.2 Automatic detection

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

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

7.9.3 Operating devices

7.9.3.1 Automatic operation

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

Electrically operated fire detection systems shall comply with the appropriate national standard. The electric power supply shall be independent of the supply for the hazard area, and shall include an emergency secondary power supply with automatic changeover in case the primary supply fails.

Because an aerosol extinguishant is a smoke-like medium in itself, release of the aerosol may cause unwanted activation of smoke detectors in adjacent areas.

When two or more detectors are used, it is preferable for the system to operate only after signals from both types of detectors have been received.

7.9.3.2 Manual operation

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

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

a) one or more means, remote from the aerosol generator containers, of manual operation; or

b) a manual device for providing direct mechanical actuation of the system; or

c) an electrical manual release system in which the control equipment monitors for abnormal conditions in the power supply and provides a signal when the power source is inadequate.

Manual operation shall cause normal operation of the generators as specified by the manufacturer.

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

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

NOTE 2 The choice of the means of operation depends upon the nature of the hazard to be protected. Automatic fire detection and alarm equipment is normally provided on a manual system to indicate the presence of a fire.

7.9.4 Electric control equipment

Electric control equipment shall be used to supervise the detecting circuits, manual and automatic releasing circuits, signaling circuits, electrical actuating devices and associated wiring and, when required, cause actuation.

The control equipment shall be capable of operation with the number and type of actuating devices utilized.

7.9.5 Operating alarm indicators

7.9.5.1 Alarms and indicators

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

7.9.5.2 Audible and visual pre-discharge alarms

Audible and visual pre-discharge alarms shall be provided within the protected area to give positive warning of impending discharge. The pre-discharge alarms shall operate immediately on commencement of time delay upon detection of fire or manual operation of the system. The operation of the warning devices shall be continued after extinguishant discharge, until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

7.9.5.3 Alarms indicating failure

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

7.9.6 System isolate switch

The discharge of electrically operated aerosol generators in total flooding applications in areas where people may be present shall be capable of being excluded by means of a system isolating switch.

For systems not compatible with occupied spaces, the system isolate shall be manually operated prior to personnel entering the protected space or adjacent areas which could be rendered hazardous by the discharge of extinguishant.

The system isolate switch shall be situated outside the protected area or adjacent to the main exit from the area and protected from an accidental operation.

While the system isolate switch is active and the discharge of the system is inhibited, the fire detection and alarm systems shall continue to function and the system shall return to its operation control when the device is reactivated.

The operation of the system isolate switch shall activate an indicator at the fire panel to ensure that the generators cannot be operated.

8 Commissioning and acceptance

8.1 General

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

8.2 Tests

8.2.1 General

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

WARNING — A system isolate switch shall be operated prior to entering the protected enclosure.

8.2.2 Enclosure check

8.2.2.1 Determine that the protected enclosure is in general conformance with the plans. The actual enclosure volume and dimensions shall be checked against the protected volume calculations specified in the system design. Fan rundown and damper closure time shall be taken into consideration.

8.2.2.2 All total flooding systems shall have the enclosure checked to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified extinguishant concentration level for the specified holding period.

8.2.2.3 Should pressure relief vents be designed for the application, determine that the effective total vent area is in conformance with the design calculations. Ensure that the type and location of the vents are in accordance with the design recommendations so as to provide maximum possible containment of the aerosol during and after its discharge.

8.2.3 Review of design calculations

8.2.3.1 The type of enclosure occupancy (occupied, normally unoccupied or unoccupied) shall be checked against that indicated in the design documentation.

8.2.3.2 The actual enclosure volumes shall be checked against those indicated in the design documentation.

8.2.3.3 The fire hazards (classes of fires) shall be checked against those indicated in the design documentation. The selected design application value shall be appropriate for the hazard. In case of multiple fire hazards the greatest design application shall be used.

8.2.3.4 An adequate quantity of extinguishant to produce the design application density shall be provided. Total flooding quantity shall be appropriate for the actual protected volume.

8.2.3.5 Operation temperature range, humidity and other expected ambient conditions shall be checked for compliance with those permissible by the manufacturer.

8.2.4 Review of the mechanical components of condensed aerosol generators

a) The number and unit size(s) of the aerosol generators shall be checked for conformance to the design calculations. The number shall be adequate to produce the specified total flooding quantity. The unit size(s) shall be appropriate in relation to maximum height and area coverage limitations.

b) Orientation of the generators should be in such a manner that optimum extinguishant dispersal and containment can be effected.

c) The aerosol generators shall be installed in such a manner that they will not potentially cause injury to personnel. Extinguishant shall not directly impinge on areas where personnel may be found in the normal work area, or on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

d) Minimum thermal clearances from the discharge outlet(s) shall be checked against those specified in the design documentation for the type of the enclosure occupancy, equipment and materials present in the enclosure.

e) The aerosol generators and mounting brackets shall be securely fastened in accordance with the manufacturer's requirements. Specified mounting brackets or supports shall be used for each unit size of the aerosol generator.

8.2.5 Review of electrical components

WARNING — Prior to the start of any work, the wiring from the releasing panel(s) to all aerosol generators shall be disconnected. When testing circuitry, it is recommended that a method be used to verify that the necessary current is available by inserting a resistor into the line equivalent to the resistance of the generator and measuring the minimum current that is specified by the manufacturer that is actually delivered.

8.2.5.1 All wiring systems shall be properly installed in compliance with the appropriate national standard and the system drawings. AC and DC voltage wiring shall not be combined in a common conduit unless properly shielded and grounded.

8.2.5.2 All field circuitry should be tested for maximum supervisory and minimum activation current.

8.2.5.3 All field circuitry shall be tested for ground fault and short circuit condition. When testing field circuitry, all electronic components (such as smoke and flame detectors or special electronic equipment for other detectors, or their mounting bases) shall be removed and jumpers properly installed to prevent the possibility of damage within these devices. Replace components after testing the circuits.

8.2.5.4 Adequate and reliable primary standby sources of energy which comply with 7.9.1 shall be used to provide for operation of the detection, signaling, control and actuation requirements of the system.

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

8.2.5.6 Alarm devices shall be installed so that they are audible and visible under normal operating and environmental conditions. Where possible, all air-handling and power cut-off controls should be of the type that once interrupted require manual restart to restore power.

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

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

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

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

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

8.2.5.12 Check that for systems using isolate switches these are located at each entrance to the protected area, properly installed and clearly identified.

8.2.5.13 Check that the control panel is properly installed and readily accessible. Check that a system isolate switch is located in the panel, properly installed and secured from unauthorized use.

8.2.6 Preliminary function tests

8.2.6.1 Where a system is connected to a remote central alarm station, notify the station that the fire system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not required. Notify all concerned personnel at the end-user's facility that a test is to be conducted and instruct them as to the sequence of operation.

8.2.6.2 Operate system isolate switch before entering the protected area. For condensed aerosols the wiring from the releasing panel(s) to all aerosols shall be disconnected. Reconnect the release circuit with a functional device in lieu of each extinguishant unit release mechanism. For electrically actuated release mechanisms, these devices may include suitable lamps, flash bulbs or circuit breakers. Pneumatically actuated release mechanisms may include pressure gauges. Refer to the manufacturer's recommendations in all cases.

8.2.6.3 Check each resettable detector for proper response.

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

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

8.2.6.6 Check all supervised circuits for correct fault response.

8.2.7 System functional operational test

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

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

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

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

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

8.2.8 Remote monitoring operations

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

8.2.8.2 Operate each type of alarm condition and verify receipt of fault condition at the remote station.

8.2.9 Control panel primary power source

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

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

8.2.10 Completion of functional tests

When all functional tests are complete (8.2.6 to 8.2.9), reconnect each extinguishant unit so that activation of the release circuit will release the extinguishant. When reconnecting the units, ensure that the system isolate switch is activated so that release circuit will not operate.

After exiting the enclosure, disable the system isolate switch so that the system is returned to its fully operational design condition.

Notify the central alarm station and all concerned personnel at the end-user's facility that the fire system test is complete and that the system has been returned to full service condition by following the procedures specified in the manufacturers' specifications.

8.2.11 Completion certificate and documentation

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

9 Inspection, maintenance, testing and training

9.1 General

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

9.2 Inspection

9.2.1 General

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

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

9.2.1.3 At least every six months, all aerosol generator assemblies shall be visually inspected and the visual inspection shall verify whether:

a) the generator's casing and actuator(s) are undamaged;

b) the generators are securely mounted;

c) the generators are free from corrosion;

d) the expiration date does not occur prior to the next scheduled inspection;

e) the generator discharge path is unobstructed.

If the generators are installed in separate housing forming part of the listed assembly, an inspection of the housing meets the intent of this clause.

9.2.1.4 Discharged or expired aerosol generators removed during service or maintenance procedures shall be collected and recycled, or disposed of in an environmentally sound manner, and in accordance with existing laws and regulations.

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

9.2.2 Enclosures

9.2.2.1 At least every 12 months it shall be determined whether boundary penetration or other changes to the protected enclosure have occurred that could affect leakage and extinguishant performance.

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

9.2.2.3 Where it is established that changes to the volume of the enclosure or to the type of hazard within the enclosure, or both, have occurred, the system shall be redesigned to provide the original degree of protection. It is recommended that the type of hazard within the enclosure, and the volume it occupies, be regularly checked to ensure that the required concentration of extinguishant can be achieved and maintained.

9.2.2.4 Where pressure relief vents are installed, the devices shall be inspected for any mechanical damage and other impacts that could affect their operation. The effective vent area shall be checked for conformance with the design calculations.

9.3 Maintenance

9.3.1 General

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

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

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

9.3.2 User's programme of inspection

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

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

a) Weekly: Visually check the hazard and the integrity of the enclosure for changes which might reduce the efficiency of the system. Carry out a visual check that there is no obvious damage to the system and that all operating controls and components are properly set and undamaged.

b) Monthly: Check that all personnel who may have to operate the equipment or system are properly trained and authorized to do so and, in particular, that new employees have been instructed in its use.

WARNING — Always operate a system isolate switch prior to entering the protected enclosure if the unit is not approved for occupied spaces.

9.3.3 Service schedule

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

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

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

9.4 Training

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

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

Annex A
(normative)

Documentation requirements

A.1 General

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

Deviation from these documents shall require permission from the relevant authority.

A.2 Working documents

Working documents shall include at least the following items:

1) location drawings;
2) name of owner and occupant;
3) location of building in which hazard is located;
4) location and construction of protected enclosure walls and partitions;
5) enclosure cross-section, full height or schematic diagram, including raised access floor and suspended ceiling;
6) type of aerosol generators being used;
7) design application density;
8) description of occupancies and hazards to be protected against;
9) specification of aerosol generators used;
10) equipment schedule or list of materials for each piece of equipment or device, showing device name;
11) manufacturer, model or part number, quantity and description;
12) system calculation;
13) enclosure pressurization and venting calculations;
14) description of fire detection, actuation and control systems.

Annex B
(informative)

Toxicity and visibility testing

B.1 Introduction

In the fire protection sector, health and safety depends upon an individual's ability to escape a fire hazard. This ability could be impaired if a fire suppressant has an immediate toxic effect, or decreases visibility necessary to exit an occupied space. These factors may also pose risks in a non-fire situation. Both immediate and delayed toxicity are of concern when powdered aerosols are used. The following discussion provides guidance to assist in characterizing immediate and delayed toxicity. Authorities having jurisdiction may wish to consider this information when assessing powdered aerosol fire extinguishers for occupied spaces.

B.2 Assessing toxicity: irritation and inhalation toxicity tests

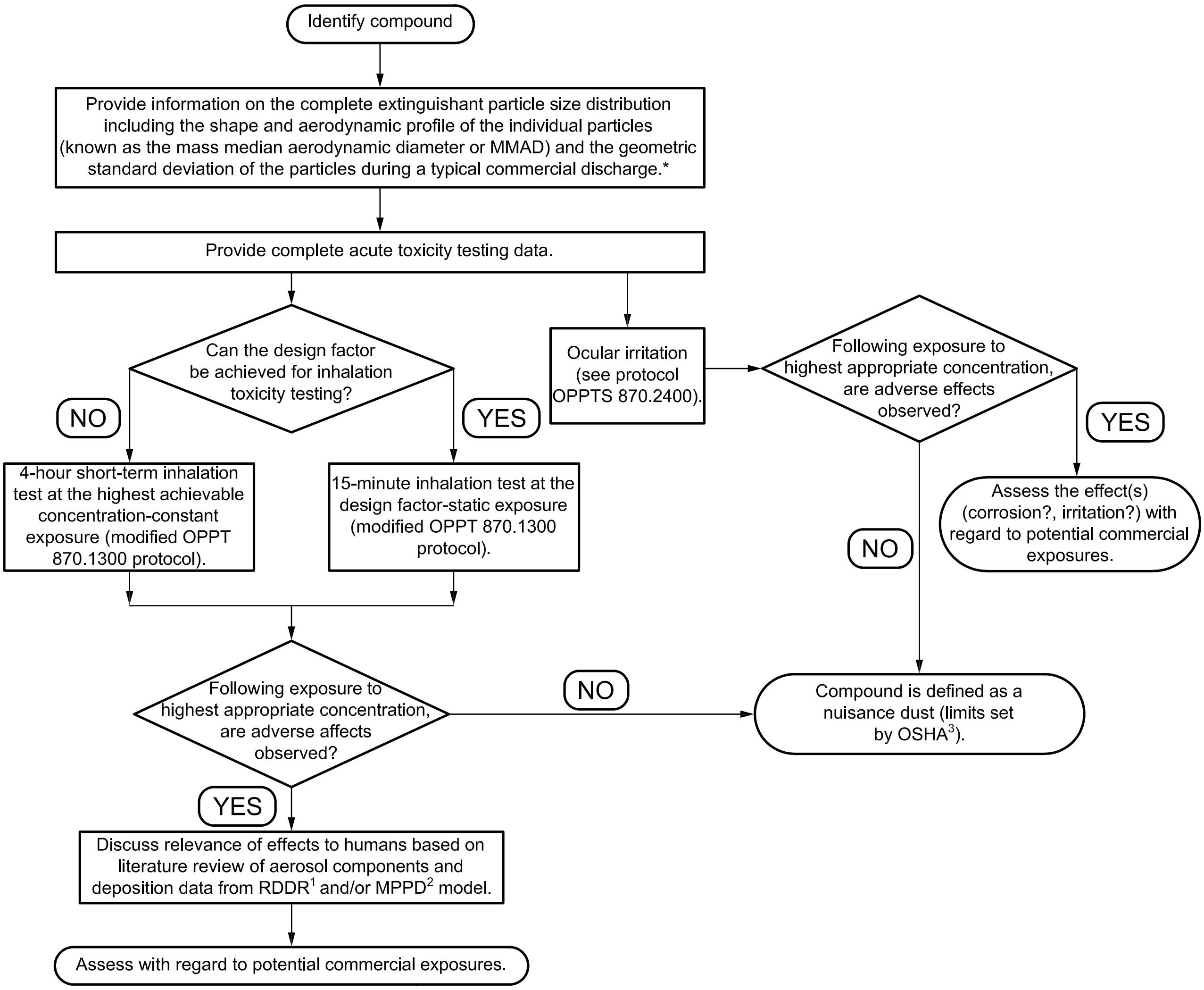
Two toxicity tests have been proposed for assessing the potential for short-term toxicity to humans following the accidental release of a powdered aerosol. The first test is the Draize test (US EPA/OPPTS 870 2400). This test is to be performed in order to analyse the potential for irritation and corrosion in the human eye following exposure to powdered aerosol particulate matter. As reported in the test guidelines, compounds that are already known to be corrosive or caustic do not need to be assessed by this test.

The second toxicity test is a 15-minute inhalation test using rats. This test should incorporate an exposure scenario that is similar to release of the powdered aerosol fire extinguisher at its design factor. In other words, the toxicity test will use an exposure of the powdered aerosol that is identical to that to which a human would be exposed at the end use in the event of an accidental release. Two different sets of rats (each set containing a group of controls and exposed rats) should be exposed for no longer than 15 min. This exposure time was chosen to provide a measure of safety regarding potential resultant toxicity because human exposure is limited to only 5 min. The rats should be exposed via whole-body inhalation methodology; nose-only exposures are not appropriate for these compounds. During and immediately following exposure, particular attention should be paid to ocular effects. Following exposure, one set of animals should be evaluated immediately for clinical signs, mortality, and inhalation and systemic toxicity as noted in OPPTS 870.1300, and for histopathology as noted below. Further, the second group of animals should be observed for 14 days post-exposure. Both sets of animals should be examined for gross pathology and histopathology of appropriate organs (e.g. lungs and potentially the nasal passages and the trachea). In addition, wet and dry lung weights should be measured in control and exposed rats to determine if edema has occurred. Specific effects to investigate in the histopathology of the lungs are pneumonia, edema, inflammation, alveolar coalescence, macrophage infiltration, and similar responses. Evaluation of these parameters may require an additional exposed group. If data are available that indicate that any components of the powdered aerosol affect systemic toxicity or particular target organs, a further evaluation of these organs in the exposed rats may be advisable.

In the event that the design factor cannot be reached during a 15-minute inhalation toxicity test, then a 4-hour inhalation toxicity test following OPPTS 870.1300 should be performed. The exposure concentration in this assay should be the highest exposure concentration achievable (e.g. the highest airborne particle concentration that can be technologically achieved given the characteristics of the powdered aerosol). The same sets of animals and control and dose groups described in the 15-minute inhalation test should be used in the 4-hour test, and the same endpoints should be measured. Particular attention should be paid to ocular irritation/corrosion during and after the exposure period and throughout the clinical observation period (14-days post-exposure).

B.3 Assessing toxicity: literature review

A comprehensive review of the published literature should be performed regarding the potential toxicity of components of the powdered aerosol, or of the whole product. These data can then be used to determine or predict toxicity of the end product. This evaluation can include, but should not be limited to, an evaluation of appropriate short-term exposure limits and other exposure values set by regulatory agencies for components of the powdered aerosol.



1 Regional Deposited Dose Ratio

2 Minimal Persistent Pigment Dose

3 Occupational Safety and Health Administration (USA)

* The submitter is responsible for developing the appropriate methodology to provide this information, which will be reviewed by EPA on a case-by-case basis. Occupational exposures may be measured as described in protocol (NMAM 0500).

Figure B.1 — Flowchart of assessment of powdered aerosols

B.4 Assessing visibility for a powdered aerosol: a model approach

To ensure that powdered aerosol products will meet the visibility requirements of the appropriate organizations, a brief assessment of visibility ratings as a function of concentration of agent and particle size is provided. Figure B.1 shows a flowchart of the steps to be taken in the assessment of powdered aerosols. Table B.1 provides an estimate of the distance an individual can see in a space where a powdered aerosol fire extinguisher has been discharged in the absence of a fire. This distance is based on a standard contrast value of 0,02 for particulate matter with a given mass median aerodynamic diameter (MMAD) at varying concentrations, under sunlight conditions for a refractive index of 1,5 which represents the typical value for atmospheric particles including organic liquid aerosols (Rawle, [7]. It can be anticipated that the relationships presented in Table B.1

would also apply to typical indoor lighting conditions, although the changes in visibility would be somewhat less; therefore, the indoor visibility will be slightly lower than that of the outdoors.

Table B.1 — Visibility as a function of particle MMAD and concentration

Particle size MMAD in µm	**10**	285600	2856	286	143	95	71	57	41	32	26	22
	9	248400	2484	248	124	83	62	50	36	28	23	19
	8	207600	2076	208	104	69	52	42	30	23	19	16
	7	177600	1776	178	89	59	44	36	25	20	16	14
	6	156000	1560	156	78	52	39	31	22	17	14	12
	5	139200	1392	139	70	46	35	28	20	16	13	11
	4	123600	1236	124	62	41	31	25	18	14	11	10
	3	114000	1140	114	57	38	29	23	16	13	10	9
	2	81600	816	82	41	27	20	16	12	9	7	6
	1	25200	252	25	13	8	6	5	4	3	2	2
	0.8	15600	156	16	8	5	4	3	2	2	1	1
	0.5	1200	120	12	6	4	3	2	2	1	1	1
	0.1	163200	1632	163	82	54	41	33	23	18	15	13
	0	**10**	**1,000**	**10,000**	**20,00**	**30,000**	**40,000**	**50,000**	**70,000**	**90,000**	**110,000**	**130,000**
	Concentration in mg/m³											

NOTE Numbers that are not in bold type represent visibility in cm.

Table B.1 estimates the visibility (cm) in a space where a powdered aerosol has been emitted. The table shows that the visibility is a strong function of the powdered aerosol's concentration and MMAD. As the MMAD of the aerosol deviates (i.e. increases or decreases) from 0,5 µm and the concentration of the powdered aerosol remains constant, the visibility in the space improves. Additionally, as the concentration of the released powdered aerosol increases, the visibility in the space decreases.

The model is based on daylight conditions, and may not precisely correspond to visibility in machinery spaces without natural light; however, the model can still be used as an approximate gauge for these circumstances. If lighting is substantially below daylight conditions, then the values in Table B.1 overestimate visibility.

B.5 Design of the model

This model is based upon the standard visual range formula and Mie Theory[1)]. The following standard visual range formula is based on typical aerosol distribution in sunlight and the standard visual contrast:

$$L_\mathrm{V} \approx 1200/C$$

where

L_V is visibility in km;

C is the concentration of the aerosol particles in µg/m³ for particles with MMAD falling in the range of 0,1 µm to 1 µm.

Figure B.2 is based on Mie Theory and shows how the amount of light scattering, represented by a scattering coefficient, is dependent upon particle MMAD. This figure shows how solar light at sea level, which has its peak wavelength in the range from 0,3 µm to 0,6 µm, is most effectively scattered by particles with similar dimensions (i.e. 0,3-0,6 µm in diameter). Thus, light is less effectively scattered by particles whose size is larger or smaller than this optimal size range, and the resulting visibility improves. Thus, the visibility for a powdered aerosol

1) Mie theory is a mathematical-physical theory of the scattering of electromagnetic radiation by spherical particles [4].

is approximated by a function of the concentration, as shown by the standard visual range formula, and the particle MMAD for a given characteristic standard distribution of solar light based on Mie scattering functions.

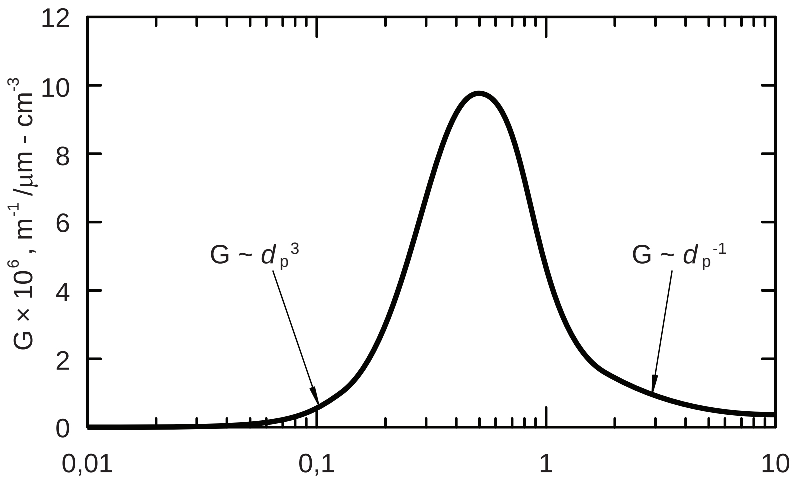


Figure B.2 — Particle MMAD (µm)

NOTE The scattering coefficient has been calculated, and shown in Figure B.2 (see B.12), for a given characteristic standard distribution of solar light based on Mie scattering functions over typical ground level visual wavelengths (0,36 µm to 0,68 µm) for a typical refractive index of 1,5.

Table B.2 — Aerosol settling velocity — Spherical particles in air

Mass median aerosol diameter (µm)	**Settling velocity** (cm/s)
0,1	0,000 086
0,2	0,000 23
0,5	0,001 0
1,0	0,003 5
2,0	0,013
5,0	0,078
10	0,31
20	1,2
50	7,6

B.6 Potential settling rates and the effect on visibility

The scattering model described in B.5 does not include any adjustment for the velocity at which the particles settle. If the particles settle quickly, the concentration of the powdered aerosol in the air decreases and visibility increases. Table B.2 shows settling velocity for spherical particles based on Stokes law and adjustments for friction and slip corrections. The table shows that over the time period of interest (< 10 min), the vast majority of particles will remain suspended for particles with MMAD < 10 µm. Fire suppressant systems tend not to use particles having MMAD > 10 µm because the particles agglomerate and fall out of suspension, rendering the fire suppressant less effective. Therefore, since the settling velocities are minimal for the size particle used in fire suppressants, the settling velocity will not significantly alter the visibilities presented in Table B.1.

B.7 Accounting for refractive index

The refractive index (i.e. the change in direction of light passing through the substance) of a particle can also influence visibility. This refractive index includes both scattering and absorption of light. If the particular powdered aerosol of concern has a relatively low refractive index (e.g. 1,2) then assuming spherical particles, the particle would be approximately five times less effective in scattering light than typical atmospheric aerosols. Conversely, if a powdered aerosol has a refractive index of 1,8, then for spherical aerosols the scattering would be five times greater. Fire suppressants containing powdered aerosols with a low refractive index will yield better visibility in the space than those with a higher refractive index. Therefore, choosing chemicals (i.e. powdered aerosols) with a low refractive index for use in a fire suppressant is one means of increasing the visibility resulting from these types of materials.

B.8 Designing the lighting and space to conform with physical properties of the powdered aerosol

Visibility in a room where a powdered aerosol has been discharged can also be increased by careful design of the environment in which the fire extinguisher is used. Through utilization of lights with specific wavelengths rather than white light, and a room design that provides easily accessible exits, the chances for escape from a room where a powdered aerosol has been discharged can be improved.

B.9 Utilizing light of specific wavelengths and photoluminescent marking systems

Light is most effectively scattered by a particle size that is the same dimension as the wavelength of the incident light. As the wavelength of light deviates from the size of the powdered aerosol distributed in the air, interference between the particles and the light decreases and visibility increases. Because powdered aerosol products each have their own MMAD and refractive index, each fire suppressant will have particular wavelengths of light that penetrate through its suspended particles with minimal scattering. It is therefore possible to research the different types of light that may be used in the occupied spaces and determine which type of lighting may best be suited for use with a particular powdered aerosol. For example, mercury or sodium vapor lamps may improve visibility depending on particle size.

During an emergency situation in which a powdered aerosol fire extinguisher is released, electrical or battery powered lighting systems may be unreliable. In anticipation of power failure in emergency situations, a photoluminescent floor lighting system has been developed as an alternative to traditional lighting. Photoluminescent lights, originally used in many of Norway's hydro power plants, and the underground facilities of Oslo's airport, have now been considered for use in high-rise towers and in planes to provide emergency lighting (Jensen, 1999).

Additionally, a US Federal Aviation Administration (FAA) sponsored study tested the efficacy of a photoluminescent escape path-marking system in an airplane. During a nighttime evacuation scenario in a cabin without identifier lights or illuminated signs (i.e. to mimic smoke obscuring conditions in the cabin environment from the ceiling to four feet above the cabin floor), both zinc sulfide and strontium aluminate photoluminescent marking systems were tested. These materials absorb energy from natural light and the plane's standard aircraft lighting. Then, in emergency situations, when all other lighting is extinguished, the photoluminescent system emits the energy as visible light. The FAA study concluded that the strontium aluminate system, though it charges more slowly than the zinc sulfide material, emits more light and provides adequate lighting to mark a path of egress (FAA, 1998). Thus, a photoluminescent floor marking system would potentially help in marking an exit route in a scenario involving powdered aerosol discharge. The effectiveness of such a system would depend upon the powdered aerosol concentration and particle size distribution.

B.10 Decreasing distance to exits

The rooms in which the powdered aerosol fire extinguishers are used may be designed such that the distance to the nearest exit is as short as possible. Other designs to consider are ones in which the distance to any wall which leads to an exit is minimized. A room constructed in this manner would allow one to see well enough to get to the wall and then feel one's way to the closest exit.

B.11 Training

Increasing the ability of an individual to exit a space where a powdered aerosol has been released can also be achieved through training of the space's occupants. Workers that occupy areas in which powdered aerosol fire extinguishers are present should be trained on how to react in the event of an accidental release of the fire suppressant. Personnel should be made aware of the locations of all the exits and the distance and direction of all doorways and other means of egress, even when a view of the exits is obscured by the released powdered aerosol.

B.12 Recommended testing procedures

After consideration of modeling and engineering adjustments identified in this annex leads to a determination that the powdered aerosol is likely to meet visibility standards, then physical testing of visibility should be performed. A nephelometer may be used to measure this visibility. Usually used to assess visual air quality or particulate matter concentrations in air, a nephelometer measures the extinction of light, which is dependent upon both the scattering and absorption of light over some distance (Parikh, 2001). Using the scattering coefficient provided by the nephelometer and the design factor, the visibility resulting from the discharge of the powdered aerosol may be assessed.

Annex C
(normative)

Test methods

C.1 General

The following shall apply to the condensed aerosol generators.

C.2 Conditions

The components shall be tested assembled as recommended for installation by the manufacturer. The tests shall be carried out at a temperature of (25 ± 10) °C, except when otherwise stated.

The tolerance for all test parameters is 5 %, unless otherwise stated.

C.3 Samples

The manufacturer shall submit a sufficient number of samples from the same batch for testing.

Unless otherwise noted, a minimum of 200 ignition devices of each type shall be tested for the ignition performance test in C.15.

A minimum of five generators in each size within a family shall be tested in the as-received condition for the function test in C.16, which also includes the discharge time test in C.16.1 and the casing and aerosol flow temperature tests in C.16.2 and C.16.3.

A minimum of three generators in the smallest and largest size within a family shall be tested for each of the following tests: temperature and humidity test in C.7, low temperature test in C.7.3, accelerated ageing test in C.8, corrosion test in C.9, stress corrosion test in C.10, vibration test in C.11, impact test in C.12, drop test in C.13, and fire exposure test in C.17.

The number of generators for coverage determination in C.5 will depend upon the installation limitations of each generator within a family. A minimum of one generator in each size within a family shall be tested for the minimum height/maximum coverage test in D.5.1. A minimum of one generator in each size within a family shall be tested for the maximum height test in D.5.2.

The number of generators and generator size for the extinguishing application density determination in C.5 will depend upon the area coverage limitations and generator efficiency. The generator having the smallest efficiency (that is, smallest amount of aerosol extinguishing agent produced related to the generator's solid aerosol-forming compound mass) shall be used.

The sequence of tests is shown in Table C.1 and is given by the numbers 1, 2, 3, etc., in the table. A, B, etc., are the different samples.

Table C.1 — Test sequence

Test method	Test order for sample												
	A	B	C	D	E	F	G	H	I	J	K	L	M
C.4 Compliance	1	1	1	1	1	1	1	1	1	1	1	1	1
C.5 Extinguishing application density determination	—	—	—	—	—	—	—	—	—	—	—	—	2
C.5 Coverage determination	—	—	—	—	—	—	—	—	—	—	—	2	—
C.6 Discharge time test	2	—	—	—	—	—	—	—	—	—	—	—	—
C.7 Temperature and humidity test	—	—	2	—	—	—	—	—	—	—	—	—	—
C.7.3 Low temperature test	—	—	—	2	—	—	—	—	—	—	—	—	—
C.8 Accelerated ageing test	—	—	—	—	2	—	—	—	—	—	—	—	—
C.9 Corrosion test	—	—	—	—	—	2	—	—	—	—	—	—	—
C.10 Stress corrosion test	—	—	—	—	—	—	2	—	—	—	—	—	—
C.11 Vibration test	—	—	—	—	—	—	—	2	—	—	—	—	—
C.12 Impact test	—	—	—	—	—	—	—	—	2	—	—	—	—
C.13 Drop test	—	—	—	—	—	—	—	—	—	2	—	—	—
C.14 Casing and aerosol flow temperatures tests	3	—	—	—	—	—	—	—	—	—	—	—	—
C.15 Ignition performance test	—	2	—	—	—	—	—	—	—	—	—	—	—
C.16 Function test	4	—	3	3	3	3	3	3	3	3	3	3	3
C.17 Fire exposure test	—	—	—	—	—	—	—	—	—	—	2	—	—

NOTE 1 At the option of the manufacturer, the temperature and humidity test in C.7 can be conducted with the same generator samples following the impact test in C.12.

NOTE 2 At the option of the manufacturer, the low temperature test in C.7.3 can be conducted with the same generator samples following the drop test in C.13.

C.4 Compliance

A visual and measurement check shall be made to determine whether the condensed aerosol generator corresponds to the description in the technical literature (drawings, parts lists, description of functions, operating and installation instructions).

C.5 Extinguishing application density determination

The extinguishing application density for specific fuels under different classes of fires shall be determined by specific tests using the fire test procedures described in Annex D.

Extinguishing application density tests should be conducted with generator(s) of the same family. The number of aerosol generator units shall be sufficient to provide the needed extinguishing application density in the test enclosure. The mass of the generator unit prior and after discharge shall be recorded.

C.6 Discharge time test

The discharge time test is an integral part of the function test. See C.16.1 for the discharge time test procedure.

C.7 Temperature and humidity operation range tests

C.7.1 Object of the test

The object of the test is to demonstrate the ability of the equipment to function correctly at high relative humidity (with condensation) which may occur for short periods in the anticipated service environment.

C.7.2 Test procedure

C.7.2.1 General

The test procedure described in EN 60068-2-30, using the variant 1 test cycle and controlled recovery conditions shall be used.

C.7.2.2 Conditioning

Apply the following severity of conditioning:

a) lower temperature: (25 ± 3) °C

b) upper temperature: (55 ± 2) °C

c) relative humidity at lower temperature: (93 ± 3) %

d) relative humidity at upper temperature: (93 ± 3) %

e) number of cycles: 10

f) hold time at temperature and recovery time before each test: (12 ± 0,5) h

C.7.2.3 Final measurements

After the recovery period, the sample shall be visually checked for mechanical damage externally, and shall be subjected to the function test.

C.7.2.4 Requirements

When subjected to the function test, the sample shall respond correctly.

C.7.3 Low temperature test

Condition the sample at $-20\,^{0}_{-2}$ °C, or the service temperature recommended by the manufacturer $^{0}_{-2}$ °C, whichever is the lower, for a minimum of 16 h.

Then carry out the function test immediately. When subjected to the function test, the sample shall respond correctly.

C.8 Accelerated ageing test

C.8.1 Test results

Test time shall be calculated to fulfill requirements as follows:

$$\frac{t_2}{t_1} = 2^{\Delta T/10} \qquad \text{(C.1)}$$

where

t_1 is test time, in days;

t_2 is expected service life, in days;

$\Delta T = T_1 - T_2$;

T_1 is test temperature, in degrees Celsius;

T_2 is maximum operating temperature, in degrees Celsius.

Table C.2 — Example for the calculation result of Equation (C.1) at $T_2 = 25$ °C

Test temperature T_1	Test days for 10 years expected service life	Test days for 5 years expected service life
90 °C	40 days	20 days
100 °C	20 days	10 days

C.8.2 Test procedure

The test procedure is the following.

a) Tests are performed on three fully assembled condensed aerosol generators of the selected model size(s).

b) The manufacturer shall specify the maximum operation temperature and expected service life.

c) The generators shall be subjected to air-oven ageing at temperature T_1, which shall be at least 10 °C higher than the specified maximum operation temperature, for a period of t_1 days as calculated by Equation (C.1).

d) Following the ageing test, the aerosol generators shall be subjected to and pass the function test.

C.9 Corrosion test

The sample shall be exposed to a salt spray within a fog chamber.

The essential components and properties of the reagents and the test configuration are:

— solution consists of NaCl in distilled water;

— concentration of the solution: (5 ± 1) %;

— pH Value: 6,5 to 7,5;

— spray pressure: 0,6 bar to 1,5 bar;

— spray volume: 1 ml/h to 2 ml/h on an area of 80 cm^2;

— temperature in test cabinet: $35^{+1,0}_{-1,7}$ °C;

— position of the sample: 15° to the vertical axis;

— spray time: (240 ± 2) h;

— drying time: (168 ± 5) h at a humidity of maximum 70 %.

The sample shall be subjected to a function test in accordance with C.16.

C.10 Stress corrosion test

This test is to be conducted only on generators using copper alloys. The stress corrosion test is to be conducted unless it can be shown to the listing authority that the materials used in the construction are not susceptible to ammonia stress corrosion.

The aqueous ammonia solution shall have a specific weight of (0,94 ± 0,02) kg/l. The sample shall be filled with (10 ± 0,5) ml of the solution for each litre of container volume.

The sample shall be degreased for the test and shall be exposed for 10 days to the moist atmosphere of ammonia and air, at a temperature of (34 ± 2) °C. The samples shall be positioned (40 ± 5) mm above the level of the liquid.

After testing, the samples shall be cleaned and dried and subjected to careful visual examination. To make cracking clearly visible, the liquid penetration method shall be used. Cracks are unacceptable, resulting in test failure.

C.11 Vibration test

The drawings and the technical data shall be checked to determine whether vibration could have an adverse effect on the performance.

The sample is attached to a vibration table using fixing materials provided by the manufacturer.

The test apparatus and procedure shall be as described in EN 60068-2-6, Test Fc:

— Frequency range: 10 Hz to 150 Hz.

— Acceleration amplitude for components which are designed to be attached to machinery:

  — 10 Hz to 50 Hz: 9,81 m/s^2 (= 1,0 g_n);

  — 50 Hz to 150 Hz: 29,43 m/s^2 (= 3,0 g_n).

— Acceleration amplitude for components which are designed to be attached to walls:

  — 10 Hz to 50 Hz: 1,962 m/s^2 (= 0,2 g_n);

  — 50 Hz to 150 Hz: 4,905 m/s^2 (= 0,5 g_n).

— Sweep rate: 1 octave per 30 min.

— Number of sweeps: 0,5 per axis.

— Number of axes: 3 mutually perpendicular.

The sample shall not operate during the test as a result of the vibrations.

No deterioration or detachment of parts shall occur. The sample shall be inspected for external mechanical damage and shall be subjected to a function test in accordance with C.16.

C.12 Impact test

C.12.1 Test procedure

The test apparatus shall consist of a swinging hammer incorporating a rectangular-section aluminium alloy head (aluminium alloy $AlCu_4SiMg$) with the plane impact face chamfered to an angle of (60 ± 1)° to the horizontal, when in the striking position. A suitable apparatus is described in C.12.2.

The specimen shall be rigidly mounted to the apparatus by its normal mounting means and shall be positioned so that it is struck by part of the upper half of the impact face of the hammer (i.e. above the centre line), when the hammer is in the vertical position (i.e. when the hammer head is moving horizontally). The direction of impact relative to the specimen shall be chosen as the most likely to impair the normal functioning of the specimen.

A horizontal blow shall be delivered to the specimen at an impact energy level of (1,9 ± 0,1) J by a hammer velocity of (1,5 ± 0,125) m/s.

C.12.2 Test apparatus

The tolerance for all dimensions in this test apparatus shall be 0,5 mm, unless otherwise specified.

The test apparatus (see Figure C.1) shall consist essentially of a swinging hammer comprising a rectangular section head (striker), with a chamfered impact face, mounted on a tubular steel shaft. The hammer shall be fixed into a steel boss, which runs on ball bearings on a fixed steel shaft mounted in a rigid steel frame, so that the hammer can rotate freely around the axis of the fixed shaft. The design of the rigid frame shall be such as to allow complete rotation of the hammer assembly when the specimen is not present.

The striker shall be 76 mm wide, 50 mm deep and 94 mm long (overall dimensions) and shall be manufactured from aluminium alloy ($AlCu_4SiMg$), solution treated and precipitation treated condition. It shall have a plane impact face chamfered at (60 ± 1)° to the long axis of the head. The tubular steel shaft shall have an outside diameter of (25 ± 0,1) mm with walls (1,6 ± 0,1) mm thick.

The striker shall be mounted on the shaft so that its long axis is at the radial distance of 305 mm from the axis of rotation of the assembly, the two axes being mutually perpendicular. The central boss shall be 102 mm in external diameter and 200 mm long and shall be mounted coaxially on the fixed steel pivot shaft, which is approximately 25 mm in diameter; however, the precise diameter of the shaft will depend on the bearings used.

Diametrically opposite the hammer shaft are two steel counter-balanced arms, each 20 mm in external diameter and 185 mm long. These arms shall be screwed into the boss so that a length of 150 mm protrudes. A steel counter-balance weight shall be mounted on the arms so that its position can be adjusted to balance the mass of the striker and arms. On the end of the central boss shall be mounted a 12 mm wide and 150 mm diameter aluminium alloy pulley and round this an inextensible cable is wound, one end being fixed to the pulley. The other end of the cable shall support the operating weight.

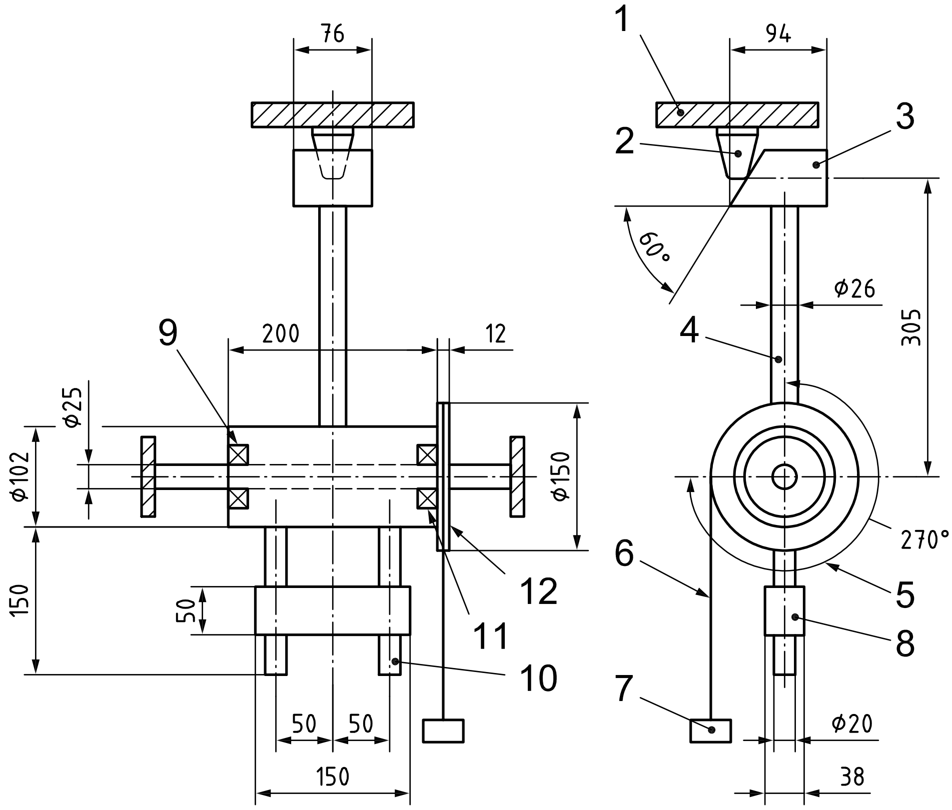
The rigid frame shall also support the mounting board on which the specimen is mounted by its normal fixings. The mounting board shall be adjustable vertically so that the upper half of the impact face of the hammer will strike the specimen when the hammer is moving horizontally, as shown in Figure C.1.

To operate the apparatus, the position of the specimen and the mounting board shall be first adjusted as shown in Figure C.1 and the mounting board shall then be secured rigidly to the frame. The hammer assembly shall then be balanced carefully by adjustment of the counter balance weight with the operating weight removed. The hammer arm shall then be drawn back to the horizontal position ready for release and the operating weight reinstated. On release of the assembly, the operating weight will spin the hammer and arm through an angle of $3\pi/2$ radians to strike the specimen. The mass of the operating weight to produce the required impact energy of 1,9 J equals $(0{,}388/3\pi r)$ kg where r is the effective radius of the pulley in metres. This equals approximately 0,55 kg for a pulley radius of 75 mm.

As a hammer velocity at impact of (1,5 ± 0,125) m/s is specified, the mass of the hammer head will need to be reduced by drilling the back face sufficiently to obtain this velocity. It is estimated that a head of mass of about 0,79 kg will be required to obtain the specified velocity, but this will have to be determined by trial and error.

The sample shall be inspected for external mechanical damage and shall be subjected to a function test in accordance with C.16.

Dimensions in millimetres



Key

1 mounting board
2 specimen
3 striker
4 striker shaft
5 270° angle of movement
6 cord
7 operating weight
8 counter balance weight
9 boss
10 counter balance arms
11 ball bearings
12 pulley

NOTE The sizes given to the dimensions are for guidance only.

Figure C.1 — Impact test apparatus

C.13 Drop test

C.13.1 Impact surface

The impact surface is a solid base with a reasonably smooth surface. An example of such a surface is as follows:

— steel plate, with a minimum thickness of 75 mm and Brinell hardness of not less than 200 mm, solidly supported by a concrete foundation having a minimum thickness of 600 mm.

The length and width of the surface should be not less than one and a half times the dimension of the unit being tested.

C.13.2 Procedure

The test unit without packaging is dropped from a height of 2 m as measured from the lowest point of the test unit to the impact surface. A safe waiting period following impact prescribed by the test laboratory should be observed, even if no visible initiation or ignition occurs at impact.

C.13.3 Requirements

The sample shall be subjected to a function test in accordance with C.16.

C.14 Casing and aerosol flow temperatures test

C.14.1 Casing temperature test

The casing temperature test is an integral part of the function test. See C.16.3 for the casing temperature test procedure.

C.14.2 Aerosol flow temperature test

The aerosol flow temperature test is an integral part of the function test. See C.16.2 for the aerosol flow temperatures test procedure.

C.15 Ignition performance test

The ignition of the generator shall be tested in accordance with the manufacturer's specifications.

All samples of the complete ignition devices shall operate as intended. If the ignition device is a commercially/military available component with reliability test data, that data may be used to satisfy this requirement, at the discretion of the listing organization.

The power output of the ignition device shall be not less than that specified by the manufacturer at minimum power output sufficient to ignite the maximum designed mass of the aerosol-forming compound at the lowest operating temperature specified by the manufacturer.

Ignitors already certified by authority for ignition reliability will be not re-tested.

C.16 Function test

C.16.1 Discharge time

Discharge time shall be measured by using one or more of the following techniques:

— thermocouples recording temperature changes at the start and end of the discharge;

— infrared video recording;

— generator combustion pressure;

— visual;

— audible.

NOTE The reference points identified as the start and the end of the aerosol generator discharge should be the same as taken during performance testing and as defined by the manufacturer.

C.16.2 Aerosol flow temperatures

Aerosol flow temperatures shall be measured by thermocouples.

The following thermocouples arrangement shall be used for measuring temperatures at the specified minimum distances for 75 °C, 200 °C and 400 °C:

— three cross-shaped poles are used as a support for the thermocouples and installed at the specified minimum clearances;

— the centre of each cross should be in line with a centre of a condensed aerosol generator's discharge outlet with the ends of the cross being within the cone-shaped discharge path;

— crosses may be rotated against each other (i.e. X, Y, Z axis) to minimize the impact of the aerosol flow on the temperature readings;

— five thermocouples may be used — one at the centre of the cross, and four at its ends;

— the three highest readings out of five shall be taken for recording.

Any measuring technique other than those described above which is acceptable to and approved by a listing authority may be used for measuring discharge time, temperatures and enclosure pressure.

C.16.3 Casing temperature test

The following thermocouples arrangement may be used for measuring the temperature of the outer generator's casing.

— Three thermocouples should be attached to the outer casing of the aerosol generator in the locations with the highest expected temperature.

C.16.4 Effective mass of extinguishant

The mass of aerosol generator shall be measured before and after the discharge. The difference of mass shall be recorded and is called effective mass of aerosol.

C.16.5 Test procedure

Condition a fully assembled condensed generator for 16 h at ambient temperature of (21 ± 4) °C.

Discharge the generator in a test enclosure.

C.16.6 Requirements

Full function requirements apply to the discharge of a condensed aerosol generator prior to conducting any of the performance testing.

The conditions are described in Table C.3.

Table C.3 — Test conditions for function test C.16

Parameter	Subclause	Requirement	Tolerance
Visual examination	—	During discharge: no flame coming out from discharge outlet	—
Discharge time	C.16.1	As specified by manufacturer	±5 s
Temperatures at the specified minimum clearances for 75 °C, 200 °C and 400 °C	C.16.2	As specified by manufacturer	±10 %
Temperature of the outer casing	C.16.3	—	±10 %
Mass of aerosol compound discharged	C.16.4	—	±5 %

C.17 Fire exposure test

NOTE This test relates to the requirements of 6.3.10.

C.17.1 Object of the test

The object of the fire exposure test is to demonstrate the safe operation of the condensed aerosol generator during and/or after its exposure to an external fire simulating a realistic accident.

C.17.2 Test procedure

Each sample shall be weighed and installed in a mounting bracket such that the bottom most portion of the generator is centred (915 ± 15) mm above the bottom of the pan specified in D 6.2.2.2.

For each test, at least 2,5 cm of heptane is to be placed in the pan, ignited and burnt for at least 60 s. During or after fire exposure, each aerosol generator sample shall be discharged as described in C.16.5, except the environmental condition need not to be maintained at (21 ± 4) °C.

C.17.3 Requirements

a) Operate as intended.

b) Have a discharge time within 20 % or within ±5 s of the average discharge time determined at (21 ± 4) °C in the function test in C.16.1.

c) Have an agent discharge quantity at list 90 % of the average agent discharge quantity determined at (21 ± 4) °C in the discharge test in C.16.5.

The discharge time shall be in accordance with the function requirements as specified in the function test.

Annex D
(normative)

Extingushing application density/Coverage test procedure

D.1 General

The tests shall be carried out in accordance with Table D.1.

Table D.1 — Tests

Test objective	Enclosure size	Test fires	Tests in accordance with
Aerosol generator distribution verification Min. height/max. protected volume and distance Max. height/max. protected volume and distance	To suit aerosol generator unit size	 heptane test pans heptane test pans	 D.5.1 D.5.2
Extinguishing factor	≥ 100 m³ No side less than 4 m, height: not less than 3,5 m	(a) wood crib	D.6.1
		(b) n-heptane pan	D.6.2
		(c) polymeric sheet (i) PMMA (ii) Polypropylene (iii) ABS (d) Class A compatible wood crib test	D.6.3 D.6.4
Hold time	≥ 100 m³ No side less than 4 m, height: not less than 3,5 m	n-heptane pan	D.7

D.2 Principle

D.2.1 An aerosol generating system shall mix and distribute its extinguishant and shall totally flood the enclosure when tested in accordance with this test method under the maximum design limitations and most severe installation instructions (see also D.2.2).

D.2.2 When tested as described in D.5.1, D.5.2 and D.6.2, an extinguishing system unit shall extinguish all visible flaming within 30 s of the end of extinguishant discharge. When tested as described in D.6.1 and D.6.4, an extinguishing system unit shall extinguish all visible flaming and prevent re-ignition of the fires after a 10 min soaking period (also measured from the end of extinguishant discharge). When tested as described in D.6.3, an extinguishing system unit shall “knock down” the flames within 60 s of the end of extinguishant discharge (that means there are only flames allowed at the top edges of the two inner sheets) and extinguish all visible flaming within 3 min of the end of extinguishant discharge and also prevent re-ignition of the fires after a 10 min soaking period (also measured from the end of extinguishant discharge).

Measures shall be taken to avoid effects of blowing out the fire leading to positive results of the extinguishing test.

As an alternative to direct measurement of the aerosol density, the method using test cans can be used.

In addition to the main test object, eight 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 four 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 two 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 mm 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 with their bottom line going 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.

D.2.3 The tests described herein consider the intended use and limitations of the extinguishing system unit, with specific reference to:

a) the coverage for each aerosol generator unit size;

b) the maximum and minimum height of the protected enclosure for each aerosol generator unit size;

c) location of aerosol generators in the protected area;

d) maximum pressure built up during discharge;

e) maximum discharge time;

f) extinguishing application density for specific fuels;

g) the maximum leakage area to volume ratio that ensures compliance with the hold time requirements.

D.2.4 The tolerance applicable to dimensions specified in the description of test facilities shall be ±5 %, if not otherwise stated.

D.3 Extinguishing system

D.3.1 For the extinguishing tests described in D.6.1, D.6.2, D.6.3, and D.6.4, jet energy from the discharge outlets shall not influence the development of the fire. Therefore, the discharge outlets shall be directed away from the fires.

D.3.2 Adequate pressure relief vents in the form of closeable flaps shall be provided during all tests. Calculations for the minimum vent area as well as location of the vents shall be in accordance with manufacturer's specifications.

D.4 Extinguishing application density

The extinguishing application density for each test is to be 76,9 % (see 5.2) of the intended end use design application density specified in the manufacturer's design and installation instructions at the ambient temperature of (20 ± 5) °C within the enclosure. In the tests described in D.5.1 and D.5.2, the same extinguishing application density shall be used as in the tests described in D.6.2. The application density for the test described in D.7 is to be the intended end use design application density specified in the manufacturer's design and installation instructions at the ambient temperature of (20 ± 5) °C within the enclosure.

In the tests according to D.6.1, D.6.2, D.6.3 and D.6.4, it is necessary to ensure that the main test object has been extinguished by the agent density and that the agent is distributed homogenously. The homogenous distribution shall be verified by measurements.

As an alternative to direct measurement of the aerosol density, the method using test cans as described in D.6.2 can be used.

If test cans are used for verification of the homogenous distribution (see D.6.2) in the tests according to D.6.1, D.6.2, D.6.3 and D.6.4, the same aerosol extinguishing density and the same type, size and placement of generators shall be used (in order to transfer the verified homogenous distribution from the heptane pan test to the others).

The exact volume shall match the intended application quantity of the extinguishing units used for the test described in D.7.

D.5 Aerosol generator distribution verification tests

D.5.1 Minimum height/maximum coverage test

D.5.1.1 Test facility

D.5.1.1.1 Construction

The test enclosure shall meet the following requirements.

a) The area ($a \times b$) and height (H) of the enclosure (see Figure D.1) shall correspond to the maximum area coverage and minimum height specified by the manufacturer for a specific aerosol generator unit size.

b) Test room volume shall be determined from the result of the heptane fire test (see D.6.2):

$$V_{\text{test}} = \frac{M}{0{,}769 \cdot R_{\text{max}}} \quad (\text{m}^3) \qquad \text{(D.1)}$$

where

M is the generator's effective mass of extinguishant in grams;

R_{max} is the design application density, in grams per cubic metre.

c) Area sides a and b shall be calculated to fulfill the following requirements:

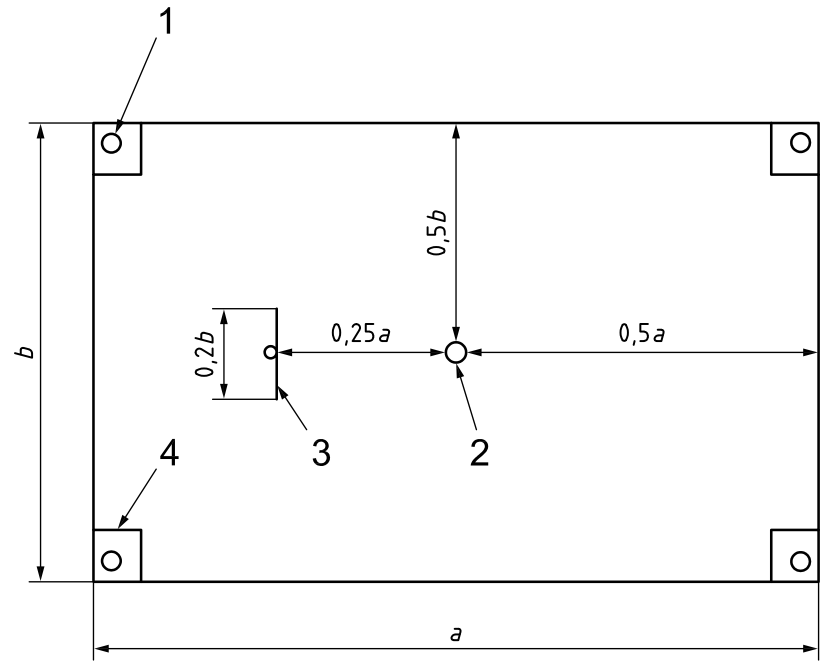
$$a \times b = \frac{V_{\text{test}}}{H} \qquad \text{(D.2)}$$

The distance c (see Figures D.1 and D.2) shall be equal to maximum coverage distance (R_{max}) specified by the manufacturer.

d) Means of pressure relief shall be provided.

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

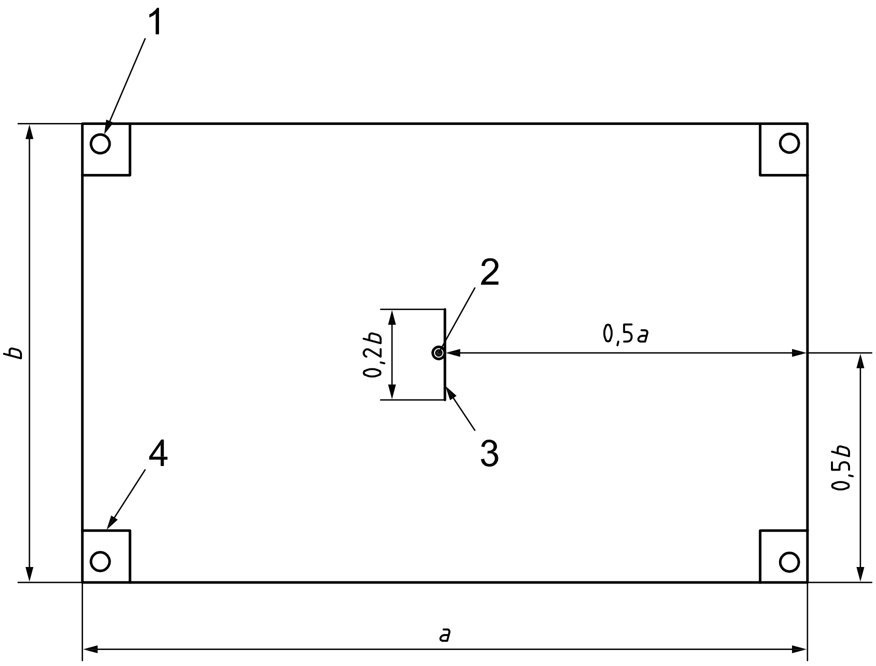
f) One baffle is to be installed between the floor and ceiling with the height of the room. It is to be installed halfway between the discharge outlet location and the walls of the enclosure (see Figure D.1 for centre mounting generator and Figure D.2 for side mounting generator). The baffle is to be perpendicular to the direction between the discharge outlet location and walls of the enclosure (see Figures D.1 and D.2), and be 20 % of the length of the short wall of the enclosure.



Key

$a \times b$	maximum generator area coverage for a single generator
1	test pans
2	generator
3	baffle
4	vents

Figure D.1 — Example configuration for generator minimum height/maximum coverage test for centre mounting generator



Key

$a \times b$ maximum generator area coverage for a single generator

1 test pans

2 generator

3 baffle

4 vents

Figure D.2 — Example configuration for generator minimum height/maximum coverage test for side mounting generator

D.5.1.1.2 Instrumentation

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

D.5.1.1.3 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 D.3 and D.4). The three sensors shall be located in a horizontal distance from the centre of the room 850 mm to 1 250 mm and in the following heights: 0,1 × H, 0,5 × H and 0,9 × H (H = height of the enclosure) above the floor.

D.5.1.1.4 Discharge pressure

The pressure built up in the test enclosure during system discharge shall be measured and recorded.

D.5.1.1.5 Enclosure temperature

At least the temperature in a horizontal distance from the centre of the room of 850 mm to 1 250 mm and 0,5 × H (H = room height) above the floor shall be recorded (Figures D.3 and D.4).

The use of K type thermocouples (Ni-CrNi), diameter 1 mm, is recommended.

D.5.1.1.6 Aerosol temperature and discharge times

A thermocouple shall be placed just outside the discharge outlet of the aerosol generator to record aerosol temperature at the outlet as well as commencement and end of the aerosol discharge. Additional thermocouples may be placed at the minimum thermal clearance from the discharge outlet as specified by the manufacturer for each unit size of the aerosol generators.

The use of K type thermocouples (Ni-CrNi), diameter 1 mm, is recommended.

D.5.1.1.7 Flame out times

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.

A thermocouple can be located centrally 30 mm above each fire pot to provide additional information.

Dimensions in millimetres

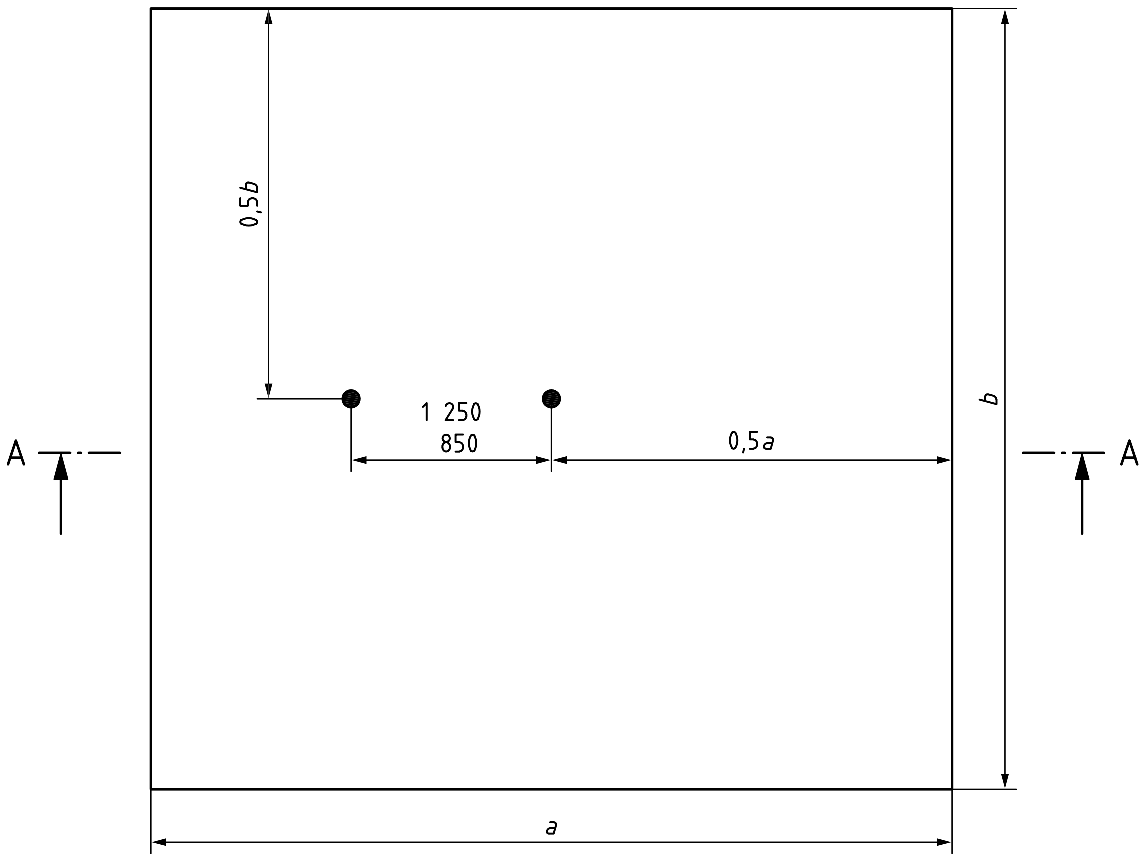
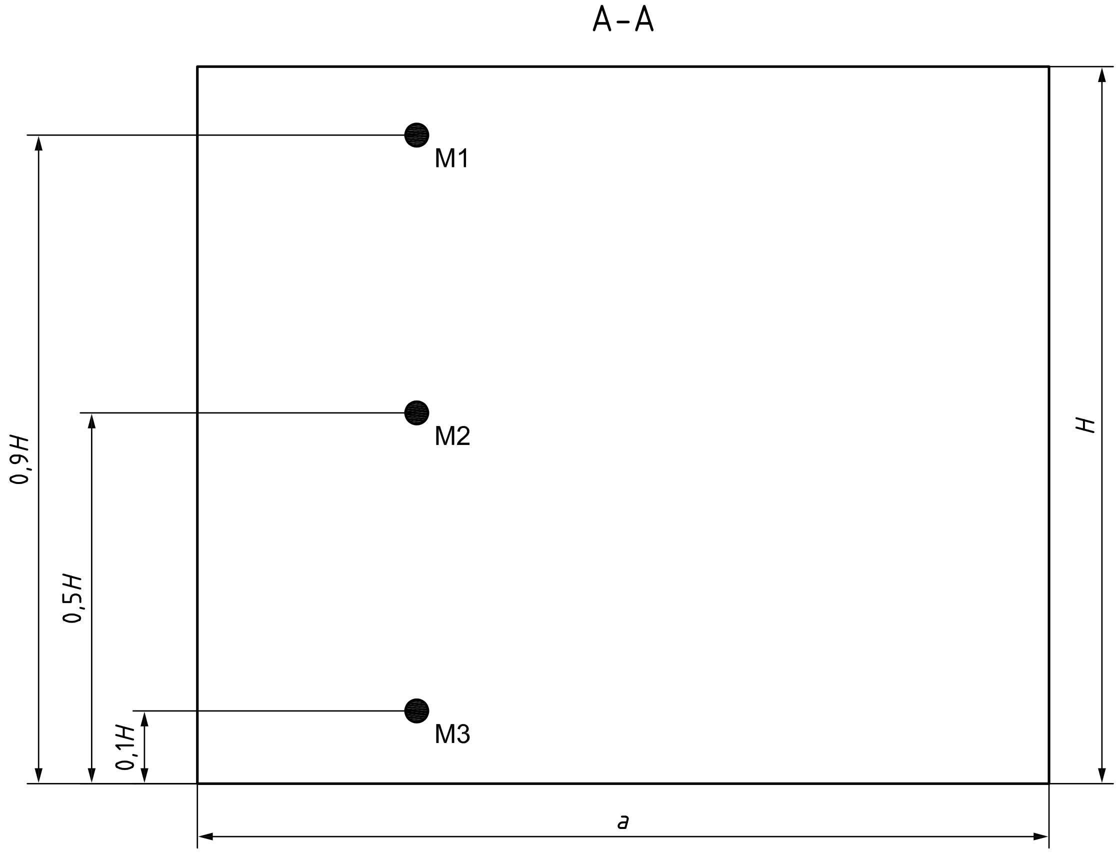


Figure D.3 — Plan view of instrumentation placement for generator minimum height/maximum area coverage and maximum height/maximum area coverage test

Dimensions in millimetres



Key

M1 At measuring point 1, record the O_2 concentration.

M2 At measuring point 2, record the O_2 concentration and temperature.

M3 At measuring point 3, record the O_2 concentration.

Figure D.4 — Side view of instrumentation placement for generator minimum height/maximum area coverage and maximum height/maximum area coverage test

D.5.1.2 Fuel specification

D.5.1.2.1 Test pans

The test cans are to be cylindrical (80 ± 5) mm in diameter and at least 100 mm high made of mild or stainless steel with a thickness of 5 mm to 6 mm.

D.5.1.2.2 n-Heptane

The heptane used shall have the following characteristics.

a) Distillation

 1) Initial boiling point: 90 °C minimum.

 2) Dry point: 100 °C maximum.

b) Density (at 15,6 °C): (700 ± 50) kg/m^3.

D.5.1.2.3 Fire configuration and placement

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

The test cans are to be placed within 50 mm of the corners of the test enclosure and directly behind the baffle (see Figures D.1 and D.2), and located vertically within 300 mm of the top or bottom of the enclosure, or both top and bottom if the enclosure permits such placement.

D.5.1.3 Test procedure

D.5.1.3.1 General

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

D.5.1.3.2 Operation

The heptane-filled test pans are to be ignited and allowed to burn for 30 s with the closeable openings above in the open position.

After 30 s 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 measured oxygen concentration in this test (averaged over the three sensors).

D.5.1.3.3 Results recording

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

a) the discharge time of extinguishant, in seconds;

b) the time required to achieve extinguishment, in seconds. This time shall be determined by visual observation, thermocouple readings or other suitable means.

D.5.1.4 Determination of distribution performance of the generator

Using the extinguishing factor for n-heptane determined according to D.5.2, all test cans shall be extinguished within 30 s after the end of agent discharge.

D.5.2 Maximum height test

D.5.2.1 Test facility

D.5.2.1.1 Construction

The test enclosure shall meet the following requirements:

a) The area ($a \times b$) and height (H) of the enclosure (see Figure D.1) shall correspond to the maximum area coverage and maximum height specified by the manufacturer for a specific aerosol generator's unit size.

b) Test room volume shall be determined from the result of heptane fire test (see D.6.2):

$$V_{\text{test}} = \frac{M}{0{,}769 \cdot c} \quad (\text{m}^3) \qquad \text{(D.3)}$$

where

M is the generator's effective mass of extinguishant in grams;

c is the design factor, in grams per cubic metre.

c) Area sides a and b shall be calculated to fulfill the following requirements:

$$a \times b = \frac{V_{\text{test}}}{H}$$

The distance R_{max} (see Figures D.1 and D.2) shall be equal to maximum coverage distance specified by the manufacturer and shall be the same as specified for minimum height.

d) Means of pressure relief shall be provided.

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

f) One baffle is to be installed between the floor and the ceiling with the height of the room. It is to be installed halfway between the nozzle location and the walls of the enclosure (see Figure D.1 for centre mounting generator and Figure D.2 for side mounting generator). The baffle is to be perpendicular to the direction of nozzle discharge and be 20 % of the length of the short wall of the enclosure.

D.5.2.1.2 Instrumentation

Instrumentation of the enclosure is as described in D.5.1.1.2.

D.5.2.2 Fuel specification

D.5.2.2.1 Test cans

Specification of test cans is as described in D.5.1.2.1.

D.5.2.2.2 Heptane

The grade of heptane is specified in D.5.1.2.2.

D.5.2.2.3 Fire construction and placement

The test can filling requirements and placement within the enclosure are as described in D.5.1.2.1.

D.5.2.3 Test procedure

D.5.2.3.1 General

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

D.5.2.3.2 Operation

The heptane-filled test pans are to be ignited and allowed to burn for 30 s with the closeable openings above in the open position.

After 30 s, 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 measured oxygen concentration in this test (averaged over the three sensors).

D.5.2.3.3 Results recording

Results are to be recorded as specified in D.5.1.3.3.

D.5.2.4 Determination of distribution performance of the generator

Using the extinguishing factor for heptane, determined according to D.6.2, all test pans shall be extinguished within 30 s after the end of agent discharge.

D.6 Extinguishing application density tests

D.6.1 Wood crib test

D.6.1.1 Test facility

D.6.1.1.1 Construction

The test enclosure shall meet the following requirements:

a) the test enclosure shall have a minimum volume of 100 m^3. The height shall be at least 3,5 m. The floor dimensions shall be at least 4 m wide by 4 m long;

b) a means of pressure relief shall be provided;

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.

D.6.1.1.2 Instrumentation

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

D.6.1.1.3 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 D.5 and D.6). One sensor shall be located at the equivalent height of the top of the test object from the floor, 0,6 m to 1 m away from the test object. The other two sensors shall be located at 0,1 × H and 0,9 × H (with H = height of the enclosure) See Figures D.5 and D.6.

D.6.1.1.4 Discharge pressure

The pressure built up in the test enclosure during system discharge shall be measured and recorded.

D.6.1.1.5 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 (see Figures D.5 and D.6).

The use of K type thermocouples (Ni-CrNi), diameter 1 mm, is recommended.

D.6.1.1.6 Aerosol temperature and discharge times

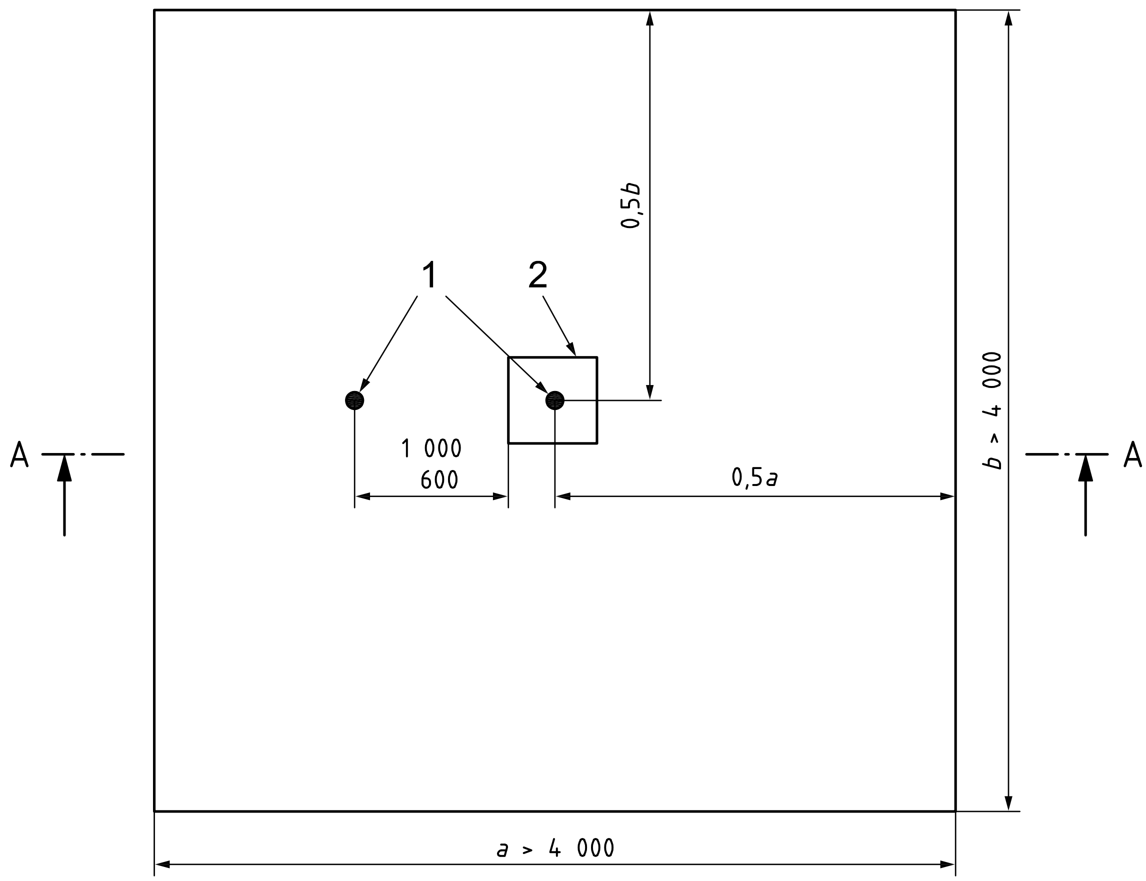
A thermocouple shall be placed just outside the discharge outlet of the aerosol generator to record aerosol temperature at the outlet as well as commencement and end of aerosol discharge. Additional thermocouples may be placed at the minimum thermal clearance from the discharge outlet as specified by the manufacturer for each unit size of the aerosol generators.

The use of K type thermocouples (Ni-CrNi), diameter 1 mm, is recommended.

D.6.1.1.7 Flame out times

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. Thermocouples may be located 30 mm above and inside the wood crib in order to aid in determining flame out time (see Figures D.5 and D.6).

Dimensions in millimetres



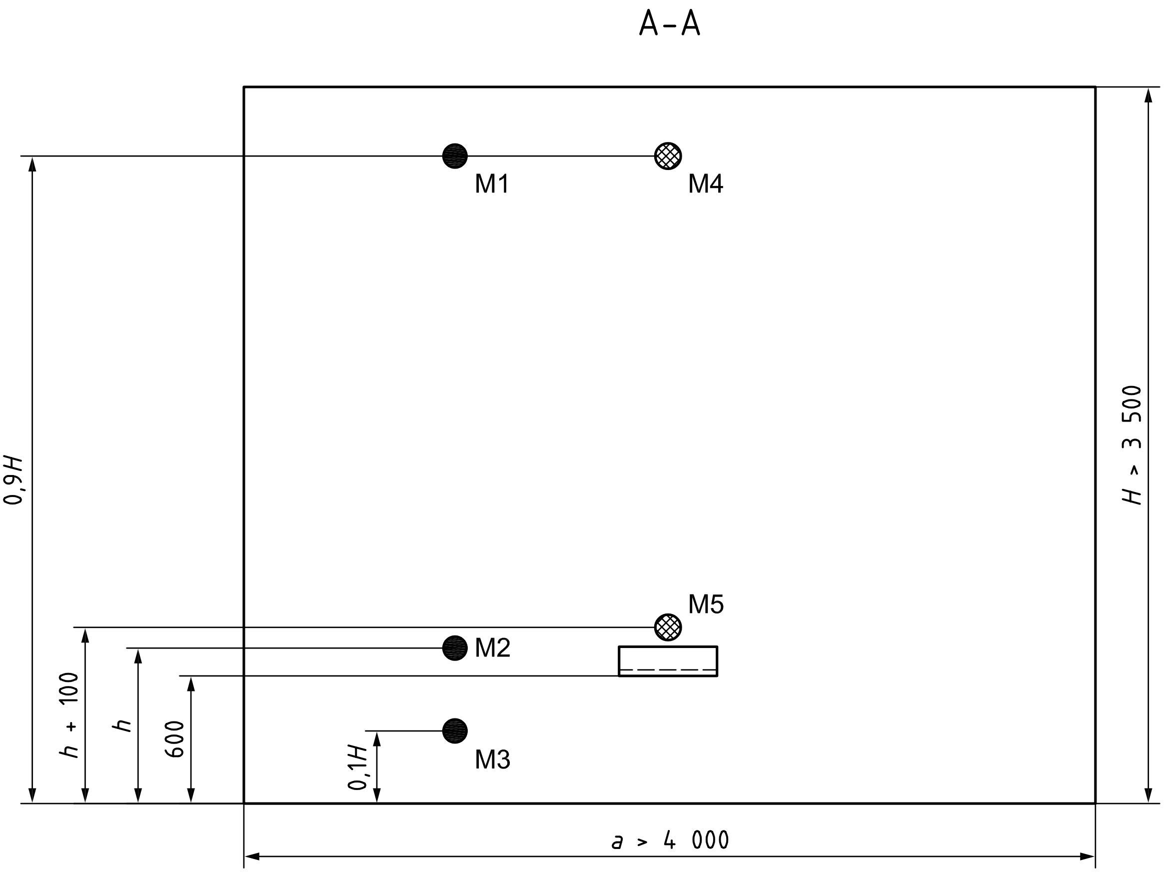
Key

1 measuring point

2 test object

Figure D.5 — Plan view of instrumentation placement for the extinguishing factor test

Dimensions in millimetres



Key

M1 At measuring point 1, record the O_2 concentration.

M2 At measuring point 2, record the O_2 concentration and temperature.

M3 At measuring point 3, record the O_2 concentration.

M4 At measuring point 4, record the temperature.

M5 At measuring point 5, record the temperature.

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

D.6.1.2 Fuel specification

D.6.1.2.1 Crib igniter fuel

Ignition of the crib is achieved by burning 1,5 l of heptane (specified in D.5.1.2.2) on a 12,5 l layer of water in a square steel pan 0,25 m^2 in area, 100 mm in height and with a wall thickness of 6 mm (see Figure D.7).

Dimensions in millimetres

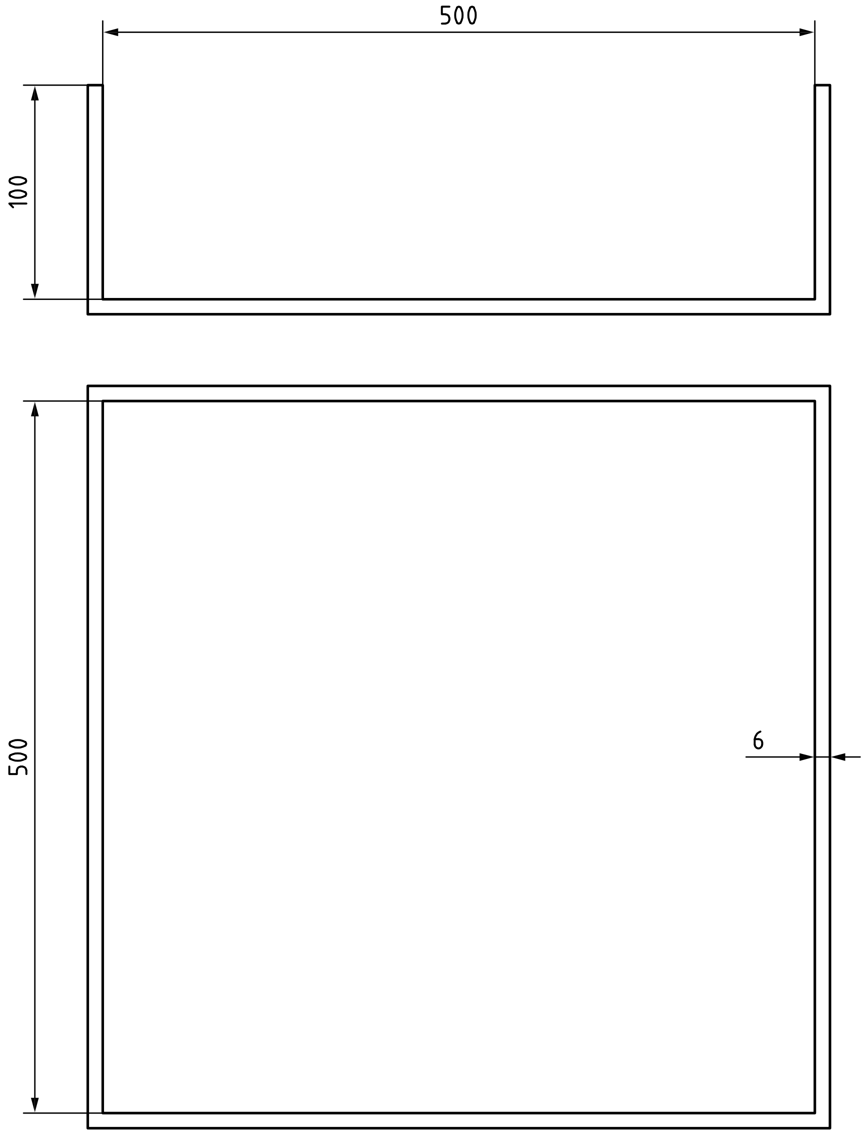


Figure D.7 — Pan geometry for wood crib and n-heptane pan fire test

D.6.1.2.2 Fire configuration and placement

The wood crib shall consist of four layers of six, approximately 40 mm × 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 D.6.1.3.2).

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 D.6.1.3.2).

D.6.1.3 Test procedure

D.6.1.3.1 General

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

D.6.1.3.2 Operation

Centre the crib with the bottom of the crib approximately 300 mm above the top of the pan on a test stand constructed 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, or sun. The maximum wind speed in the proximity of the fire shall be 3 m/s. If necessary, adequate means for protection against wind, etc., shall be used. Record the weather conditions including location of pre-burn, air temperature, humidity and wind speed.

Ignite the n-heptane and allow the crib to burn freely. The 1,5 l of n-heptane will provide a burn time of approximately 3 min. After the n-heptane is exhausted, the crib shall be allowed to burn freely for an additional time of 3 min resulting in a total pre-burn time of $6^{+0,1}_{0}$ min 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 s.

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 by more than 1,5 vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

From the end of system discharge, the enclosure is to remain sealed for a total of 10 min. 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;

c) mass of the crib after the test.

If necessary, amend the aerosol extinguishing factor and repeat the experimental programme until three successive, successful extinguishments are achieved.

D.6.1.3.3 Results recording

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

a) the discharge time of extinguishant, in seconds;

b) the time required to achieve extinguishment, in seconds. This time shall be determined by visual observation, thermocouples readings or other suitable means;

c) the soaking time (time from the end of system discharge until the opening of the test enclosure);

d) recording the temperature profile of the wood crib, using the infrared camera, is recommended.

D.6.1.4 Determination of extinguishant design application density

The laboratory extinguishing application density is that which achieves satisfactory extinguishment of the fire over three successive tests (no re-ignition or existence of burning embers after 10 min after end of discharge). The design application density is the laboratory extinguishing factor multiplied by an appropriate “safety factor”.

The extinguishing application density shall be calculated by dividing the total generator’s effective mass of extinguishant installed by the test room volume.

D.6.2 Heptane pan test

D.6.2.1 Test facility

D.6.2.1.1 Construction

Construction of the enclosure is as described in D.6.1.1.1.

D.6.2.1.2 Instrumentation

Instrumentation of the enclosure is as described in D.6.1.1.2.

D.6.2.2 Fuel specification

D.6.2.2.1 Heptane

The grade of heptane is specified in D.5.1.2.2.

D.6.2.2.2 Fire configuration and placement

The fire test can shall be a square steel can of 0,25 m^2, 100 mm high with a wall thickness of 6 mm as specified in D.6.1.2.1. The test can shall contain 12,5 l of n-heptane. The resulting n-heptane surface is then 50 mm below the top of the can.

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.

D.6.2.3 Test procedure

D.6.2.3.1 General

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

D.6.2.3.2 Operation

The heptane is to be ignited and allowed to burn for 30 s.

The heptane in the test cans shall be ignited at the same time or before the main pan. The first test can shall be ignited at a maximum of 60 s before the main pan.

After 30 s 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 by more than 1,5 vol% due to fire products. This change shall be determined by comparing the oxygen concentration measured in the cold discharge test with the oxygen concentration measured in this fire test (averaged values).

The test is only positive if the main test object is extinguished later than the test cans are extinguished or at a maximum of 10 s earlier.

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

D.6.2.3.3 Results recording

Results are to be recorded as specified in D.6.1.3.3 with the exception of d).

D.6.2.4 Determination of extinguishant design application density

The laboratory extinguishing application density is that which achieves satisfactory extinguishment of the fire over three successive tests (no flaming 30 s after the end of extinguishant discharge). The design factor is the laboratory extinguishing factor multiplied by an appropriate safety factor.

Extinguishing application density shall be calculated by dividing the total generator's effective mass of extinguishant installed by the test room volume.

D.6.3 Polymeric sheet fire test

D.6.3.1 Test facility

D.6.3.1.1 Construction

Construction of the enclosure is as described in D.6.1.1.1.

D.6.3.1.2 Instrumentation

Instrumentation of the enclosure is as described in D.6.1.1.2.

D.6.3.2 Fuel specification

D.6.3.2.1 Igniter fuel

The ignition source is a heptane pan (constructed of 2 mm thick mild or stainless steel) with inside to inside 51 mm × 112 mm and 21 mm deep centred 12 mm below the bottom of the plastic sheets of polymeric fuel (see Figures D.8 and D.9). 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 heptane (specified in D.6.1.2.2) on a water base of 40 ml.

D.6.3.2.2 Polymeric fuel

Tests are to be conducted with three plastic fuels:

— polymethyl methacrylate (PMMA);

— polypropylene;

— acrylonitrile-butadiene-styrene polymer (ABS).

Plastic properties are given in Table D.2.

Table D.2 — Plastic properties
25 kW/m² **exposure in cone calorimeter — ISO 5660-1 cone calorimeter test**

Fuel	Colour	Density	Ignition time		180 s average Heat release rate		Effective Heat of combustion	
		g/cm³	s	Tolerance	kW/m²	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 %

D.6.3.2.3 Polymeric fuel array

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

— polymethyl methacrylate (PMMA): (10 ± 1) mm;

— polypropylene (PP): (10 ± 1) mm;

— acrylonitrile-butadiene-styrene polymer (ABS): (10 ± 1) mm.

Sheets are spaced and located as per Figure D.8. 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.

The fuel array shall be located centrally within the enclosure.

D.6.3.2.4 Fuel shield

A fuel shield consisting of a metal frame with sheet metal on the top and two sides shall be provided around the fuel array as indicated in Figures D.8 and D.9. The fuel shield is 380 mm wide, 850 mm high and 610 mm deep. The 610 mm (wide) × 850 mm (high) sides and the 610 mm × 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 mm to 3 mm.

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

D.6.3.2.5 External baffles

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

D.6.3.3 Test procedure

D.6.3.3.1 General

Prior to commencing tests the composition of the extinguishing aerosol shall be analysed. Record the mass of the plastic sheets prior to the test.

D.6.3.3.2 Operation

The n-heptane is ignited and allowed to burn completely. All openings are to be closed and the extinguishing system is to be manually actuated 210 s after ignition of the n-heptane.

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).

The enclosure is to remain sealed for a total of 10 min 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) mass of the fire structure after the test.

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

D.6.3.3.3 Results recording

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

a) The discharge time of extinguishant, in seconds.

b) The time required to achieve extinguishment, in seconds. This time shall be determined by visual observation, thermocouples readings or other suitable means.

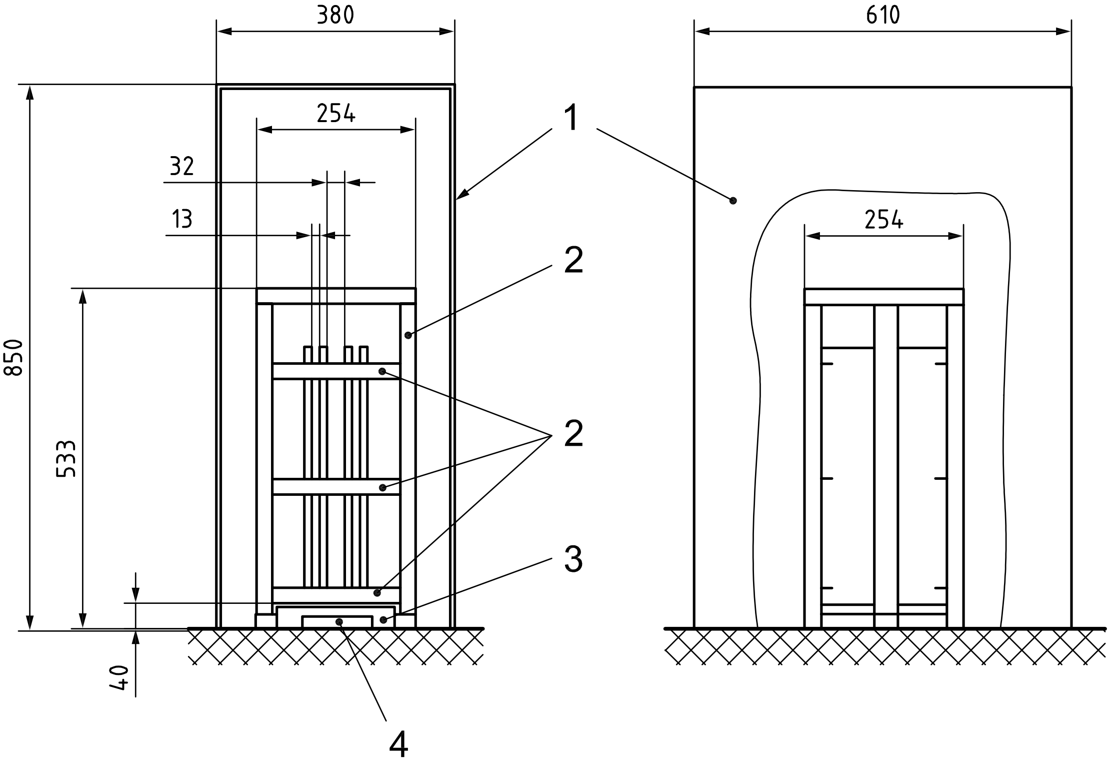
c) The soaking time (time from the end of system discharge until the opening of the test enclosure).

D.6.3.4 Determination of the extinguishant design application density

The laboratory extinguishing application density for each fuel is that which achieves satisfactory extinguishment of the fire over three successive tests (flame knock down within 60 s, no flaming after 180 s, and no re-ignition after 10 min, all from end of discharge).

The design application density is the highest of the laboratory extinguishing factors for the three fuels (see D.6.3.2.2) multiplied by an appropriate safety factor. Extinguishing application density shall be calculated by dividing the total mass of aerosol generator's effective mass of extinguishant installed by the test room volume.

Dimensions in millimetres



Key

1 channel metal frame covered with metal sheeting on top and two sides

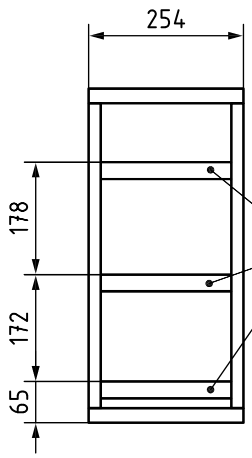
2 metal angle frame

3 fuel guide bars

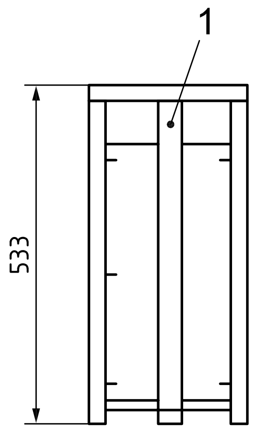
4 load cell

Figure D.8 — Polymeric sheet fire

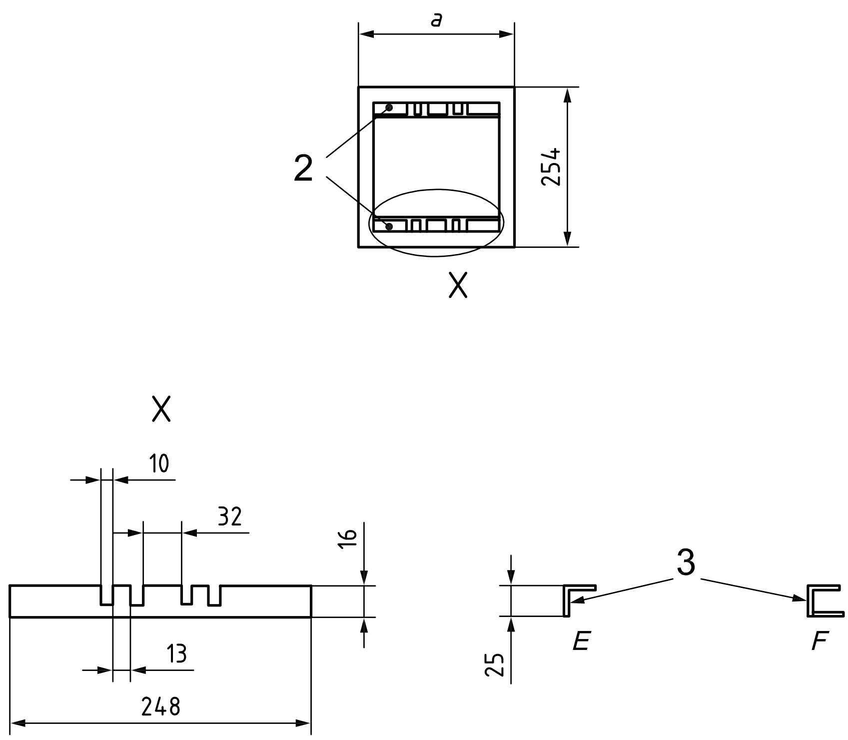
Dimensions in millimetres



a) Front



b) Side



c) Plan and load cell details

Key

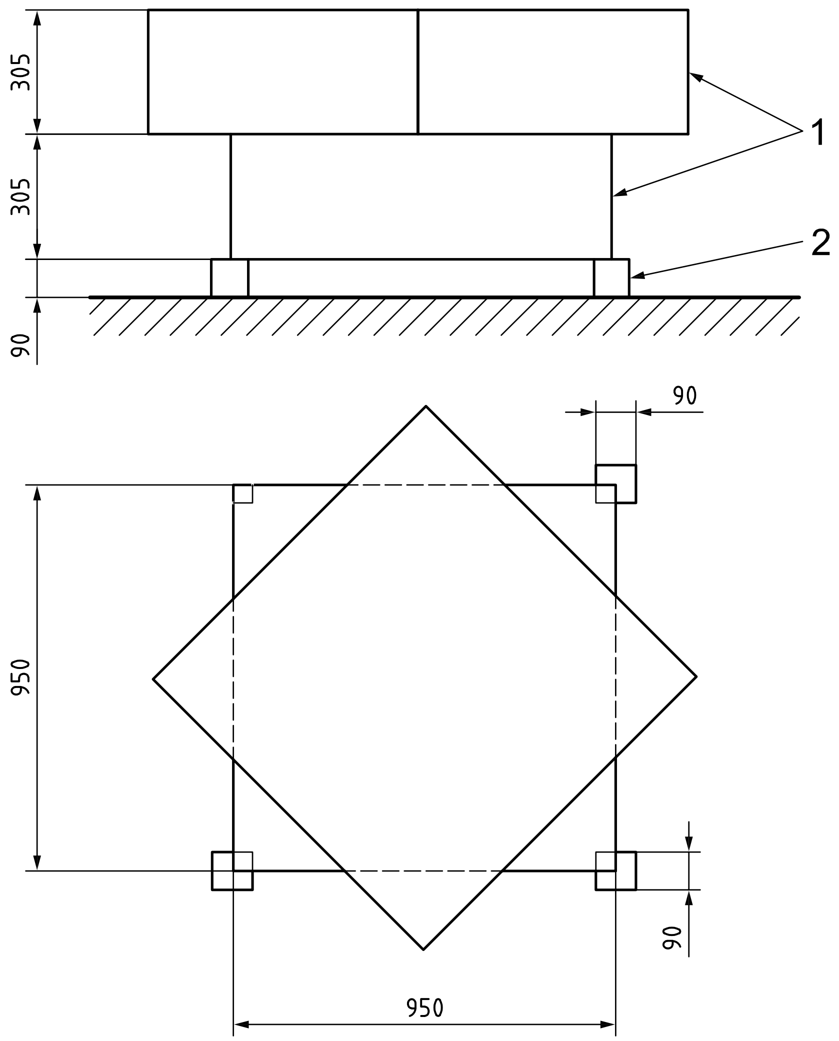
1 metal angle frame

2 load cell

3 fuel guide bars

Figure D.9 — Support rack for plastic sheets

Dimensions in millimetres



Key

1 polycarbonate or metal baffles

2 cinder block

Figure D.10 — Polymeric sheet fire baffle arrangement

D.6.4 Class A compatible wood crib test

D.6.4.1 Fuel configuration

This Class A compatible fire test shall consist of two wood cribs, each measuring 0,3 m × 0,3 m × 0,3 m. The crib shall consist of eight alternate layers of four trade size 3,8 cm by 3,8 cm kiln-dried spruce or fir lumber 0,3 m long. The alternate layers of lumber shall be placed at right angles to the adjacent layers. The individual wood members in each layer are to be evenly spaced along the length of the previous layer of wood members and fastened by staples or nails.

The wood cribs shall be preconditioned to have a moisture content of 9 % and 13 % by weight.

D.6.4.2 Fuel placement

One crib is to be placed behind a baffle installed between the floor and ceiling at the midpoint between the direction of discharge and a wall. The baffle is to be perpendicular to the direction of nozzle discharge, and be 20 % of the length or width of the enclosure, whichever is applicable with respect to discharge location. The crib is to be placed on a stand and supported by four 5,1 cm bricks placed at each corner of the crib such that the bottom of the crib is 50 mm above the floor. The crib shall have a 113,5 g mass of shredded newspaper placed under the crib in the centre of the four blocks.

One crib is to be placed on a stand in the centre of the enclosure and supported by four 5,1 cm bricks placed at each corner of the crib such that the bottom of the crib is 50 mm above the floor. The crib shall have a 113,5 g mass of shredded newspaper placed under the crib in the centre of the four bricks.

D.6.4.3 Fuel shield

A fuel shield consisting of a metal frame with sheet steel on the top shall be provided around the crib located in the centre of the enclosure as indicated in Figures D.11 and D.12. The fuel shield is to be 76 cm wide, 82,5 cm high and 76 cm deep. The 76 cm by 76 cm top is to be sheet steel. The remaining four sides and the bottom are to be open.

Two external baffles measuring 1 m square and 30 cm tall are to be located around the exterior of the fuel shield as shown in Figures D.11 and D.12 The baffles are to be placed 9 cm above the floor. The lower baffle is to be oriented with its sides parallel to the fuel shield and the top baffle is to be rotated 45° with respect to the bottom baffle.

A baffle is to be installed between the floor and ceiling at the midpoint between the centre of the enclosure and a wall parallel to the baffle width. The floor to ceiling baffle width is to be 20 % of the length of the walls parallel to the baffle as indicated in Figures D.11 and D.12.

The two cribs are to be placed on the floor supported by four 5,1 cm high bricks, one at each corner of the crib as indicated in Figures D.11 and D.12. One of the cribs is to be centred between the two walls perpendicular to the floor to ceiling baffle with two sides of the crib parallel to the floor to ceiling baffle and the centre of the crib located 45 cm behind the floor to ceiling baffle relative to the centre of the enclosure. The other crib is to be centred in the enclosure.

D.6.4.4 Test procedure

D.6.4.4.1 General

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

D.6.4.4.2 Operation

D.6.4.4.2.1 Aerosol generator placement

The aerosol generator(s) shall be installed under the maximum design limitations and most severe installation instructions according to the methods specified in the manufacturer's design and installation instructions. For the Class A wood crib fire tests, the aerosol generator(s) shall be installed on the side of the enclosure opposite the crib located behind the floor to ceiling baffle.

The aerosol generator(s) are to be conditioned to (70 ± 5) °F [(21 ± 2,8) °C].

D.6.4.4.2.2 Fuel ignition

Each crib shall have a 113,5 g mass of shredded newspaper placed under the crib in the centre of the four bricks and 236 ml of denatured ethyl alcohol is to be poured over each crib and paper, and then ignited.

D.6.4.4.2.3 Pre-burn

After ignition, each crib is to be allowed to burn for 2 min. The percent of oxygen is to be measured by a calibrated analyser at locations which are at the same height as the wood cribs and centred from the edge of the crib to the near wall. Two additional measurements are to be made at 0,1 H and 0,9 H, with H being the height of the enclosure. Just prior to discharging agent into the enclosure, the vents, except for the pressure relief, are to be quickly closed and the aerosol generator system is to be manually actuated. At the time of system discharge, the percent oxygen within the enclosure at the level of the cribs is to be within 0,5 units of the normal oxygen level at atmospheric conditions.

D.6.4.4.2.4 Aerosol generator actuation

Except for the pressure relief, the vents are to be closed and the system is to be actuated. At the time of actuation, the percent oxygen within the enclosure at the level of the crib shall be within 0,5 units of the normal oxygen level at atmospheric conditions. The percent of oxygen is to be measured by a calibrated analyser at a location which is at the same height as the bottom of the wood crib and centred from the edge of the crib to the wall. Two additional measurements are to be made at 0,1 H and 0,9 H, with H being the height of the enclosure.

D.6.4.4.2.5 Results recording

The following shall be recorded:

— presence and location of burning embers;

— whether or not the glowing embers or crib re-ignite;

— mass of the crib after the test.

If necessary, amend the aerosol extinguishing factor and repeat the experimental programme until three successive, successful extinguishments are achieved.

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

a) The discharge time of extinguishant, in seconds.

b) The time required to achieve extinguishment, in seconds. This time shall be determined by visual observation, thermocouples readings or other suitable means.

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

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

D.6.4.4.2.6 Pass/fail criteria

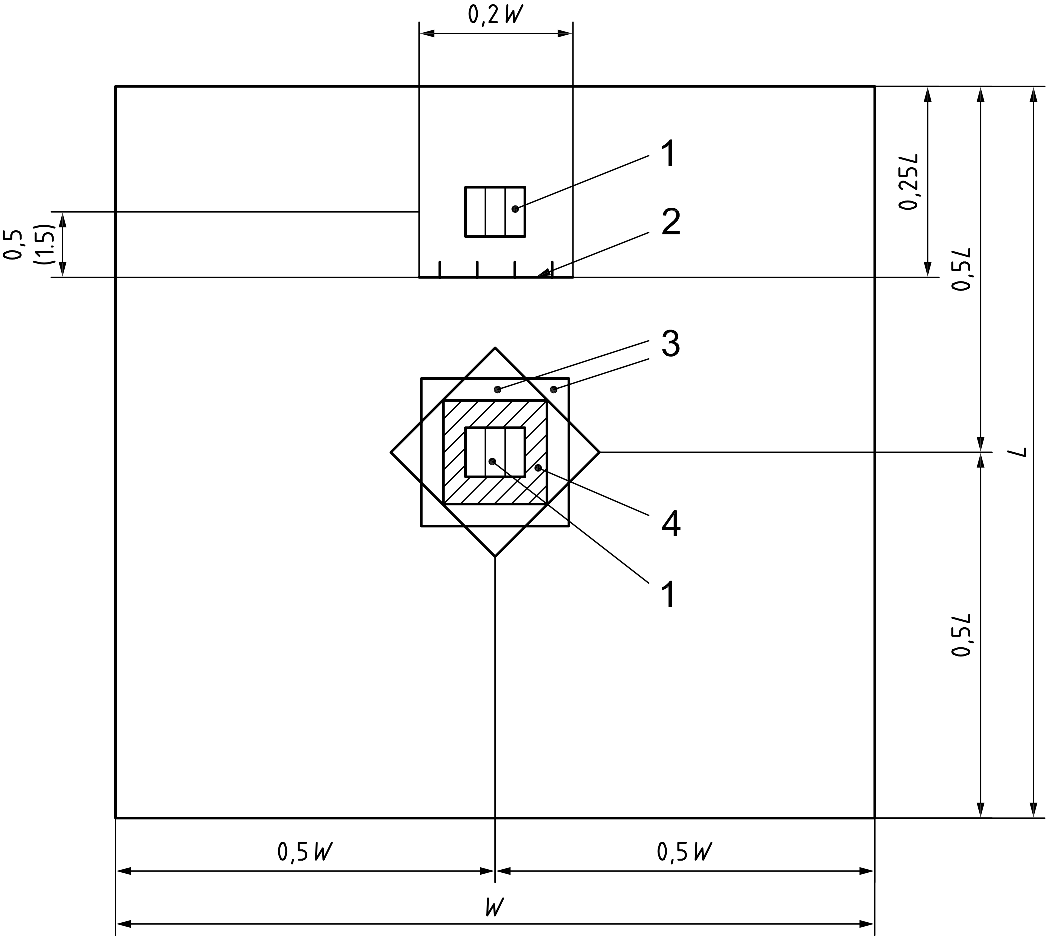
After the start of system discharge, observations shall be made for crib extinguishment. The enclosure is to remain sealed for a total of 600 s after the end of discharge. After the 600 s soak period, the cribs are to be quickly removed from the enclosure, and observed to determine whether fuel remains to sustain combustion and for signs of re-ignition.

D.6.4.4.2.7 Determination of the extinguishant application density

The laboratory extinguishing application density is that which achieves satisfactory extinguishment of the fire over three successive tests (no re-ignition or existence of burning embers after 10 min after end of discharge). The design application density is the laboratory extinguishing factor multiplied by an appropriate “safety factor”.

The extinguishing application density shall be calculated by dividing the total generator’s effective mass of extinguishant installed by the test room volume.

The extinguishing application density for each test shall be 76,92 % of the intended end use design application density or densities specified in the manufacturer’s design and installation instructions.



Key

1 wood crib location

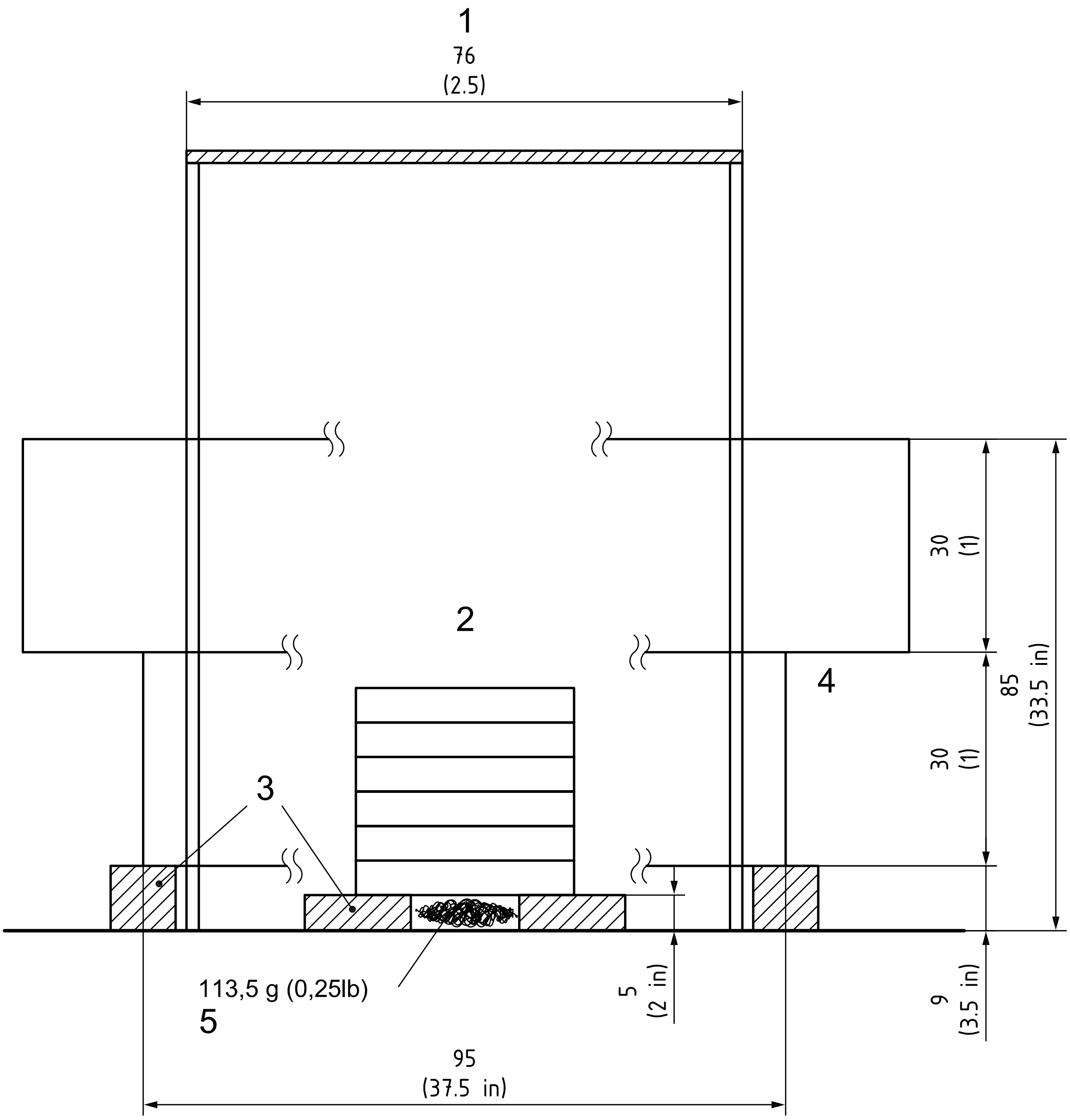
2 floor-to-ceiling baffle

3 polycarbonate baffles

4 fuel shield

Figure D.11 — Wood crib locations — Plan view

Dimensions in centimetres



Key

1 table baffle

2 wood crib (eight layers of four members - Trade 5 & 5 & 30 cm/2 & 2 & 12 in)

3 brick

4 polycarbonate baffles

5 shredded newspaper

Figure D.12 — Centre wood crib detail — Elevation view

D.7 Test of the determination of the maximum leakage area/volume ratio

D.7.1 Principle

An engineered or pre-engineered aerosol extinguishing formulation shall be able to keep extinguishing conditions for the hold time when tested in accordance with this test method under the maximum design limitations and most severe installation instructions.

The test is based on the ability of the extinguishing unit to prevent ignition of heptane cans distributed through the enclosure.

D.7.1.1 Test facility

D.7.1.1.1 Construction

Construction of the enclosure is as described in D.6.1.1.1.

Two identical open areas shall also be provided, one on the ceiling of the enclosure and the other on the bottom centre opposite on the short side of the enclosure. The shape shall be square or rectangular with a base:height maximum ratio of 2:1. The sum of the two areas will be taken as the leakage area.

D.7.1.1.2 Instrumentation

Instrumentation of the enclosure is as described in D.6.1.1.2. Cameras or an alternative method described for flame out time in D.6.1.1.7 shall be used to determine the appearance of flames. All cans described shall be monitored.

D.7.1.2 Fuel specification

D.7.1.2.1 n-Heptane

The n-heptane is commercial grade as specified in D.5.1.2.2.

D.7.1.2.2 Fire configuration and placement

Test cans will be as described in D.5.1.2.1.

The test pans may contain either n-heptane or n-heptane and water. If they are to contain n-heptane and water, the n-heptane is to be at least 50 mm deep. The level of n-heptane in the pans shall be at least 50 mm below the top of the can.

Two sets of three test cans are to be placed within 500 mm of two walls. One set will be located opposite to the other and for each set the cans will be located at 10 %, 50 % and 90 % of the height of the enclosure.

Means for remote ignition shall be provided for each of the test cans.

D.7.1.3 Test procedure

D.7.1.3.1 General

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

D.7.1.3.2 Operation

The extinguishing system is to be manually actuated.

Prior to the expected hold time, all the remote ignitors will begin to actuate and the time at which it is done is to be recorded at given intervals (e.g. 5 s).

D.7.1.3.3 Results recording

Record the following data for each test.

a) The discharge time of extinguishant, in seconds.

b) The time at which each actuation of the ignitors is produced, in seconds.

c) The time required for the first can to ignite, in seconds. This time shall be determined by visual observation, thermocouples readings or other suitable means.

D.7.1.4 Determination of hold time

The hold time for the test is the time from the end of discharge until the last activation of all the ignitors that did not produce ignition of any of the cans. The test is to be repeated three times. The maximum hold time applicable to the specified leakage area to volume ratio is the shortest hold time obtained from the three tests.

If the hold time obtained is less than 10 min, the test shall be repeated using a smaller leakage area.

Different leakage area values can be tested to provide different hold times for different leakage area to volume ratios.

The parameter(s) obtained shall be given as m² leakage area/m³ volume protected for the specified hold time.

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