INTERNATIONAL STANDARD

ISO 6182-9

First edition
2005-11-01

Fire protection — Automatic sprinkler system —

Part 9: Requirements and test methods for water mist nozzles

Reference number
ISO 6182-9:2005(E)

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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 6182-9 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 5, *Fixed firefighting systems using water*.

ISO 6182 consists of the following parts, under the general title *Fire protection — Automatic sprinkler systems*:

— *Part 1: Requirements and test methods for sprinklers*

— *Part 2: Requirements and test methods for wet alarm valves, retard chambers and water motor alarms*

— *Part 3: Requirements and test methods for dry pipe valves*

— *Part 4: Requirements and test methods for quick-opening devices*

— *Part 5: Requirements and test methods for deluge valves*

— *Part 6: Requirements and test methods for check valves*

— *Part 7: Requirements and test methods for early suppression fast response (ESFR) sprinklers*

— *Part 8: Requirements and test methods for pre-action dry alarm valves*

— *Part 9: Requirements and test methods for water mist nozzles*

— *Part 10: Requirements and test methods for domestic sprinklers*

— *Part 11: Requirements and test methods for pipe hangers*

— *Part 12: Requirements and test methods for grooved end pipe couplings*

— *Part 13: Requirements and test methods for extended coverage sprinklers*

Introduction

This part of ISO 6182 is one of a number of ISO Standards prepared by ISO/TC 21 covering components for automatic sprinkler systems.

They are included in a series of ISO Standards planned to cover the following:

a) carbon dioxide systems,

b) explosion suppression systems,

c) foam systems.

Fire protection — Automatic sprinkler system —

Part 9:
Requirements and test methods for water mist nozzles

1 Scope

This part of ISO 6182 specifies performance requirements, test methods and marking requirements for water mist nozzles.

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 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

ISO 5660-1, *Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method)*

ANSI/UL 723:2003, *Test for surface burning characteristics of building materials*

ASTM E11:2004, *Standard specification for wire cloth and sieves for testing purposes*

ASTM E799:2003, *Standard practice for determining data criteria and processing for liquid drop size analysis*

IMO Resolution A.653(16), *Recommendation on improved fire test procedures for surface flammability of bulkhead, ceiling and deck finish materials*

3 Terms and definitions

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

3.1
assembly load
force exerted on the nozzle body at 0 MPa [0 bar[1)]] hydraulic pressure at the inlet

3.2
conductivity factor
C
measure of the conductance between the nozzle's heat-responsive element and the fitting

NOTE The conductivity factor is expressed in units of $(m/s)^{0,5}$.

3.3
control spaces
shipboard areas such as the bridge, radio room and emergency power room

3.4
corrosion-resistant material
material of bronze, brass, copper-and-nickel-base alloy, stainless steel or plastic

3.5
design load
force exerted on the release element at the service load of the nozzle

3.6
fire control
limiting the growth of a fire and controlling ceiling gas temperatures to prevent structural damage

3.7
fire suppression
sharply reducing the rate of heat release of a fire and preventing its regrowth

3.8
fire extinguishment
zero rate of heat release, definite stoppage of flames and no re-ignition

3.9
flame spread index
FSI
fire-spread characteristic measured in accordance with ANSI/UL 723

3.10
fuel package
combustible materials in which the fire is ignited and the combustible materials covering the walls and ceiling

3.11
low hazard area
area where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected

1) 1 bar = $10^5 N/m^2$ = 0,1 MPa.

3.12
shipboard machinery spaces
engine rooms and cargo pump rooms containing combustible or flammable liquids having fire characteristics no more severe than that of light diesel oil

3.13 Nozzles

3.13.1
automatic nozzle
thermosensitive device designed to react at a predetermined temperature by automatically releasing water mist into a designated area and volume having a response time index (RTI) of not more than 50 $(m \cdot s)^{1/2}$ and a conductivity factor (C) not more than 1,0 $(m/s)^{1/2}$

3.13.2
coated nozzle
nozzle that has a factory applied coating for corrosion protection

3.13.3
fast response nozzle
automatic nozzle having a response time index (RTI) not more than 50 $(m \cdot s)^{1/2}$ and a conductivity factor (C) not more than 1,0 $(m/s)^{1/2}$

3.13.4
fusible element nozzle
nozzle that opens under the influence of heat by the melting of a component

3.13.5
glass bulb nozzle
nozzle that opens under the influence of heat by the bursting of the glass (frangible) bulb through pressure resulting from expansion of the enclosed fluid

3.13.6
multiple orifice nozzle
nozzle having two or more outlet orifices arranged to distribute the water discharge in a specified pattern and quantity for a definite protection area

3.13.7
open nozzle
nozzle without a thermosensitive element

3.13.8
pendent nozzle
nozzle that is arranged in such a way that the water mist is directed initially downward by striking a distribution plate or by nozzle orientation

3.13.9
upright nozzle
nozzle that is arranged in such a way that the water mist is initially directed upwards against a distribution plate

3.14
operating pressure
service pressure at which a nozzle is intended to operate

3.15
rated working pressure
maximum service pressure at which a nozzle is intended to operate, but no less than 1,2 MPa (12 bar)

3.16
protective cap
device attached to the nozzle for the purpose of protecting the nozzle throughout transport and installation but mainly for the protection of the nozzle while in service

3.17
response time index
RTI
measure of automatic nozzle sensitivity

$$\text{RTI} = \tau u^{1/2}$$

where

τ is the time constant of the heat-responsive element, expressed in units of seconds;

u is the gas velocity, expressed in meters per second

NOTE 1 RTI is expressed in units of $(\text{m}\cdot\text{s})^{1/2}$.

NOTE 2 RTI can be used in combination with the conductivity factor (C) to predict the response of a nozzle in fire environments defined in terms of gas temperature and velocity versus time.

3.18
service load
combined force exerted on the nozzle body by the assembly load of the nozzle and the equivalent force of the rated working pressure applied at the inlet

3.19
shipboard passenger cabin
area with sleeping facilities that are assigned to passengers for their private use

3.20
shipboard public space
area where people may gather such as restaurants, dining rooms, lounges, corridors and offices

3.21
shipping cap
device attached to the nozzle for the purpose of protecting the nozzle only during transport and installation

NOTE Shipping caps are not intended to remain on the nozzle after the installation is complete.

3.22
standard hazard area
area where the quantity and combustibility of contents is moderate, stockpiles of combustibles do not exceed 1,5 m and fires with moderate rates of heat release are expected

3.23
standard orientation
orientation where the airflow is perpendicular to both the axis of the nozzle's inlet and the plane of the frame arms, if provided, that produces the shortest response time

3.24
worst-case orientation
orientation that produces the longest response time with the axis of the nozzle inlet perpendicular to the airflow

4 Product consistency

It shall be the responsibility of the manufacturer to implement a quality control program to ensure that production continuously meets the requirements in the same manner as the originally tested samples. Before testing, nozzles shall be examined with respect to marking, conformity to manufacturer's drawings and obvious defects.

Every automatic water mist nozzle shall pass a leak resistance test equivalent to a hydrostatic pressure of at least 2,5 times the rated working pressure, but no less than 3,0 MPa (30,0 bar), applied for at least 2 s.

5 General requirements

5.1 Materials

5.1.1 All water mist nozzles shall be made from corrosion-resistant materials.

5.1.2 A water mist nozzle shall be constructed to effect closure of its water seat for extended periods of time without leakage and to open as intended and release all parts from the minimum operating pressure up to the rated working pressure. For nozzles with intended operating pressures of 1,2 MPa (12 bar) or less, the closure of the water seat shall not be achieved by the use of a dynamic O-ring or similar seal (an O-ring or similar seal that moves during operation or is in contact with a component that moves during operation).

5.2 Prevention of field adjustment

The load on the heat-responsive element in automatic nozzles shall be set by the manufacturer in such a manner so as to prevent field adjustment or replacement. The nozzle orifice/deflector shall be permanently attached to the nozzle so as to prevent field adjustment or replacement.

5.3 Drawing review

The requirements and tests in Clauses 7 and 8 shall be conducted for each type of nozzle. Before testing, precise drawings of parts and the assembly shall be submitted together with the appropriate specifications and a copy of the manufacturer’s design and installation instructions.

5.4 Pipe and fitting threads

5.4.1 Pipe and fitting threads shall conform to the applicable requirements of ISO 7-1.

5.4.2 If International Standards are not applicable, then National Standards are permitted to be used.

5.5 Strainers and filters

5.5.1 All nozzles shall be constructed so that a sphere of diameter 5 mm can pass through each water passage in the nozzle. Nozzle with smaller openings shall utilize an integral strainer with each nozzle.

5.5.2 Nozzle strainers or filters shall be constructed from corrosion-resistant materials. The maximum dimension of an opening in the strainer or filter shall not exceed 80 % of the smallest orifice diameter being protected.

6 Elastomeric materials

6.1 Properties

An elastomer used to provide a water seal shall be tested to determine that it has the following properties.

a) As-received materials, when tested in accordance with ISO 37, shall be of minimum tensile strength of 3,4 MPa for silicone rubber having the characteristic constituent of poly-organo-siloxane and 10,3 MPa for other elastomers.

b) When tested in accordance with ISO 188, the physical properties after oven aging at the time and temperature specified in Table 1 shall be at least 60 % of the original tensile strength and elongation values.

6.2 Test specimen

A part with an inside diameter larger than 25 mm shall be subjected in whole to the above tests. If the size of the actual part is less than 25 mm or otherwise precludes accurate testing, larger samples of similar parts or sheet material made of the same compound are to be subjected to the tests.

Table 1 — Oven ageing

Maximum service temperature °C	Oven time h	Oven temperature °C
60	70	100
75	168	100
80	168	113
90	168	121
105	168	136
115	1 440	123
125	1 440	133
135	1 440	143
145	1 440	153
150	1 440	158
155	1 440	164
165	1 440	174
175	1 440	184
185	1 440	194
195	1 440	204
200	1 440	210
210	1 440	220
220	1 440	230
230	1 440	240
240	1 440	250
250	1 440	260

7 Water mist nozzle requirements (see Clause 8)

7.1 Dimensions

Nozzles shall be provided with a 6 mm or larger nominal inlet thread. The dimensions of all threaded connections shall conform to International Standards where applied. If International Standards are not applicable, National Standards may be used.

7.2 Nominal operating temperatures

7.2.1 The nominal operating temperatures of automatic glass bulb nozzles shall be as indicated in Table 2.

7.2.2 The nominal operating temperatures of automatic fusible element nozzles shall be specified in advance by the manufacturer and verified in accordance with 7.3. They shall be determined as a result of the nominal release temperature test. See 8.6.1. Nominal operating temperatures shall be within the ranges specified in Table 2.

7.2.3 The nominal operating temperature that is to be marked on the nozzle shall be that which is determined when the nozzle is tested in accordance with 8.6.1, taking into account the specifications of 7.3.

Table 2 — Nominal release temperature

Glass bulb nozzles		Fusible element nozzles	
Nominal release temperature °C	Liquid colour code	Nominal release temperature °C	Colour code
57	orange	57 to 77	uncoloured
68	red	80 to 107	white
79	yellow	121 to 149	blue
93 to 107	green	163 to 191	red
121 to 141	blue		
163 to 182	mauve		

7.3 Operating temperatures

Automatic nozzles shall open within a temperature range of $\vartheta \pm (0{,}035\vartheta + 0{,}62)$ °C where ϑ is the nominal operating temperature.

7.4 Water flow and distribution and droplet size

7.4.1 Flow constant (see 8.10)

7.4.1.1 The flow constant K for nozzles shall be calculated by the following formula:

$$K = \frac{q}{p^{0,5}}$$

where

p is the pressure, in bars;

q is the flow rate, in l/min.

7.4.1.2 The value of the flow constant K published in the manufacturer's design and installation instructions shall be verified using the test method of 8.10. The average flow constant K shall be within ± 5 % of the manufacturer's value.

7.4.2 Water distribution [see 8.11.1 and 10.2 g)]

The discharge characteristics of the nozzle shall be determined in accordance with 8.11.1.

7.4.3 Water droplet size and velocity [see 8.11.2 and 10.2 g)]

The water droplet size distribution and droplet velocity distribution of the nozzle shall be determined in accordance with 8.11.2.

7.5 Function (see 8.5)

7.5.1 When tested in accordance with 8.5.1 to 8.5.4, an open nozzle fitted with a protective device for the outlet shall release within 10 s after the application of pressure. An automatic nozzle shall open and, within 5 s after the release of the heat responsive element, shall operate satisfactorily by complying with the requirements of 7.4.1. Any lodgement of released parts shall be cleared within 10 s of release or the nozzle shall then comply with the requirements of 7.4.2 and 7.4.3.

7.5.2 A nozzle shall not sustain damage as a result of the functional test specified in 8.5.5 and shall have the same flow constant range and water droplet size and velocity within 5 % of values as previously determined in 7.4.1 and 7.4.3.

7.6 Strength of body (see 8.3)

An automatic nozzle shall not show permanent elongation of more than 0,2 % between the load-bearing points after being subjected to two times the average service load as determined using the method of 8.3.

7.7 Strength of release element

7.7.1 Glass bulb (see 8.9.1)

When tested in accordance with 8.9.1, glass bulb elements shall

a) have an average strength of at least six times the average service load, and

b) have a design strength lower tolerance limit ($L_{\mathrm{tol},1}$) on the strength distribution curve of at least two times the upper tolerance limit ($L_{\mathrm{tol},2}$) of the service load distribution curve based on calculations with a degree of confidence (Γ) of 0,99 for 99 % of the samples (P). Calculations will be based on Normal or Gaussian distribution except where other distribution can be shown to be more applicable due to manufacturing of design factors.

7.7.2 Fusible elements

Fusible heat-responsive elements in the ordinary temperature range shall be designed to

a) sustain a load of 15 times its design load corresponding to the maximum service load measured in 8.3 for a period of 100 h when tested in accordance with 8.9.2 or

b) demonstrate the ability to sustain the design load when tested in accordance with 8.9.2.

7.8 Leak resistance and hydrostatic strength

7.8.1 An automatic nozzle shall not show any sign of leakage when tested by the method specified in 8.4.1.

7.8.2 A nozzle shall not rupture, operate or release any parts when tested by the method specified in 8.4.2.

7.9 Heat exposure

7.9.1 Glass bulb nozzles

There shall be no damage to the glass bulb element when the nozzle is tested by the method specified in 8.7.1.

7.9.2 Uncoated automatic nozzles

Uncoated automatic nozzles shall withstand exposure to increased ambient temperature without evidence of leakage, weakness or failure when tested by the method specified in 8.7.2.

7.10 Thermal shock for glass bulb nozzles

Glass bulb nozzles shall not be damaged when tested by the method specified in 8.8. Proper operation shall not be considered as damage.

7.11 Corrosion

7.11.1 Stress corrosion

When tested in accordance with 8.12.1, brass nozzles or parts shall show no cracking, delamination or failure that could affect their ability to function as intended.

When tested in accordance with 8.12.2, stainless steel nozzles or parts shall show no cracking, delamination or failure that could affect their ability to function as intended.

7.11.2 Sulfur dioxide corrosion

Nozzles shall be resistant to sulfur dioxide saturated with water vapour when conditioned in accordance with 8.12.3. Following exposure, the water flow rate of the open nozzles at their minimum operating pressure shall be within 5 % of the value specified in the manufacturer’s design and installation instructions. For automatic nozzles, five nozzles shall operate when functionally tested at their minimum flowing pressure (see 7.5.1 and 7.5.2) and the remaining five samples shall meet the dynamic heating requirements of 7.14.2.

7.11.3 Salt spray corrosion

Coated and uncoated nozzles shall be resistant to salt spray when conditioned in accordance with 8.12.4. Following exposure, the water flow rate of the open nozzles at their minimum operating pressure shall be within 5 % of the value specified in the manufacturer’s design and installation instructions. For automatic nozzles, the samples shall meet the dynamic heating requirements of 7.14.2.

7.11.4 Moist air exposure

Nozzles shall be resistant to moist air exposure when tested in accordance with 8.12.5. Following exposure, the nozzles shall be functionally tested at their minimum flowing pressure in accordance with 7.5.1 and meet the dynamic heating requirements of 7.14.2.

7.12 Integrity of nozzle coatings

7.12.1 Evaporation of wax and bitumen used for atmospheric protection of nozzles

Waxes and bitumens used for coating nozzles shall not contain volatile matter in sufficient quantities to cause shrinkage, hardening, cracking or flaking of the applied coating. The loss in mass shall not exceed 5 % of that of the original sample when tested by the method detailed in 8.13.1.

7.12.2 Resistance to low temperatures

All coatings used for nozzles shall not crack or flake when subjected to low temperatures by the method detailed in 8.13.2.

7.12.3 Resistance to high temperature

Coated nozzles shall meet the requirements of 7.9.3.

7.13 Water hammer

Automatic nozzles shall show no signs of leakage or mechanical damage when tested in accordance with 8.15 and shall operate within the parameters of 7.5.1 at the minimum operating pressure.

7.14 Dynamic heating

7.14.1 When tested in accordance with 8.6.2 in their standard orientation, automatic nozzles shall have an RTI not exceeding 50 $(m·s)^{1/2}$ and a conductivity factor (C) less than 1 $(m/s)^{1/2}$. When tested at an angular offset of 25° to the worst-case orientation, the RTI shall not exceed 250 % of the value of RTI in the standard orientation.

7.14.2 After exposure to the corrosion test described in 7.11.2, 7.11.3 and 7.11.4, automatic nozzles shall be tested in the standard orientation as described in 8.6.2.1 to determine the post-exposure RTI. All post-exposure RTI values shall not exceed the limits specified in 7.14.1. In addition, the average RTI value shall not exceed 130 % of the pre-exposure average value. All post-exposure RTI values shall be calculated in accordance with 8.6.2.3 using the pre-exposure conductivity factor (C).

7.15 Resistance to heat

Nozzles shall be resistant to high temperatures when tested in accordance with 8.14. After exposure, the nozzle shall not show any of the following:

a) visual breakage or deformation,

b) change in flow constant K of more than 5 %, and

c) no changes in the discharge characteristics of the water distribution test (see 7.4.2) exceeding 5 %.

7.16 Resistance to vibration

Nozzles shall be able to withstand the effects of vibration without deterioration of their performance characteristics when tested in accordance with 8.16. After the vibration test of 8.16, automatic nozzles shall show no visible deterioration and shall meet the requirements of 7.5 and 7.8. Open nozzles shall not rupture when subjected to the body strength test in accordance with 8.4.2.

7.17 Resistance to impact (see 8.17)

Nozzles shall have adequate strength to withstand impacts associated with handling, transport and installation without deterioration of their performance or reliability. Resistance to impact shall be determined in accordance with 8.17.

7.18 Lateral discharge

Automatic nozzles shall not prevent the operation of adjacent automatic nozzles when tested in accordance with 8.18.

7.19 30-day leakage resistance

Automatic nozzles shall not leak, sustain distortion or other mechanical damage when subjected to twice the rated pressure for 30 d. Following exposure, the nozzles shall satisfy the test requirements of 8.19.

7.20 Vacuum resistance

Automatic nozzles shall not exhibit distortion, mechanical damage or leakage after being subjected to the test detailed in 8.20.

7.21 Clogging

A water mist nozzle and strainer or filter shall show no evidence of clogging during 30 min of continuous flow at rated working pressure using water that has been contaminated in accordance with 8.21.3. Following the 30 min of flow, the water flow at rated pressure of the nozzle and strainer or filter shall be within ± 10 % of the value obtained prior to conducting the clogging test.

7.22 Fire tests

7.22.1 General

7.22.1.1 Water mist nozzles shall be tested for compliance with one or more of the fire test categories described in 7.23 to 7.25 as follows:

a) shipboard Class 1 machinery spaces;

b) shipboard Class 2 machinery spaces;

c) shipboard Class 3 machinery spaces;

d) shipboard passenger cabins;

e) shipboard corridors;

f) shipboard luxury passenger cabins;

g) shipboard open public spaces and corner public spaces;

h) shipboard storage and shopping areas;

i) low hazard areas;

j) standard hazard areas.

NOTE Tests are in preparation for items (i) and (j)

7.22.1.2 The types of fire tests conducted shall include the hazards, areas and occupancies referenced in the manufacturer's design and installation instructions.

7.22.1.3 Nozzle configurations, flow rates and spacings shall be constant for all of the fire tests within a category. Use of different nozzle types for different areas is acceptable.

Corridor nozzles are permitted to be different from passenger cabin nozzles.

7.23 Shipboard machinery spaces

7.23.1 When tested as described in 8.22, water mist nozzles intended for the protection of Category A engine rooms shall extinguish the test fires and prevent reignition.

7.23.2 Classes 1, 2 and 3 Category A engine rooms shall be characterized as in Table 3.

7.23.3 For Class 2 Category A engine rooms, the maximum floor area and ceiling height specified in the manufacturer's design and installation instructions shall be those used in the fire tests specified in 8.22.2.3.

7.24 Shipboard passenger cabins

7.24.1 Water mist nozzles intended for the protection of passenger cabins up to 12 m^2 in area shall comply with the passenger cabin fire test methods described in 8.23.1. If protection is desired for passenger cabins greater than 12 m^2 in area, the fire tests described in 8.23.2 shall also be conducted.

Table 3 — Classification of Category A engine rooms

Class	Typical engine room features	Typical net volume m^3	Typical oil flow and pressure in fuel and lubrication systems
1	Auxiliary engine room, small main machinery or purifier room etc.	500	Fuel: — Low pressure 0,15 kg/s to 0,20 kg/s at 0,3 MPa to 0,6 MPa (3 bar to 6 bar) — High pressure 0,02 kg/s at 20 MPa to 30 MPa (200 bar to 300 bar) Lubrication oil: 0,3 MPa to 0,5 MPa (3 bar to 5 bar) Hydraulic oil: 15 MPa (150 bar)
2	Main diesel machinery in medium-sized ships such as passenger ferries	3 000	Fuel: — Low pressure 0,4 kg/s to 0,6 kg/s at 0,3 MPa to 0,8 MPa (3 bar to 8 bar) — High pressure 0,030 kg/s at 25 MPa (250 bar) Lubrication oil: 0,3 MPa to 0,5 MPa (3 bar to 5 bar) Hydraulic oil: 15 MPa (150 bar)
3	Main diesel machinery in large ships such as oil tankers and container ships	> 3 000	Fuel: — Low pressure 0,7 kg/s to 1,0 kg/s at 3 bar to 8 bar — High pressure 0,20 kg/s Lubrication oil: 0,3 MPa to 0,5 MPa (3 bar to 5 bar) Hydraulic oil: 15 MPa (150 bar)

7.24.2 Water mist nozzles installed for the protection of passenger cabins and corridors in accordance with 8.23.1 shall:

a) prevent flashover of the cabin or corridor except in the disabled nozzle test;

b) comply with the fire source damage criteria described in Table 4;

c) prevent operation of any automatic water mist nozzles located in the corridor in fire Tests A and B;

d) operate no more than two water mist nozzles in fire Tests E to G.

Table 4 — Performance criteria for 12 m^2 cabin/corridor fire test

Test	Maximum 30 s average ceiling temperature in cabin °C	Maximum 30 s average gas temperature in cabin °C	Maximum 30 s average ceiling temperature in corridor °C	Maximum fire source damage	Other criteria
A	360	320	120	40 % lower bunk bed and 10 % of upper bunk bed	No nozzles in corridor allowed to operate
B	360	320	120	40 % of upper bunk bed	No nozzles in corridor allowed to operate
C	—	—	120	—	—
D	—	—	400	—	Fire not permitted to propagate in corridor beyond nozzles closest to cabin door opening
E to G	—	—	120	—	Only two adjacent nozzles in corridor allowed to operate

7.24.3 Water mist nozzles installed for the protection of passenger cabins greater than 12 m^2 in accordance with 8.23.2 shall:

a) suppress the fire in the cabin;

b) limit the ceiling surface temperature to 260 °C;

c) limit the ceiling gas temperature to 320 °C;

d) not totally consume the foam and wood.

7.25 Shipboard public spaces

Water mist nozzles installed to protect public spaces other than shopping and storage areas shall:

a) suppress or control the open public space and corner fire tests described in 8.24.1.1 as evidenced by no more than 50 % consumption of the mattresses in any single test and an average loss no greater than 35 % in any series of fire tests conducted at the same ceiling height (both open and corner public space tests) excluding the disabled nozzle fire test;

b) prevent ignition of either target sofa in the corner public space fire tests described in 8.24.1.1 excluding the disabled nozzle fire test;

c) prevent more than 50 % consumption of either target sofa in the corner public space fire test when the nozzle closest to the corner is disabled;

d) prevent the maximum 30-s average ceiling surface temperature from exceeding 360 °C and the maximum 30-s average ceiling gas temperature from exceeding 220 °C (excluding the disabled nozzle fire test).

7.26 Shipboard storage and shopping areas

Water mist nozzles installed to protect shopping and storage areas shall comply with the following performance criteria when tested as described in 8.24.2:

a) Empty target cartons are not to be ignited or charred.

b) No more than 50 % of the plastic cups are to be damaged.

7.27 Low hazard areas

Alternative fire test methods and requirements are in preparation for other applications involving low hazard areas.

7.28 Standard hazard areas

Alternative fire test methods and requirements are in preparation for other applications involving standard hazard areas.

7.29 Resistance to low temperature (see 8.25)

Water mist nozzles shall be resistant to low temperatures when tested in accordance with 8.25. After exposure, the water mist nozzles shall either be visibly damaged, leak subsequent to thawing, or not be damaged. Water mist nozzles not visibly damaged shall be subjected to the requirements of 7.8 and shall meet the requirement of 7.3.

8 Test methods

8.1 General

The following tests shall be conducted for each type of nozzle. Before testing, precise drawings of parts and the assembly shall be submitted together with the appropriate specifications (using SI units). Tests other than fire tests shall be carried out at an ambient temperature of (20 ± 5) °C, unless other temperatures are indicated. Unless otherwise specified, fire tests shall be conducted at an ambient temperature of (20 ± 10) °C.

Nozzles shall be tested with all the components required by their design and intended installation.

8.2 Visual examination

Before testing, nozzles shall be examined visually with respect to the following points:

a) marking,

b) conformity of the nozzles with the manufacturer's drawings and specification,

c) obvious defects.

8.3 Service load and body strength test (see 7.6)

8.3.1 The service load shall be measured on ten automatic nozzles by securely installing each nozzle, at ambient temperature, in a tensile/compression test machine and applying a force equivalent to the application of the rated working pressure.

An indicator capable of reading deflection to an accuracy of 0,001 mm shall be used to measure any change in length of the nozzle between its load-bearing points. Movement of the nozzle shank thread in the threaded bushing of the test machine shall be avoided or taken into account.

The hydraulic pressure and load shall then be released and the heat-responsive element shall then be removed by a suitable method. When the nozzle is at ambient temperature, a second measurement is to be made using the indicator.

An increasing mechanical load to the nozzle shall then be applied at a rate not exceeding 500 N/min, until the indicator reading at the load-bearing point initially measured returns to the initial value achieved under hydrostatic load. The mechanical load necessary to achieve this shall be recorded as the service load. Calculate the average service load.

8.3.2 The applied load shall then be progressively increased at a rate not exceeding 500 N/min on each of the specimens until twice the average service load has been applied. Maintain this load for (15 ± 5) s.

The load shall then be removed and any permanent elongation as defined in 7.6 shall be recorded.

8.4 Leak resistance and hydrostatic strength tests (see 7.8)

8.4.1 Twenty automatic nozzles shall be subjected to a water pressure of twice their rated working pressure, but no less than 3 MPa (30 bar). Other sample sizes shall be used as required in specific post-exposure tests. The pressure shall be increased from 0 MPa (0 bar) to the test pressure at a rate of (0,1 ± 0,03) MPa/s, [(1 ± 0,25) bar/s] maintained at twice the rated working pressure for a period of 3 min and then decreased to 0 MPa (0 bar). After the pressure has returned to 0 MPa (0 bar), it shall be increased to a pressure equivalent to 10 percent below the design pressure rapidly. This pressure is to be maintained for 15 s and then increased to the rated working pressure at a rate of (0,1 ± 0,03) MPa/s, [(1 ± 0,25) bar/s].

8.4.2 In preparation for this test, open nozzles shall be fitted with a ball or similar device to seal the orifice. Other sample sizes shall be used as required in specific post-exposure tests. Twenty nozzles shall be subjected to an internal hydrostatic pressure of four times the rated working pressure. The pressure shall be increased from 0 MPa (0 bar) to four times the rated working pressure and held there for a period of 1 min.

8.5 Functional test

8.5.1 Eight sample automatic nozzles heated to activation in an oven, or eight open nozzles fitted with a protective device for the outlet shall be subjected to each of the water pressures specified in 8.5.2 applied to their inlet. Other sample sizes shall be used as required in specific post-exposure tests. The temperature of the oven shall be increased from ambient to (400 ± 20) °C in 3 min measured in close proximity to the automatic nozzle. Heating shall continue until the automatic nozzle has activated. Heating shall not be required for the open nozzle samples.

8.5.2 Eight nozzles shall be tested in each normal mounting position and at pressures equivalent to the minimum operating pressure, the rated working pressure and at the average operating pressure (midpoint of operating range specified in 10.2 f). For each condition the pressure shall be at least 75 % of the release pressure.

8.5.3 If lodgement occurs at any operating pressure and mounting position, 24 more nozzles shall be tested in that mounting position and at that pressure. The total number of nozzles for which lodgement occurs shall not exceed 1 in the 32 tested at that pressure and mounting position.

8.5.4 A lodgement shall be considered to have occurred when one or more of the released parts lodges in the discharge assembly for more than 10 s in such a way as to cause the water distribution to be altered.

8.5.5 In order to check the strength of the deflector/orifice assembly, three nozzles shall be submitted to a test in each normal mounting position at 125 % of the rated working pressure. The water shall be allowed to flow at that pressure for a period of 15 min.

8.6 Heat-responsive element operating characteristics

8.6.1 Operating temperature test (see 7.3)

Ten nozzles shall be heated from a temperature of (20 ± 5) °C to $(20\ ^{+2}_{\ 0})$ °C below their nominal operating temperature. The rate of increase of temperature shall not exceed 20 °C/min and the temperature shall be maintained for 10 min. The temperature shall then be increased at a rate of (0,5 ± 0,1) °C/min until the nozzle operates.

The nominal operating temperature shall be ascertained with equipment having an accuracy of ± 0,25 %.

The test shall be carried out in a liquid bath. Release elements having nominal operating temperatures less than or equal to 80 °C shall be tested in a bath of demineralized water. For release elements with the nominal temperature higher than 80 °C, a bath of glycerine, vegetable oil or synthetic oil shall be used. The glass bulbs shall be located in the liquid bath in a vertical position. The test zone is located at a distance, below the liquid surface, level with the geometric centre of the glass bulb. The test zone shall be at (40 ± 5) mm below the liquid surface level. The liquid bath shall be constructed such that the temperature deviation within the test zone is maintained within ± 0,25 °C.

Any rupture of a glass bulb within the prescribed temperature rate constitutes an operation. Partial fracture of glass bulb shall necessitate an additional functional test.

A laboratory temperature-measuring device, calibrated to a depth of 40 mm immersion, is to be used to determine temperatures of liquids in bath tests and operation temperature. The temperature-measuring device shall be located within the test zone such that the temperature sensor is held level with the nozzle operating parts by a support member. To control the temperature in the thermal bath a PT100 IEC 60751 can be used. An example of a suitable liquid bath is shown in Figure 14.

8.6.2 Dynamic heating test

8.6.2.1 Plunge test

Tests shall be conducted to determine the standard (3.19) and worst-case orientations (3.20). Ten additional plunge tests shall be performed at both of the orientations identified in 7.14.1. The RTI shall be calculated as described in 8.6.2.3 and 8.6.2.4 for each orientation, respectively. The plunge tests are to be conducted using a brass nozzle mount designed such that the mount or water temperature rise does not exceed 2 °C for the duration of an individual plunge test up to a response time of 55 s. The temperature shall be measured by a thermocouple heatsinked and embedded in the mount not more than 8 mm radially outward from the root diameter of the internal thread or by a thermocouple located in the water at the centre of the nozzle inlet.

The nozzle under test shall have 1 to 1,5 wraps of PTFE sealant tape applied to the nozzle threads. It shall be screwed into a mount to a torque of (15 ± 3) N·m. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of not less than 30 min.

At least 25 ml of water, conditioned to ambient temperature, shall be introduced into the nozzle inlet prior to testing. A timer accurate to ± 0,01 s with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates shall be utilized to obtain the response time.

A tunnel shall be utilized with airflow and temperature conditions at the test section (nozzle location) selected from the appropriate range of conditions shown in Table 6. To minimize radiation exchange between the sensing element and the boundaries confining the flow, the test section of the apparatus shall be designed to limit radiation effects to within ± 3 % of calculated RTI values. One method for determining radiation effects shall be to conduct comparative plunge tests on a blackened (high emissivity) metallic test specimen and a polished (low emissivity) metallic test specimen.

The range of tunnel operating conditions that shall be permissible is shown in Table 6. The selected operating condition shall be maintained for the duration of the test with the tolerances as specified by Table 5 footnotes.

Table 5 — Plunge oven test conditions

Normal temperature °C	Plunge oven temperature[a] °C	Plunge oven velocity[b] m/s
57 to 77	129 to 141	1,65 to 1,85
79 to 107	191 to 203	1,65 to 1,85
121 to 149	282 to 300	1,65 to 1,85
163 to 191	382 to 432	1,65 to 1,85

[a] The selected air temperature shall be known and maintained constant within the test section throughout the test to an accuracy of ± 1 °C for the air temperature range of 129 °C to 141 °C within the test section and within ± 2 °C for all other air temperatures.

[b] The selected air velocity shall be known and maintained constant throughout the test to an accuracy of ± 0,03 m/s.

Table 6 — Plunge oven test conditions for conductivity determination

Nominal nozzle temperature °C	Plunge oven temperature °C	Maximum variation of air temperature during test °C
57	85 to 91	± 1,0
58 to 77	124 to 130	± 1,5
78 to 107	193 to 201	± 3,0
121 to 149	287 to 295	± 4,5
163 to 191	402 to 412	± 6,0

8.6.2.2 Determination of conductivity factor (C)

The conductivity factor (C) shall be determined using the prolonged plunge test (see 8.6.2.2.1) or the prolonged exposure ramp test (see 8.6.2.2.2).

8.6.2.2.1 Prolonged plunge test

The prolonged plunge test shall be an iterative process to determine C and shall require up to twenty nozzle samples. A new nozzle sample shall be used for each test in this section even if the sample does not operate during the prolonged plunge test.

The nozzle under test shall have 1 to 1,5 wraps of PTFE sealant tape applied to the nozzle threads. It shall be screwed into a mount to a torque of (15 ± 3) N·m. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of no less than 30 min. At least 25 ml of water, conditioned to ambient temperature, shall be introduced into the nozzle inlet prior to testing.

A timer accurate to ± 0,01 s with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates shall be utilized to obtain the response time.

The mount temperature shall be maintained at (20 ± 0,5) °C for the duration of each test. The air velocity in the tunnel test section at the nozzle location shall be maintained with ± 2 % of the selected velocity. Air temperature shall be selected and maintained during the test as specified in Table 7.

The selected operating condition shall be maintained for the duration of the test with the tolerances as specified in Table 7.

To determine C, the nozzle shall be immersed in the test stream at various air velocities for a maximum of 15 min. Velocities are to be chosen such that actuation is bracketed between two successive test velocities. That is, two velocities shall be established such that at the lower velocity (u_L) actuation does not occur in the 15-min test interval. At the next higher velocity (u_H), actuation shall occur within the 15-min time limit. If the nozzle does not operate at the highest velocity, select an air temperature from Table 7 for the next higher temperature rating. The range of permissible tunnel operating conditions is shown in Table 6.

Test velocity selection shall ensure that the following is true:

$$(u_H/u_L)^{0,5} \leqslant 1,1$$

The test value of C shall be the average of the values calculated at the two velocities using the following equation:

$$C = (\Delta T_g/\Delta T_{ea} - 1)u^{0,5}$$

where

ΔT_g is actual gas (air) temperature minus the mount temperature (T_m) in °C;

ΔT_{ea} is mean liquid bath operating temperature minus the mount temperature (T_m) in °C;

u is actual air velocity in the test section in m/s.

The nozzle C value shall be determined by repeating the bracketing procedure three times and calculating the numerical average of the three C values. If the value of C is determined to be less than 0,5 (m/s)^{0,5}, a C of 0,25 (m/s)^{0,5} shall be assumed for the RTI value. This nozzle C value is used to calculate all standard orientation RTI values for determining compliance with 7.14.1.

8.6.2.2.2 Prolonged exposure ramp test

The prolonged exposure ramp test for the determination of the parameter C shall be carried out in the test section of a wind tunnel and with the requirements for the temperature in the nozzle mount as described for the dynamic heating test. A preconditioning of the nozzle shall not be necessary.

Ten samples shall be tested of each nozzle type; all nozzles shall be positioned in standard orientation. The nozzle shall be plunged into an air stream of a constant velocity of (1 ± 0,1) m/s and an air temperature at the nominal temperature of the nozzle at the beginning of the test.

The air temperature shall then be increased at a rate of (1 ± 0,25) °C/min until the nozzle operates. The air temperature, velocity and mount temperature shall be controlled from the initiation of the rate of rise and shall be measured and recorded at nozzle operation. The C value shall be determined using the same equation as in 8.6.2.2.1 as the average of the ten test values.

8.6.2.3 RTI value calculation

The equation used to determine the RTI value shall be as follows:

$$\mathrm{RTI} = \frac{-\,t_\mathrm{r}\,u^{0,5}\left(1 + C/u^{0,5}\right)}{\ln\left[1 - \Delta T_\mathrm{ea}\left(1 + C/u^{0,5}\right)/\Delta T_\mathrm{g}\right]}$$

where

t_r is response time of nozzles, in seconds;

u is actual air velocity in the test section of the tunnel, in m/s from Table 6;

ΔT_ea is mean liquid bath operating temperature of the nozzle minus the ambient temperature, in °C;

ΔT_g is actual air temperature in the test section minus the ambient temperature, in °C;

C is conductivity factor as determined in 8.6.2.2.

8.6.2.4 Determination of worst-case orientation RTI

The equation used to determine the RTI for the worst-case orientation shall be as follows:

$$\mathrm{RTI}_\mathrm{wc} = \frac{-\,t_{\mathrm{r,wc}}\,u^{0,5}\left[1 + C\left(\mathrm{RTI}_\mathrm{wc}/\mathrm{RTI}\right)/u^{0,5}\right]}{\ln\left\{1 - \Delta T_\mathrm{ea}\left[1 + C\left(\mathrm{RTI}_\mathrm{wc}/\mathrm{RTI}\right)/u^{0,5}\right]/\Delta T_\mathrm{g}\right\}}$$

where

$t_{\mathrm{r,wc}}$ is the response time, in seconds, of the nozzles for the worst-case orientation;

RTI_wc is the response time index for the worst-case orientation.

All variables are known at this time in the equation in 8.6.2.3, which can be solved iteratively using the above equation.

8.7 Heat exposure test

8.7.1 Glass bulb nozzles

Four glass bulb sprinklers having nominal release temperatures less than or equal to 80 °C shall be heated in a demineralized water bath from a temperature of (20 ± 5) °C to a temperature of (20 ± 2) °C below their nominal operating temperature. The rate of increase of temperature shall not exceed 20 °C/min. Glycerine, vegetable oil or synthetic oil shall be used for higher-rated release elements.

This temperature shall then be increased at a rate of 1 °C/min to the temperature at which the gas bubble dissolves, or to a temperature 5 °C lower than the lower limit of the tolerance range of the operating temperature, whichever is lower. Remove the sprinkler from the liquid bath and allow it to cool in air until the gas bubble has formed again.

During the cooling period, the pointed end of the glass bulb (seal end) shall be pointed downwards. This test shall be performed four times on each of four sprinklers.

8.7.2 Uncoated automatic nozzles

Twelve nozzles shall be exposed for a period of 90 d to a high ambient temperature that is 11 °C below the nominal rating or at the temperature shown in Table 7, whichever is lower, but not less than 49 °C. If the service load is dependent on the service pressure, nozzles shall be tested under the rated working pressure. After exposure, four of the nozzles shall meet the requirements of 7.8.1; four nozzles shall meet the requirements of 7.5.1 when tested to 8.5.1; two at the minimum operating pressure and two at the rated working pressure; and four nozzles shall meet the requirements of 7.3. If a nozzle fails any applicable requirements of a test, eight additional nozzles shall be tested as described above and subjected to the test in which the failure was recorded. All eight nozzles shall comply with the requirements.

At the manufacturer's option, additional samples may be furnished for this test to provide early evidence of failure. The additional samples may be removed from the test chamber at 30-d intervals for testing.

8.7.3 Coated automatic nozzles

In addition to the exposure test described in 8.7.2 in an uncoated version, twelve coated automatic nozzles shall be exposed to the test of 8.7.2 using the temperatures shown in Table 7 for coated nozzles.

The test shall be conducted for 90 d. During this period, the samples shall be removed from the oven at intervals of approximately 7 d and allowed to cool for 2 h to 4 h. During this cooling period, the sample shall be examined. After exposure, four of the nozzles shall meet the requirements of 7.8.1; four nozzles shall meet the requirements of 7.5.1 when tested as detailed in 8.5.1; two at the minimum operating pressure and two at the rated working pressure; and four nozzles shall meet the requirements of 7.3.

At the manufacturer's option, additional samples may be furnished for this test to provide early evidence of failure. The additional samples may be removed from the test chamber at 30-d intervals for testing.

Table 7 — Test temperatures for coated and uncoated automatic nozzles

Nominal release temperature °C	Uncoated nozzle temperature °C	Coated nozzle test temperature °C
57 to 60	49	49
61 to 77	52	49
78 to 107	79	66
108 to 149	121	107
150 to 191	149	149

8.8 Thermal shock test for glass bulb nozzles

8.8.1 Before starting the test, condition at least five nozzles at (20 ± 5)°C for at least 30 min.

8.8.2 Nozzles having nominal operating temperatures less than or equal to 80 °C shall be tested in a bath of demineralized water. Nozzles with higher-rate elements shall be tested in a bath of glycerine, vegetable oil or synthetic oil. The temperature of the bath shall be (10 ± 0,5) °C below the lower limit of the tolerance range of the operating temperature of the nozzles. After 5 min, remove the sprinklers from the bath and immerse them immediately in another bath of liquid (demineralized water), with the bulb seal downwards, at a temperature of (10 ± 0,5)°C. Then test the nozzles in accordance with 7.5.1

8.9 Strength test for release elements

8.9.1 Glass bulbs (see 7.7.1)

At least 55 bulbs in the lowest temperature rating of each bulb type shall be positioned individually in a test fixture using the sprinkler seating parts. Each bulb shall then be subjected to a uniformly increasing force at a rate of (250 ± 25) N/s in the test machine until the bulb fails.

Each test shall be conducted with the bulb mounted in new seating parts. The seating parts may be reinforced externally or can be out of hardened steel [Rockwell hardness: (44 ± 6) HRC] in accordance to the specification of the sprinkler manufacture to prevent collapse, but in a manner that does not interfere with bulb failure.

Record the crush force for each bulb.

Using the lowest 50 measured bulb strength results and calculate the average strength and the lower tolerance limit ($L_{tol,1}$) for bulb strength (see Annex B). Using the values of service load recorded in 8.3.1, calculate the upper tolerance limit ($L_{tol,2}$) for the bulb design load. See Annex A. Verify compliance with 7.7.1.

8.9.2 Fusible elements

8.9.2.1 Determine compliance by subjecting fusible release elements to loads in excess of the maximum design load, which will produce failure within and after 1 000 h. At least 10 samples shall be subjected to different loads up to 15 times the maximum design load. Abnormal failures shall be rejected. A full logarithmic regression analysis using the method of least squares shall be performed. From this, the load at 1 h, and the load at 1 000 h, shall be calculated where:

$$L_d \leqslant 1{,}02\, L_M^2/L_0$$

where

L_d = maximum design load;

L_M = load at 1 000 h;

L_0 = load at 1 h.

See Annex B.

8.9.2.2 These tests shall be conducted at an ambient temperature of (20 ± 3) °C.

8.10 Water flow test

The nozzle and a pressure gauge shall be mounted on a supply pipe. The water flow shall be measured at pressures ranging from the minimum operating pressure to the rated working pressure at intervals of approximately 10 % of the service pressure range on two sample nozzles. In one series of tests, the pressure shall be increased from zero to each value and, in the next series, the pressure shall be decreased from the rated pressure to each value. The flow constant shall be averaged from each series of readings, i.e. increasing pressure and decreasing pressure, and, in each case, shall be within 10 % of the average flow constant value for both samples. During the test, pressures shall be corrected for differences in height between the gauge and the outlet orifice of the nozzle.

8.11 Water distribution and droplet size tests

8.11.1 Water distribution

Two series of tests shall be conducted in a test chamber of minimum dimensions 5 m by 5 m in plan. For the first series of tests, install a single open nozzle near the centre of the test chamber. For the second series of tests, install four open nozzles of the same type arranged in a square, at maximum spacings specified by the manufacturer, on piping prepared for this purpose.

The distance between the ceiling and the distribution plate shall be 50 mm for upright nozzles and 275 mm for pendent nozzles. For nozzles without distribution plates, the distances shall be measured from the ceiling to the highest nozzle outlet.

The water discharge distribution in the protected area below a single nozzle and between the multiple nozzles shall be collected and measured by means of square measuring containers nominally 500 mm on a side. The distance between the nozzles and the upper edge of the measuring containers shall be the maximum specified by the manufacturer. The measuring containers shall be positioned centrally, beneath the single nozzle and beneath the multiple nozzles.

The nozzles shall be discharged both at the minimum operating and rated working pressures specified by the manufacturer and the minimum and maximum installation heights specified by the manufacturer.

The water shall be collected for at least 10 min to assist in characterizing nozzle performance.

8.11.2 Water droplet size

The measurements shall be made at two representative locations as follows:

a) perpendicular to the central axis of the nozzle, exactly 1 m below the discharge orifice or discharge deflector;

b) radially outward from the first location at either 0,5 m or 1 m distance.

The location of the measurement in a) may be moved outward up to 150 mm if nonrepresentative measurements were to be recorded at the indicated locations.

The mean water droplet diameters, velocities, droplet size distribution, number density and volume flux shall be determined at both the minimum and maximum flow rates specified by the manufacturer. Once the data is gathered, the method of ASTM E799 shall be used to determine the appropriate sample size, class size widths, characteristic drop sizes and measured dispersion of the drop size distribution.

8.12 Corrosion tests

8.12.1 Stress corrosion test for brass nozzles

Five nozzles shall be subjected to the following aqueous ammonia test. The outlet of open nozzles shall be sealed as specified in the manufacturer's design and installation instructions and the inlet of each nozzle shall be sealed with a nonreactive cap, e.g. plastic.

The samples shall be degreased and exposed for 10 d to a moist ammonia/air mixture in a glass container of volume (0,02 ± 0,01) m^3.

An aqueous ammonia solution, having a density of 0,94 g/cm^3, shall be maintained in the bottom of the container, approximately 40 mm below the bottom of the samples. A volume of aqueous ammonia solution corresponding to 0,01 ml/cm^3 of the volume of the container will give approximately the following atmospheric concentrations: 35 % ammonia, 5 % water vapour, and 60 % air.

The moist ammonia/air mixture shall be maintained as closely as possible at atmospheric pressure, with the temperature maintained at (34 ± 2) °C. Provision shall be made for venting the chamber via a capillary tube to avoid the build-up of pressure. Specimens shall be shielded from condensate drippage.

After exposure, rinse and dry the nozzles, and conduct a detailed examination using a microscope with a magnification of 25×. If a crack, delamination or failure of any operating part is observed, the nozzle(s) shall be subjected to a leak resistance test at the rated pressure for 1 min and to the functional test at the maximum operating pressure only (see 7.5.1).

Nozzles showing cracking, delamination or failure of any non-operating part shall not show evidence of separation of permanently attached parts when subjected to flowing water at the rated working pressure for 30 min.

8.12.2 Stress-corrosion cracking of stainless steel nozzles and parts (see 7.11.1)

8.12.2.1 Five samples are to be degreased prior to being exposed to the magnesium chloride solution. The parts are to be tested with stresses applied to simulate normal assembly forces.

8.12.2.2 Parts used in nozzles are to be placed in a 500-ml flask that is fitted with a thermometer and a wet condenser approximately 760 mm long. The flask is to be filled approximately one-half full with a 42 % by mass magnesium chloride solution, placed on a thermostatically-controlled electrically-heated mantel, and maintained at a boiling temperature of (150 ± 1) °C. The exposure is to last for 500 h.

8.12.2.3 After the exposure period, the test samples are to be removed from the boiling magnesium chloride solution and rinsed in de-ionized water.

8.12.2.4 The samples are then to be examined using a microscope having a magnification of 25× for any cracking, delamination or failure as a result of the test exposure. Test samples exhibiting degradation are to be tested as described in 8.12.2.5 or 8.12.2.6, as applicable. Test samples not exhibiting degradation shall be considered acceptable without further test.

8.12.2.5 Operating parts of automatic nozzles exhibiting degradation are to be further tested as follows. Five new sets of parts are to be assembled in nozzle frames made of materials that do not alter the corrosive effects of the magnesium chloride solution on the stainless steel parts. These test samples are to be degreased and subjected to the magnesium chloride solution exposure specified in 8.12.5.2. Following the exposure, the test samples shall withstand, without leakage, a hydrostatic test pressure equal to the rated working pressure for 1 min and then be subjected to the functional test at the minimum operating pressure in accordance with 8.5.1.

8.12.2.6 Nonoperating parts exhibiting degradation are to be further tested as follows. The test samples are to be assembled in nozzles, if applicable, and shall withstand a flowing pressure equal to the rated working pressure for 30 min without separation or breakage.

8.12.3 Sulfur dioxide corrosion test (see 7.11.2 and 7.14.2)

Ten nozzles shall be subjected to the following sulfur dioxide corrosion test. The outlet of open nozzles shall be sealed as specified in the manufacturer's design and installation instructions and the inlet of each sample shall be sealed with a nonreactive cap, e.g. plastic.

The test equipment shall consist of a 5 l vessel made of heat-resistant glass, with a corrosion-resistant lid of such a shape as to prevent condensate dripping on the nozzles. The vessel shall be electrically heated through the base, and provided with a cooling coil around the side walls. A temperature sensor placed centrally (160 ± 20) mm above the bottom of the vessel shall regulate the heating so that the temperature inside the glass vessel is (45 ± 3) °C. During the test, water shall flow through the cooling coil at a sufficient rate to keep the temperature of the discharge water below 30 °C. This combination of heating and cooling shall encourage condensation on the surfaces of the nozzles. The sample nozzles shall be shielded from condensate drippage.

Instead of a 5 l vessel, other volumes up to 15 l may be used in which case the quantities of chemicals given below shall be increased in proportion.

The nozzles to be tested shall be suspended in their intended mounting position(s) under the lid inside the vessel and subjected to a corrosive sulfur dioxide atmosphere for 8 d. The corrosive atmosphere shall be obtained by introducing a solution made up by dissolving 20 g of sodium thiosulfate ($Na_2S_2O_3 \cdot H_2O$) crystals in 500 ml of water.

For at least 6 d of the 8-d exposure period, 20 ml of dilute sulfuric acid consisting of 156 ml of 0,5 mol/l H_2SO_4 diluted with 844 ml of water shall be added at a constant rate. After 8 d, the nozzles shall be removed from the container and allowed to dry for 4 d to 7 d at a temperature not exceeding 35 °C with a relative humidity not greater than 70 %.

After the drying period, the water flow rate of the open nozzles at their minimum operating pressure shall be within 5 % of the value specified in the manufacturer's design and installation instructions. For the automatic nozzle samples, five nozzles shall be subjected to a functional test at the minimum operating pressure in accordance with 8.5.1 and five nozzles shall be subjected to the dynamic heating requirement of 7.14.2.

8.12.4 Salt spray corrosion test (see 7.11.3 and 7.14.2)

8.12.4.1 Nozzles intended for normal atmospheres

Ten nozzles shall be exposed to a salt spray within a fog chamber. The outlet of open nozzles shall be sealed as specified in the manufacturer's design and installation instructions and the inlet of each sample is to be sealed by a nonreactive cap, e.g. plastic.

The salt solution shall be a 20 % by mass sodium chloride solution in distilled water. The pH shall be between 6,5 and 7,2 and the density between 1,126 g/ml and 1,157 g/ml when atomized at 35 °C. Suitable means of controlling the atmosphere in the chamber shall be provided. The specimens shall be supported in their normal operating position and exposed to the salt spray (fog) in a chamber having a volume of at least 0,43 m^3 in which the exposure zone shall be maintained at a temperature of (35 ± 2) °C. The temperature shall be recorded at least once per day, at least 7 h apart (except weekends and holidays when the chamber normally would not be opened). Salt solution shall be supplied from a recirculating reservoir through air-aspirating nozzles, at a pressure between 0,07 MPa (0,7 bar) and 0,17 MPa (1,7 bar). Salt solution runoff from exposed samples shall be collected and shall not return to the reservoir for recirculation. The sample nozzles shall be shielded from condensate drippage.

Fog shall be collected from at least two points in the exposure zone to determine the rate of application and salt concentration. The fog shall be such that for each 80 cm^2 of collection area, 1 ml to 2 ml of solution shall be collected per hour over a 16-h period and the salt concentration shall be (20 ± 1) % by mass.

The nozzles shall withstand exposure to the salt spray for a period of 10 d. After this period, the nozzles shall be removed from the fog chamber and allowed to dry for 4 d to 7 d at a temperature of 20 °C to 25 °C in an atmosphere having a relative humidity not greater than 70 %. Following the drying period, the water flow rate of the open nozzles at their minimum flowing pressure shall be within 5 % of the value specified in the manufacturer's design and installation instructions. For the automatic nozzle samples, five nozzles shall be submitted to the functional test at the minimum operating pressure in accordance with 8.5.1 and five nozzles shall be subjected to the dynamic heating requirement of 7.14.2.

8.12.4.2 Nozzles intended for corrosive atmospheres

Five nozzles shall be subjected to the tests specified in 8.12.4.1 except that the duration of the salt spray exposure shall be extended from 10 d to 30 d.

8.12.5 Moist air exposure test (see 7.11.4 and 7.14.2)

Ten nozzles shall be exposed to a high temperature-humidity atmosphere consisting of a relative humidity of (98 ± 2) % and a temperature of (95 ± 4) °C. The outlet of open nozzles shall be sealed as specified in the manufacturer's design and installation instructions. The nozzles are to be installed on a pipe manifold containing de-ionized water. The entire manifold is to be placed in the high temperature-humidity enclosure for 90 d. After this period, the nozzles shall be removed from the temperature-humidity enclosure and allowed to dry for 4 d to 7 d at a temperature of (25 ± 5) °C in an atmosphere having a relative humidity of not greater than 70 %. Following the drying period, the water flow rate of the open nozzles at their minimum flowing pressure shall be within 5 % of the value specified in the manufacturer's design and installation instructions. For the automatic nozzle samples, five nozzles shall meet the requirements of 7.5.1 at the minimum operating pressure only, and five nozzles shall be subjected to the dynamic heating requirements of 7.14.2.

At the manufacturer's option, additional samples may be furnished for this test to provide early evidence of failure. The additional samples may be removed from the test chamber at 30-d intervals for testing.

8.13 Nozzle coating tests

8.13.1 Evaporation test (see 7.12.1)

A 50-cm^3 sample of wax or bitumen shall be placed in a metal or glass cylindrical container, having a flat bottom, an internal diameter of 55 mm and an internal height of 35 mm. The container, without lid, shall be placed in an automatically controlled, constant ambient temperature oven with air circulation. The temperature in the oven shall be controlled at 16 °C below the nominal release temperature of the nozzle, but at no less than 50 °C. The sample shall be weighed before and after 90-d exposure to determine any loss of volatile matter; the sample shall meet the requirements of 7.12.1.

8.13.2 Low-temperature test (see 7.12.2)

Five nozzles, coated by normal production methods, whether with wax, bitumen or a metallic coating, shall be subjected to a temperature of −10 °C for a period of 24 h. On removal from the low-temperature cabinet, the nozzles shall be exposed to normal ambient temperature for at least 30 min before examination of the coating to meet the requirements of 7.12.2.

8.14 Heat-resistance test (see 7.15)

One nozzle body shall be heated in an oven at 800 °C for a period of 15 min, with the nozzle in its normal installed position. The nozzle body shall then be removed and held by the threaded inlet, and shall be promptly immersed in a water bath at a temperature of approximately 15 °C. It shall meet the requirements of 7.15.

8.15 Water-hammer test (see 7.13)

Five nozzles shall be connected, in their normal operating position, to the test equipment. After purging the air from the nozzles and the test equipment, 3 000 cycles of pressure varying from (0,4 ± 0,05) MPa [4 ± 0,5) bar] to four times the rated working pressure, for nozzles having an operating pressure greater than 100 bars or to four times the rated working pressure, for nozzles having an operating pressure up to 10 MPa (100 bar), but no less than 3 MPa (30 bar) shall be applied. The pressure shall be raised from 0,4 MPa (4 bar) to four times the rated pressure at a rate of (100 ± 10) bar/s. At least 30 cycles of pressure per minute shall be generated. The pressure shall be measured with an electrical pressure transducer or equivalent device.

Visually examine each nozzle for leakage during the test. After the test, each nozzle shall meet the leakage resistance requirement of 7.8.1 and the functional requirement of 7.5.1 at the minimum operating pressure only.

8.16 Vibration test (see 7.16)

8.16.1 Five automatic nozzles or five open nozzles with their protective caps (if part of the nozzle), as specified in the manufacturer's design and installation instructions, shall be fixed vertically to a vibration table. While at ambient temperature, they shall be subjected to sinusoidal vibrations. The direction of vibration shall be along the axis of the connecting thread.

8.16.2 The nozzles shall be vibrated continuously from 5 Hz to 40 Hz at a maximum rate of 5 min/octave and an amplitude of 1 mm (1/2 peak-to-peak value). If one or more resonant points are detected, the nozzles, after coming to 40 Hz, shall be vibrated at each of these resonant frequencies for 120 h/number of resonances. If no resonances are detected, the vibration from 5 Hz to 40 Hz to 5 Hz shall be continued for 120 h.

8.16.3 Following the vibration test, each automatic nozzle shall then be subjected to the leakage test in accordance with 7.8.1 and the functional test in accordance with 7.5.1 at the minimum operating pressure only.

8.17 Impact test (see 7.17)

Five nozzles shall be tested by dropping a mass onto the nozzle along the axial centreline of waterway. Nozzles provided with shipping caps, which are intended for removal only after completion of the nozzle installation, shall be impact tested with the caps in place. The kinetic energy of the dropped mass at the point of impact shall be equivalent to a mass equal to that of the test nozzle dropped from a height of 1 m. See Figure 1. The mass is to be prevented from impacting more than once upon each sample.

Following the test a visual examination of each nozzle shall show no signs of fracture, deformation, or other deficiency. If none is detected, automatic nozzles shall be subjected to the leak resistance test described in 8.4.1 and the functional test requirement of 8.5.1 at a pressure equal to the minimum flowing pressure. Open nozzles shall be subjected to the hydrostatic strength test requirement of 8.4.2 at twice the rated working pressure.

8.18 Lateral discharge test (see 7.18)

Water is to be discharged from an open nozzle at the minimum operating and rated working pressure. A second automatic nozzle located at the minimum distance specified by the manufacturer is to be mounted on a pipe parallel to the pipe discharging water.

The nozzle orifices or distribution plates (if used), are to be placed 550 mm, 350 mm and 150 mm below a flat smooth ceiling for three separate tests, respectively at each test pressure. The top of a square pan measuring 305 mm square and 100 mm deep is to be positioned 150 mm below the heat-responsive element for each test. The pan is to be filled with 0,47 l of heptane. After ignition, the automatic nozzle is to operate before the heptane is consumed.

8.19 30-day leakage test (see 7.19)

Five automatic nozzles are to be installed on a water-filled test line maintained under a constant pressure of twice the rated working pressure but no less than 2,4 MPa (24 bar) (twice minimum rated working pressure) for 30 d at ambient temperature.

The nozzles shall be inspected visually at least weekly for leakage. Following completion of this 30-d test, all samples shall meet the leak resistance requirements specified in 7.8.1 and shall exhibit no evidence of distortion or other mechanical damage.

8.20 Vacuum test (see 7.20)

Three automatic nozzles shall be subjected to a vacuum of 460 mm of mercury applied to their inlet for 1 min at ambient temperature. Following this test, each sample shall be examined to verify that no distortion or mechanical damage has occurred and then shall meet the leak resistance requirements specified in 7.8.1.

8.21 Clogging test (see 7.21)

8.21.1 The water flow rate of an open water mist nozzle with its strainer or filter shall be measured at its rated working pressure. The nozzle and strainer or filter shall then be installed in an appropriate test apparatus and subjected to 30 min of continuous flow at rated working pressure using contaminated water that has been prepared in accordance with 8.21.3.

8.21.2 Immediately following the 30 min of continuous flow with the contaminated water, the flow rate of the nozzle and strainer or filter shall be measured at rated working pressure. No removal, cleaning or flushing of the nozzle, filter or strainer is permitted during the test.

8.21.3 The water used during the 30 min of continuous flow at rated working pressure specified in 8.21.1 shall consist of 60 l of tap water into which has been mixed 1,58 kg of contaminants that sieve as described in Table 8. The solution shall be continuously agitated during the test.

Table 8 — Contaminant for contaminated water test

Sieve designation[a]	Nominal sieve opening mm	Mass of contaminant[b] ± 5 % Pipe scale g	Top soil g	Sand g
No. 25	0,706	—	456	200
No. 50	0,297	82	82	327
No. 100	0,150	84	6	89
No. 200	0,074	81	—	21
No. 325	0,143	153	—	3
	TOTAL	400	544	640

[a] Sieve designations shall correspond with those specified in ASTM E11. Cenco-Meinzer sieve sizes 25 mesh, 50 mesh, 100 mesh, 200 mesh, and 325 mesh, corresponding with the number designation in table, have been found to comply with ASTM E11. Cenco-Meinzer sieves are an example of suitable products available commercially. This information is given for the convenience of users of this part of ISO 6182 and does not constitute an endorsement by ISO of these products.

[b] The amount of each contaminant may be proportionally reduced in each sieve designation by 50 % for nozzles limited to use with corrosion-resistant system and piping materials and by 90 % for nozzles having a rated pressure of 5 MPa (50 bar) or higher and limited to use with corrosion-resistant system and piping materials.

8.22 Shipboard machinery space fire test method (see 7.23)

8.22.1 Test apparatus

The machinery space fire test apparatus is to consist of the following:

a) simulated engine 1 m by 3 m by 3 m high constructed of nominal 5-mm thick sheet steel. A 1-m by 3-m by 0,1-m high steel tray is to be positioned on top of the simulated engine. The engine mock-up is to be fitted with two steel tubes 0,3 m in diameter and 3 m in length and a solid flat steel plate. See Figures 2 and 3.

b) 4-m by 6-m by 0,75-m high solid flat steel floor plate assembly surrounding the engine mock-up. The sides of the floor plate assembly are to be fitted with steel plates 0,5 m high. A 2 m by 2 m by 0,25 m high steel tray is to be positioned centrally under the engine mock-up assembly as shown in Figures 2 to 4.

8.22.2 Test room

8.22.2.1 General

Only ceiling-mounted nozzles shall be permitted to be installed for Class 1 and Class 2 engine rooms. For Class 3 engine rooms, multiple levels of nozzles shall be permitted. The use of nozzles to protect specific hazards by direct application is not permitted. If specified in the manufacturer's design and installation instructions, additional nozzles shall be permitted to be installed:

a) along the perimeter of the enclosure to screen openings;

b) in a separate bilge area fire protection system.

8.22.2.2 Class 1 engine room

The fire tests shall be conducted in test room having a minimum floor area of 100 m^2 with no dimension less than 8 m, a ceiling height of 5 m with ventilation through a 2-m by 2-m door opening. See Figure 2.

8.22.2.3 Class 2 engine room

The fire tests shall be conducted in a test room having a floor area greater than 100 m^2 with no dimension less than 8 m, a ceiling height between 5 m and 7,5 m and a volume not exceeding 3 000 m^2 with ventilation through a 2-m by 2-m door opening. The test enclosure need not be square.

8.22.2.4 Class 3 engine room

The fire tests shall be conducted in a test room having a minimum floor area of 300 m^2 and a ceiling height in excess of 10 m, without any restrictions in air supply for the test fires, using a single array of nozzles located between 5 m and 7,5 m above the floor. The test enclosure need not be square.

8.22.3 Fire tests

8.22.3.1 Class 1, 2 and 3 engine rooms

A series of fire tests are to be conducted using the various sprays, test fuels and fire locations as described in Table 9. For the spray fire tests, the spray nozzles, discharge pressures, test fuels, flow rates, fuel temperature and nominal heat release rates shall be as described in Table 10.

Fire Test Numbers 4, 7, 8 and 13 shall not be required if the use of a separate bilge fire protection (e.g., foam, water mist etc.) is specified in the manufacturer's design and installation instructions as developed from representative bilge fire tests.

8.22.3.2 Test fuels

8.22.3.2.1 Fire Tests 1 to 6 and 13 described in Table 10 are to be conducted using commercial fuel oil or a light diesel oil. Fire Tests 7 and 9 to 12 are to be conducted using heptane. Fire Test 8 is to be conducted using SAE 10W30 mineral-based lubrication oil.

8.22.3.2.2 The wood crib, specified in Fire Test 11 is to weigh 5,4 kg to 5,9 kg and is to be dimensioned 305 mm by 305 mm by 305 mm. The crib is to consist of eight alternate layers of four trade size 38,1 mm by 38,1 mm kiln-dried spruce or fir (Picea Excelsa or Abies Lasioscapa) lumber 305 mm long. The alternate layers of the lumber are to 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 stapled. After the wood crib is assembled, it is to be conditioned at a temperature of (49 ± 5) °C for no less than 16 h. Following the conditioning, the moisture content of the crib is to be measured with a probe-type moisture meter. The moisture content of the crib shall not exceed 5 % prior to the fire test.

8.22.3.2.3 Reignition fire Test 12 is to be conducted using a 300-mm by 600-mm by 50-mm steel plate positioned as shown in Figure 3.

8.22.4 Extinguishing system

8.22.4.1 The nozzles and bilge extinguishing system, if required, shall be installed to protect the entire hazard volume in accordance with the manufacturer's design and installation instructions. For Class 3 engine rooms, nozzles shall be at a height between 5 m and 7,5 m above the floor. For bilges more than 0,75 m in depth, nozzles or a separate fire extinguishing system shall be installed in the bilges in accordance with the manufacturer's design and installation instructions as developed from representative fire tests.

8.22.4.2 Fire tests shall be conducted with the nozzles positioned at the maximum volume per nozzle, maximum enclosure ventilation rate, maximum distances from the test apparatus, maximum spacing between nozzles, maximum distance of nozzles below the ceiling and at the nominal extinguishing pressure(s) specified in the manufacturer's design and installation instructions.

Table 9 — Machinery space fire test scenarios

Test No.	Fire scenario (for additional details, see Figures 2, 3 and 4)	Test fuel
1	Low-pressure horizontal spray on top of simulated engine between agent nozzles	Commercial fuel oil or light diesel oil
2	Low-pressure spray on top of simulated engine centred with the oil spray nozzle angled upward at a 45° angle to strike a 12 mm to 15 mm diameter rod 1 m away	Commercial fuel oil or light diesel oil
3	Low-pressure concealed horizontal spray on side of simulated engine with oil spray nozzle positioned 0,1 m in from the end of engine	Commercial fuel oil or light diesel oil
4	Combination of worst spray fire from Tests 1 to 3 and fires in trays under (4 m^2) and on top of the simulated engine (3 m^2)	Commercial fuel oil or light diesel oil
5	High-pressure horizontal spray on top of simulated engine mock-up	Commercial fuel oil or light diesel oil
6	Low-pressure low flow concealed horizontal spray on side of simulated engine with oil spray nozzle positioned 0,1 m in from the end of engine and a 0,1 m^2 tray positioned 1,4 m in from the engine end at the inside edge of the solid bilge floor plate	Commercial fuel oil or light diesel oil
7	0,5 m^2 tray central under engine mock-up	Heptane
8	0,5 m^2 tray central under engine mock-up	SAE 10W30 mineral-based lubrication oil
9	0,5 m^2 tray on top of solid bilge floor plate under solid exhaust plate	Heptane
10	Flowing fire at a rate of 0,25 kg/s from top of engine mock-up (see Figure 4)	Heptane
11	Class A wood crib, see 8.23.3.2, in 2 m^2 pool fire with 30 s preburn. The test tray should be positioned 0,75 m above the floor as shown in Figures 1 and 2.	Heptane
12	A steel plate (0,3 m by 0,6 m by 0,05 m) offset 20° to the spray is heated to 350 °C by the top low-pressure low flow spray nozzle positioned horizontally 0,5 m from the front edge of the plate. When the plate reaches 350 °C, the system is activated. Following system shutoff, no re-ignition of the spray is permitted.	Heptane
13	4 m^2 tray central under mock-up	Commercial fuel oil or light diesel oil

Table 10 — Oil spray fire test parameters

Fire type	Category A engine room Classes 1 to 3		
	Low pressure	**Low pressure/low flow**	**High pressure**
Spray nozzle	Wide spray angle 120° to 125° full cone-type	Wide spray angle, 80° full cone-type	Standard angle at 0,6 MPa (6 bar), full cone-type
Nominal fuel pressure	8 Bar	8,5 Bar	150 Bar
Fuel flow	(0,16 ± 0,01) kg/s	(0,03 ± 0,005) kg/s	(0,050 ± 0,002) kg/s
Fuel temperature	(20 ± 5) °C	(20 ± 5) °C	(20 ± 5) °C
Nominal heat release rate	(5 ± 0,6) MW	(1,1 ± 0,1) MW	(1,8 ± 0,2) MW
Fuel	Commercial fuel oil or light diesel oil	Commercial fuel oil or light diesel oil for fire Test 6 and heptane for fire Test 12	Commercial fuel oil or light diesel oil

8.22.5 Test procedure

8.22.5.1 The test tray(s) shall be filled with at least 50 mm of test fuel on a water base. Freeboard shall be (150 ± 10) mm.

8.22.5.1 For oil spray fire tests, the oil flow and pressure shall be measured before each test. The oil pressure shall be measured during each test. The oil spray shall be permitted a 5-s to 15-s preburn before the extinguishing system is activated.

8.22.5.3 After ignition of the oil in the fire test trays, a 2-min preburn shall be permitted before the extinguishing system is activated.

8.22.5.4 For the fire tests involving heptane tray fires, the system is to be actuated after a 5-s to 15-s preburn.

8.22.5.5 For fire Test 11, the Class A wood crib is to be given a 30-s preburn before the extinguishing system is activated.

8.22.5.6 Water flow and pressure in the extinguishing system shall be measured continuously on the high-pressure side of a pump or equivalent equipment at intervals not exceeding 5 s during each test. Alternately, the flow shall be determined by measuring the flowing pressure at one nozzle in each feed line and knowing the discharge coefficient of the nozzles. See 7.4.

8.22.5.7 After the preburn, water to the nozzles shall be discharged for a maximum of 50 % of the discharge time recommended by the manufacturer or 15 min, whichever is less. At the end of discharge, there shall be complete extinguishment and no reignition. The oil or heptane spray, if used, shall be shut off 15 s after the end of water discharge.

8.22.6 Test observations

In addition to recording the temperature of the test room, fuel and engine mock-up before and after each test, the following observations shall be recorded:

a) start of ignition procedure;

b) ignition (start of test);

c) time of extinguishing system activation;

d) time of fire extinguishment;

e) time when extinguishing system was shut off;

f) time of reignition, if any;

g) time when oil or heptane spray was shut off;

h) time when test was completed;

i) damage to any extinguishing system components;

j) presence of fuel in all test trays.

8.23 Passenger cabin fire tests (see 7.24.1)

8.23.1 12-m^2 cabin and corridor

8.23.1.1 Test arrangement

The fire tests shall be conducted in a 3-m by 4-m by 2,4-m high cabin centrally connected to a 1,5-m by 12-m long corridor that is 2,4 m high with both ends open. The cabin is to be fitted with one door opening 0,8 m wide and 2,2 m high that provides a 0,2 m lintel above the opening. The walls of the cabin are to be constructed from an inner layer of nominally 12-mm thick wallboard with a nominally 45-mm thick mineral wool liner. The walls and ceiling of the corridor and ceiling of the passenger cabin shall be constructed of nominally 12-mm thick wallboard. The cabin or the corridor wall opposite to the cabin door shall be provided with a closed window for observation purposes during the fire tests. See Figure 5.

8.23.1.2 Wall and ceiling coverings

The cabin and corridor ceiling is to be covered with acoustical panels. The ceiling panels are to be nominally 12 mm to 15 mm thick and have a maximum flame spread index (FSI) of 25 or, alternatively, shall not ignite when tested according to IMO Resolution A.653(16). Plywood panels measuring 1,2 m by 2,4 m are to be placed on the cabin and corridor walls. The panels shall be approximately 3 mm thick and have an FSI of 200 or, alternatively, the ignition time of the panel shall not be more than 35 s and the flame spread at the 350 mm position shall not be more than 100 s as measured according to IMO Resolution A.653(16).

8.23.1.3 Fire source

8.23.1.3.1 For the cabin fire tests, two Pullman-type bunk beds having an upper and lower birth shall be installed along the opposite side walls of the cabin. See Figure 5. The frame of the bunk beds shall be of nominal 2-mm thick steel. Each bunk bed shall be fitted with 2 000-mm by 800-mm by 100-mm polyether mattresses having a cotton fabric cover. Pillows measuring 500 mm by 800 mm by 100 mm are to be cut from additional mattress material. The cut edge shall be positioned towards the doorway. A mattress shall form a backrest for the lower bunk beds and arranged in an upright position to prevent it from falling over. See Figure 6.

The mattresses shall be made of non-fire retardant polyether foam having a density of approximately 33 kg/m^3. The cotton fabric shall not be fire retardant and have a surface density of 140 g/m^2 to 180 g/m^2. When tested in accordance with ISO 5660-1, the polyether mattress shall comply with the following criteria.

a) Test conditions: irradiance 35 kW/m^2; horizontal position

b) Sample size: nominal 100 mm by 100 mm by 50 mm thick

c) Time to ignition: (4 ± 2) s

d) Average heat: 3 min

e) Release rate (Q_{180}): (270 ± 50) kW/m^2

f) Effective heat of combustion: (28 ± 3) MJ/kg

g) Total heat release: (50 ± 12) MJ/m^2

8.23.1.3.2 The corridor fire tests are to be conducted using eight foam pieces, without covers, measuring 400 mm by 400 mm by 100 mm placed on a stand 0,25 m high and in a steel test basket to prevent the pile from falling over. See Figure 7. For the corridor fire test, the walls and ceiling are to be fitted with combustible decorative wall panels and acoustical ceiling tiles as specified in 8.23.1.2. The mattress stand is to be positioned 50 mm from one wall.

8.23.1.4 Instrumentation

During each fire test, the following temperatures are to be recorded at least once every 2 s using chromel-alumel thermocouples with a diameter not exceeding 0,5 mm.

a) The ceiling surface temperatures above the ignition source in the cabin and in the centre of the corridor directly opposite the cabin doorway using thermocouples embedded in the ceiling material from above, such that the thermocouple bead is flush with the ceiling.

b) The ceiling gas temperature (75 ± 1) mm below the ceiling in the centre of the cabin.

In corridor Test E (see Table 11), the ceiling surface temperature shall be measured above the fire source. In corridor Test F (see Table 11), the ceiling surface temperature shall be measured in the centre of the corridor above the fire source.

Table 11 — Arrangements for fire tests

Test		Arrangement
A	Lower bunk test	Fire arranged in one lower bunk bed with the igniter at the front (towards door) centreline of the pillow.
B	Upper bunk bed test	Fire arranged in one upper bunk bed with the igniter located at the front (towards doorway) centreline of the pillow.
C	Arsonist test	Fire arranged by spreading 1 l of white spirits evenly over one lower bunk bed and backrest 30 s prior to ignition. The igniter shall be located in the lower bunk bed at the front (towards door) centreline of the pillow.
D	Disabled nozzle test	The water mist nozzle(s) in the passenger cabin are to be disabled. Fire arranged in one lower bunk bed with the igniter located at the front (towards doorway) centreline of the pillow. If the nozzle(s) in the cabin are linked with nozzle(s) in the corridor such that a malfunction would affect all of them, all cabin and linked corridor nozzles shall be disabled.
E	Corridor test	Fire source located against the corridor wall below one nozzle
F	Corridor test	Fire source located against the corridor wall between two nozzles
G	Ventilation test	The worst of the corridor Tests E or F is to be repeated with an ambient air velocity of 0,3 m/s measured at the midpoint between the floor and the ceiling in the centre of the corridor.

8.23.1.5 Placement of water mist nozzles

The water mist nozzles shall be installed to protect the cabin and corridor in accordance with the manufacturer's design and installation instructions subject to the following restrictions.

a) If only one water mist nozzle is installed in the cabin, it shall not be placed in the shaded area shown in Figure 8.

b) Corridor water mist nozzles shall not be placed nearer to the centreline of the cabin doorway than one-half the maximum spacing recommended by the manufacturer.

If the manufacturer's design and installation instructions require a corridor nozzle outside of each cabin doorway, a single nozzle shall be located outside the doorway and additional nozzles are to be placed in the corridor at their maximum spacing.

8.23.1.6 Required fire tests

8.23.1.6.1 The following series of four passenger cabin tests and three corridor fire tests listed in Table 11 shall be conducted with automatic activation of the nozzles at the minimum operating pressure specified by the manufacturer. The fires shall be ignited using an igniter made of some porous material such as insulating fibreboard. The igniter is permitted to either be square or cylindrical shaped, 60 mm square or 75 mm in diameter, 75 mm in length. The igniter is to be soaked in 120 ml of heptane, wrapped in a plastic bag and positioned as indicated for each passenger cabin fire test. For the corridor fire tests, the igniter is to be located in the centre at the base of the pile of foam pieces on one side of the test stand.

8.23.1.6.2 Each fire test shall be conducted for 10 min after actuation of the first water mist nozzle. After 10 min of water application, any remaining fire is to be manually extinguished. Damage to the bunk beds shall be calculated as follows, for the lower bunk:

$$D_{\mathrm{LB}} = (D_{\mathrm{LM}} + 0{,}25D_{\mathrm{LP}} + D_{\mathrm{BR}})/2{,}25$$

where

D_{LB} is the damage to the lower bunk;

D_{LM} is the damage to lower horizontal mattress;

D_{LP} is the damage to the lower pillow;

D_{BR} is the damage to the backrest;

and for the upper bunk:

$$D_{\mathrm{UB}} = (D_{\mathrm{UM}} + 0{,}25D_{\mathrm{UP}})/1{,}25$$

where

D_{UB} is the damage to the upper bunk;

D_{UM} is the damage to upper horizontal mattress;

D_{UP} is the damage to the upper pillow.

If it is not clearly obvious by visual examination whether the criteria is fulfilled or not, the test shall be repeated.

8.23.1.7 Test observations

The following observations shall be made during each fire test:

a) ignition time;

b) water mist nozzle(s) activation time(s);

c) time when water flow is shut off;

d) damage to fire source;

e) temperature recordings;

f) flow rate and flowing pressure for each nozzle;

g) total number of operating nozzles.

8.23.2 Passenger cabins greater than 12 m^2 (see 7.24.2)

8.23.2.1 Test arrangement

These fire tests are to be conducted in a 2,4 m high room having equal sides and floor area of at least 24 m^2 but not exceeding 80 m^2. The room is to be fitted with two doorway openings, in diagonal corners, both opposite the fire source. See Figure 9. Each opening is to be 0,8 m wide and 2,2 m high, which provides for a 200 mm lintel above the openings. Walls and ceilings are to be made of non-combustible, nominally 12 mm thick, wallboards.

The test room ceiling is to be covered with acoustical panels. The ceiling panels are to be nominally 12 mm to 15 mm thick and have a maximum FSI of 25 or, alternatively, shall not ignite when tested in accordance with IMO Resolution A.653(16). For each test, new acoustical panels are to be installed in the 1,2 m by 1,2 m area directly over the fire source.

Douglas fir 3-ply panels measuring 1,2 m by 2,4 m are to be placed on two of the test room walls extending out 2,4 m from a common corner. One panel is to be placed on each wall. The panels are to be approximately 6,4 mm thick and the ignition time of the panels shall not be more than 35 s and the flame spread time at the 350 mm position shall not be more than 100 s as measured in accordance with IMO Resolution A.653(16). Alternatively, the Douglas fir plywood panels are to have the burning characteristic properties listed in Table 12.

Table 12 — Burning characteristic properties of Douglas fir plywood panels

Property	Test method	Range
Flame spread index	ANSI/UL 723.	130 ± 30
Critical heat flux	Use of cone calorimeter at radiant heat fluxes between 10 kW/m^2 and 20 kW/m^2, ISO 5660-1	(15 ± 3) kW/m^2
Thermal response parameter	Use of cone calorimeter at radiant heat fluxes of 25 kW/m^2, 35 kW/m^2 and 50 kW/m^2, ISO 5660-1	(220 ± 50) kW·(s$^{1/2}$)/m^2

The plywood panels are to be conditioned at (21 ± 3) °C and (50 ± 10) % relative humidity for at least 72 h prior to test. They are to be placed on the walls by being attached to 12-mm to 15-mm thick wood furring strips. before being used in a test. The wood crib is to be placed on top of a nominal 300 mm by 300 mm by 100 mm high, 6 mm thick, steel test pan positioned on the floor near a corner of the test enclosure. The wood crib is to be positioned 50 mm from each wall.

The simulated furniture is to consist of two 76-mm thick uncovered pure polypropylene oxide polyol, polyether foam cushions having a density of 27,2 kg/m^3 to 30,4 kg/m^3 and measuring 810 mm by 760 mm. Each foam cushion is to be glued to a 835 mm by 785 mm by 12,7-mm thick plywood backing using an aerosol urethane foam adhesive. The foam pad is glued to the plywood backing leaving a 12,7-mm space on both sides and a 25-mm space along the bottom. See Figure 10 for the foam adhesion pattern. The foam cushion and plywood backing assembly is to be conditioned at (21 ± 2,8) °C and (50 ± 10) % relative humidity for at least 24 h prior to test. Prior to each test, the foam and plywood backing assembly is to be placed in a steel frame to provide support for holding each assembly in the vertical orientation.

The polyether foam shall have the following burning characteristic properties, average of 5 samples, when tested in accordance with ISO 5660-1 at a 30 kW/m^2 heat flux:

Peak heat release rate (HRR)	(230 ± 50) kW/m^2
Heat of combustion	(22 ± 3) kJ/g

The entire fire test package is to be placed on top of a nominal 6-mm thick cement board sheathing or equivalent non-combustible sheathing material having dimensions of 1,2 m by 1,2 m. For each test, a new or dried sheathing shall be used.

NOTE This fuel package has an ultra-fast t^2 fire growth (t^2 fire is a fire in which the burning rate varies proportionally to the square of time), a maximum heat release in excess of 2,5 MW and a growth time (time to reach 1 MW) of (80 ± 10) s. See Figure 10.

8.23.2.2 Nozzle installation

Water mist nozzles shall be installed in the test room for each fire test in accordance with the manufacturer's design and installation instructions. Nozzles shall be installed with their deflector/spray orifices located 76 mm below the ceiling or as specified in the installation instructions. The distance between the outer nozzles and the walls of the cabin shall be one-half the maximum spacing between nozzles specified by the manufacturer. The distance between nozzles is to be the maximum specified by the manufacturer.

Nozzles with frame arms shall be positioned with their frame arms parallel and perpendicular to the supply piping. As an alternative, and for nozzles without frame arms, the nozzles shall be positioned so that the lightest discharge density, as determined in the water distribution test, 8.11, will be directed toward the fire area.

If a non-uniform spacing is selected by the manufacturer, the maximum spacing shall be established in the open public space fire tests.

8.23.2.3 Instrumentation

During each fire test, the following temperatures shall be measured.

a) The ceiling material temperature above the centre of the wood crib shall be measured using a 0,8-mm thermocouple embedded (6,5 ± 0,5) mm into the ceiling tile.

b) The ceiling gas temperature shall be measured using a 0,8-mm thermocouple located (75 ± 1) mm below the ceiling within 0,2 m horizontally from the nozzle closest to the corner with the fuel package. The thermocouple is to be shielded from impingement of water from the nozzles by using metallic tape attached to the wire. The tape is to be formed into an umbrella shape, large enough to protect the thermocouple ends.

The 0,8 mm chromel/alumel thermocouples shall be formed by twisting the wires three times, having the remaining wire cut off, and forming a bead using an oxyacetylene torch.

8.23.2.4 Ignition

The test room is to have an ambient temperature of (25 ± 5) °C measured at the thermocouple located 76 mm below the ceiling. All water from previous testing shall be removed such that there is no visible water on the floor, ceiling or walls.

The wood crib is to be ignited with a pan of heptane and the simulated furniture is to be ignited with two 150-mm long by 6,4-mm diameter cotton wicks soaked in heptane. Place 0,5 l of water and 0,25 l of heptane in the pan directly below the wood crib. First ignite the heptane in the pan located beneath the crib, then immediately thereafter ignite the heptane-soaked cotton .

8.23.2.5 Test duration

Conduct the fire test for 10 min after automatic operation of the first nozzle. The water flow rate to the nozzles is to be the minimum flow rate specified in the manufacturer's design and installation instructions. The minimum nozzle flow rating shall be the same for single and multiple operating nozzles.

8.24 Shipboard public space fire tests (see 7.25)

8.24.1 Open public space and corner public space (see 7.25.1)

8.24.1.1 Test enclosure

The open area and corner public space fire tests are to be conducted in a test room fitted with a ceiling at least 80 m^2 in area with no dimension less than 8 m. For the open area fire test, there shall be at least 1 m between the perimeter of the ceiling and any wall. The ceiling height shall be set at 2,5 m for one set of tests and at 5 m for the second set of tests.

The public space corner fire test is to be conducted in a corner constructed by two 3,6-m wide walls. Plywood panels approximately 3 mm thick are to be placed on the walls. The FSI of the panelling is to be 200 or, alternatively, the ignition time of the panels shall not be more than 35 s and the flame spread at the 350-mm position should not be more than 100 s when measured as specified in IMO Resolution A.653(16). The ceiling is to be fitted with acoustical ceiling tiles approximately 12 mm to 15 mm thick having a maximum FSI of 25 or, alternatively, those that shall not ignite when tested in accordance with IMO Resolution A.653(16). The tiles shall be placed to cover the ceiling at least 3,6 m from each wall.

8.24.1.2 Fire source

8.24.1.2.1 Open public space

The open area fire tests shall be conducted under the centre of the ceiling. The fire source shall consist of four sofas constructed from 2 000-mm by 800-mm by 100-mm polyether mattresses fitted with a cotton fabric cover, as specified in 8.23.1.3.1. The mattresses shall be arranged and spaced 25 mm apart as shown in Figure 11 and cantered under 1 nozzle for the first fire test, between 2 nozzles for the second fire test and below 4 nozzles for the third fire test.

An igniter is to be prepared as described in 8.23.1.6.1. The igniter is then to be placed in the middle of the bottom mattress of one of the sofas as shown in Figure 11.

8.24.1.2.2 Corner public space

The corner public space fire tests are to be conducted in a corner scenario. The fire source is to consist of one full sofa and two half-target sofas constructed from 2 000-mm by 800-mm by 100-mm polyether mattresses fitted with a cotton fabric cover. See 8.23.1.3.1 for mattress specifications. The sofas shall be positioned in the corner of a test enclosure as shown in Figure 12 with the backrests 25 mm from the wall. The igniter is to be placed on the full sofa up against the backrest and adjacent to the corner wall.

8.24.1.3 Tests

The following three fire tests are to be conducted at both the 2,5 m and 5 m ceiling heights.

a) **Standard test.** Automatic operation of the nozzles.

b) **Ventilation tests.** Repeat of standard test with an air velocity of 0,3 m/s, as measured 1 m above the floor and 1 m below the ceiling, 3,5 m from each wall, directed towards the corner.

c) **Disabled nozzle test**. Repeat of standard test with the nozzle closest to the corner disabled.

8.24.1.4 Nozzle installation

Water mist nozzles are to be installed below the ceiling at the maximum spacing specified in the manufacturer's design and installation instructions. For nozzles with frame arms, tests are to be conducted with the frame arms positioned both perpendicular and parallel to the system supply piping. For nozzles without frame arms, the nozzles shall be oriented so that the lightest discharge density, as determined in the water distribution test, 8.11, is directed towards the fire area. For the corner public space fire tests, at least four nozzles in a 2 by 2 array are to be installed. The distance between the outer nozzles and the corner walls shall be one-half of the maximum spacing between nozzles specified by the manufacturer.

8.24.1.5 Instrumentation

During the fire tests, the following temperatures shall be measured, using thermocouples with a diameter not exceeding 0,5 mm.

8.24.1.5.1 Instrumentation for open public space test

a) The ceiling material temperature above the ignition source shall be measured using a thermocouple embedded in the ceiling such that its bead is flush with the surface.

b) The ceiling gas temperature shall be measured (75 ± 1) mm below the ceiling at four points located symmetrically around the ignition source at 1,8 m horizontal distance.

8.24.1.5.2 Instrumentation for corner public space test

a) The ceiling surface temperature above the ignition source shall be measured using a thermocouple embedded in the ceiling material such that the thermocouple bead is flush with the ceiling surface.

b) The ceiling gas temperature shall be measured (75 ± 1) mm below the ceiling within 0,2 m horizontally from the nozzle closest to the corner and perpendicular to the line between the nozzle and the corner.

The water flow and operating pressure are to be monitored for 10 min after activation of the first nozzle.

8.24.1.6 Observations

The following observations are to be made during each test:

a) time of ignition;

b) activation times of each nozzle;

c) time of flashover, if any;

d) time when target sofa(s) ignite;

e) time when water is shut off;

f) percent of damage to each mattress, walls and ceiling;

g) total quantity of water used.

8.24.2 Shipboard storage and shopping areas (see 7.25.2)

8.24.2.1 Test arrangement

The fire tests are to be conducted in a test room having a ceiling at least 80 m^2 in area with no dimension less than 8 m. The ceiling height shall be set at 2,5 m.

8.24.2.2 Nozzle positioning

For nozzles with frame arms, tests are to be conducted with the frame arms positioned both perpendicular and parallel to the system supply piping. For nozzles without frame arms, the nozzles shall be oriented so that the lightest discharge density, as determined in water distribution test 8.11, is directed towards the fire area.

8.24.2.3 Fire source

The fire source consists of two solid piled stacks of cardboard cartons 2 by 3 by 3 cartons high packed with polystyrene unexpanded plastic cups with a 305-mm flue space. Each carton shall be approximately 533 mm by 533 mm by 533 mm high and contain 125 one-half litre capacity polystyrene cups. Five layers of 25 cups with each cup in an individual compartment shall be formed by cardboard separators. The total mass of each carton is approximately 6,4 kg of which 3,6 kg is plastic cups.

Six 1,5 m high target arrays of empty cardboard cartons are to be arranged on each side of the fire source as shown in Figure 13. The cartons shall be stabilized to prevent displacement.

8.24.2.4 Fire test

Fire tests shall be conducted with the ignition under one, between two, and cantered below four nozzles. The fire shall be ignited using two igniters as described in 8.23.1.6.1. The igniters shall be placed on the floor, each against the base of one of the two central stacks and simultaneously ignited. See Figure 13. Water shall be applied for 10 min after operation of the first nozzle.

8.25 Freezer test (see 7.28)

Five samples shall be individually attached to one end of a 100 mm length of 5 mm nominal diameter steel pipe using an appropriate fitting. A pipe coupling shall be attached to the opposite end of each pipe. Each assembly shall then be filled to capacity with water and sealed using a pipe plug. The assemblies shall be exposed to a temperature of (-30 ± 5) °C for a period of 24 h. After the freezer test, each nozzle shall meet the requirements of 7.28.

9 Water mist nozzle marking

9.1 General

Each nozzle complying with the requirements of this part of ISO 6182 shall be permanently marked with the following:

a) trademark or manufacturer's name;

b) model identification;

c) manufacturer's factory identification if manufacturer has more than one nozzle manufacturing facility

d) identification of release element if more than one type used;

e) the last two digits of the year of manufacture (automatic nozzles only); the marked year of manufacture shall be permitted to include the last three months of the preceding year and the first six months of the following year;

f) K-factor, this is only required if a given model nozzle is available with more than one K-factor.

g) nominal release temperature (automatic nozzles only). Except for coated and plated nozzles, the nominal release temperature range shall be colour-coded on the nozzle to identify the nominal rating. The colour code shall be visible on the yoke arms holding the distribution plate for fusible element nozzles, and shall be indicated by the colour of the liquid in the glass bulbs. All nozzles shall be stamped, cast, engraved or colour-coded in such a way that the nominal rating is recognizable even if the nozzle has operated. This shall be in accordance with Table 2.

9.2 Nozzle housings

Recessed housings, if provided, shall be marked for use with the corresponding nozzles unless the housing is a non-removable part of the nozzle.

10 Design, installation and maintenance instructions

10.1 General

A copy of the manufacturer’s design and installation instructions shall be furnished for use as a guide in the examination and testing of water mist fire suppression system devices.

10.2 Requirements

The instructions shall reference the limitations of each device and shall include at least the following items:

a) description and operating details of each water mist nozzle and all accessory equipment, including identification of extinguishing system components or accessory equipment by part or model number;

b) degree and type of protection afforded by the system and limitations for each fire use type;

c) type of pipe, tubing, and fittings to be used;

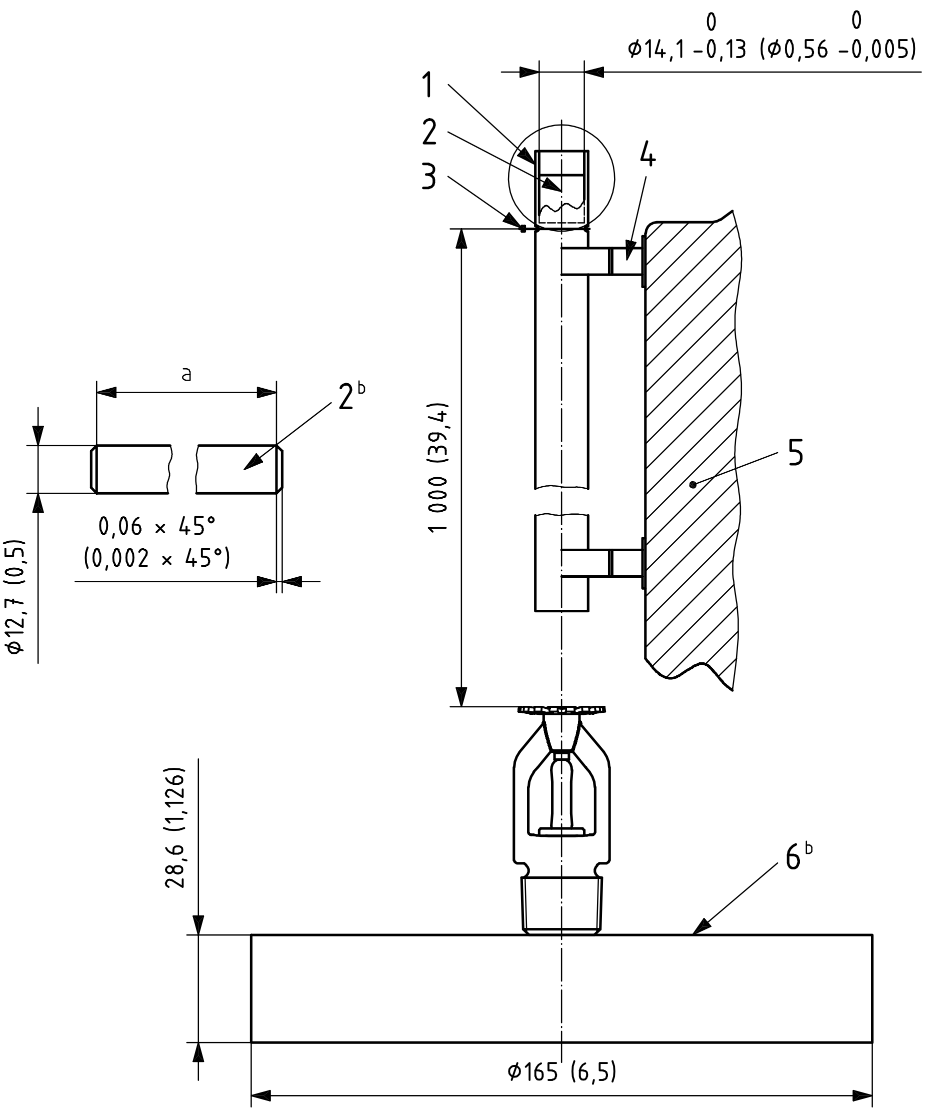
d) typical nozzle layout and specific limitations and recommendations for correct nozzle installation and effective protection;

e) discharge nozzle limitations, including maximum dimensional and area coverage, minimum and maximum installation height limitations, and nozzle location in the protected volume;

f) operating pressure ranges of the water mist nozzles;

g) water distribution, water droplet size, and velocity characteristics.

Dimensions in millimetres (inches)



Key

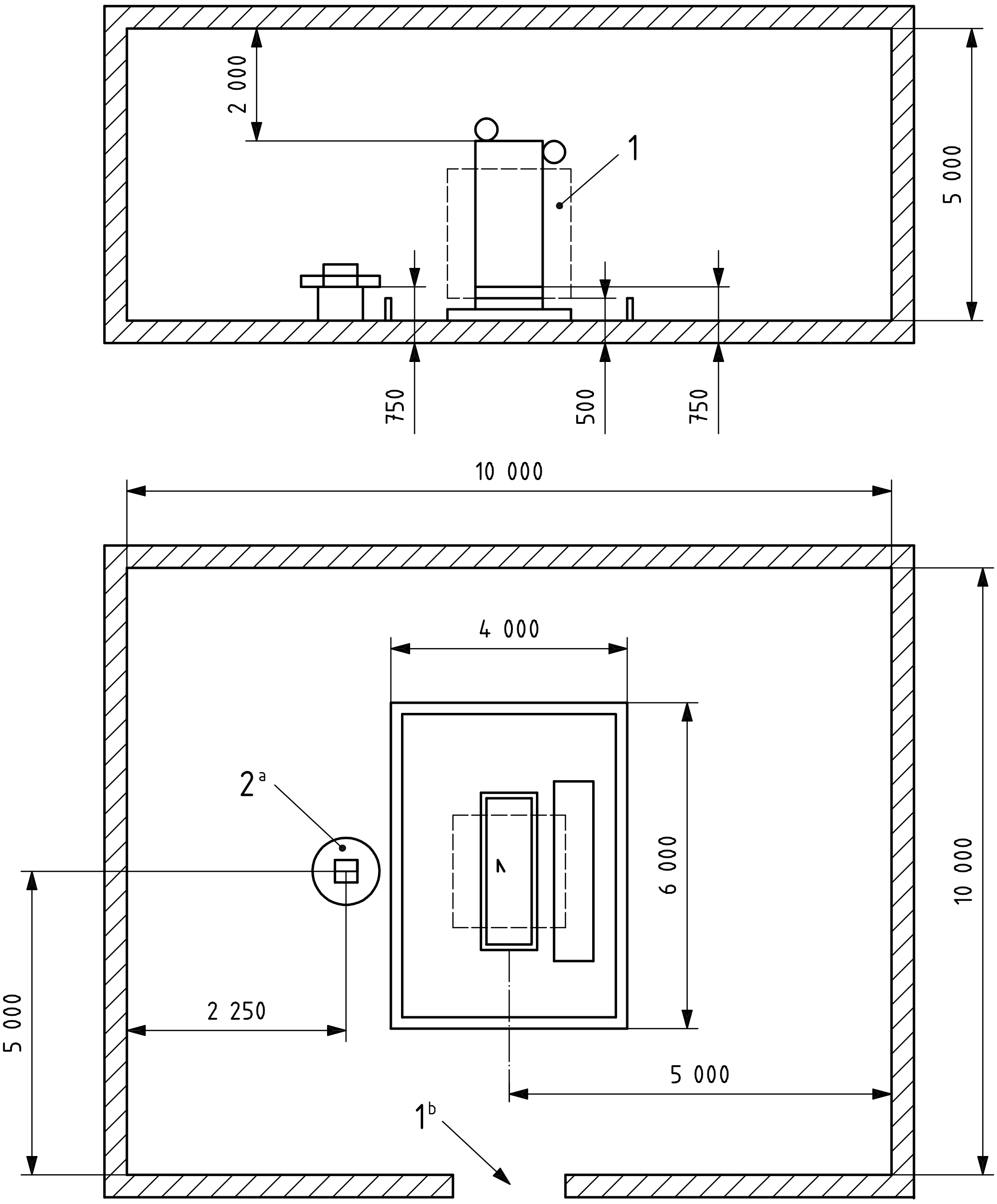
1 cold drawn seamless steel tubing
2 weight
3 latching pin
4 adjustable brackets (2)
5 rigid support
6 nozzle support

a Length to be determined (function of required weight).

b AISI C1018 cold finished steel (AISI American Iron and Steel Institute).

Figure 1 — Impact test apparatus

Dimensions in millimetres



Key

1 door

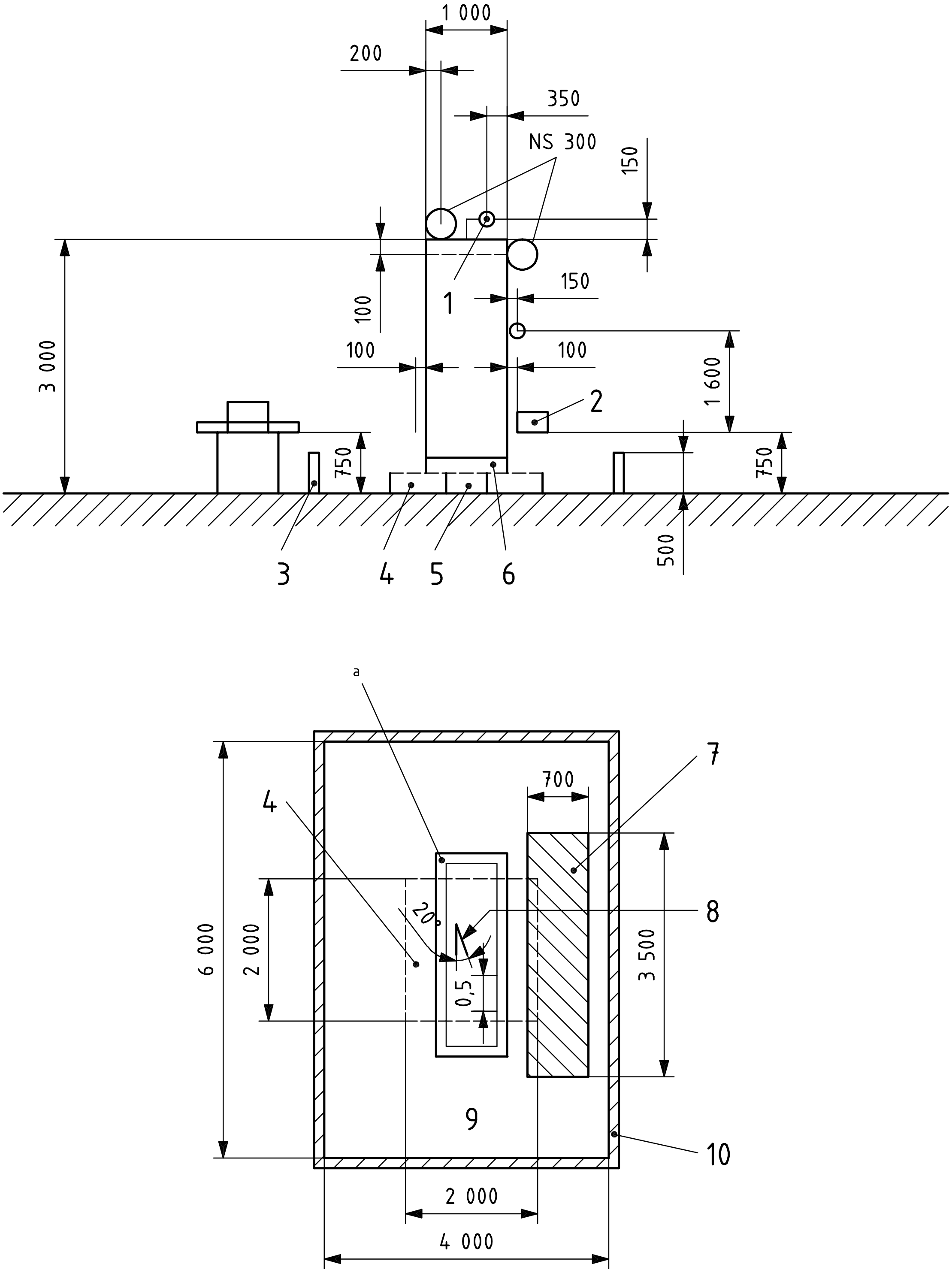
2 location of tray

[a] Tray 2 m for Class A fire test.

[b] Door 2 000 mm × 2 000 mm.

Figure 2 — Class 1 engine mock-up enclosure

Dimensions in millimetres



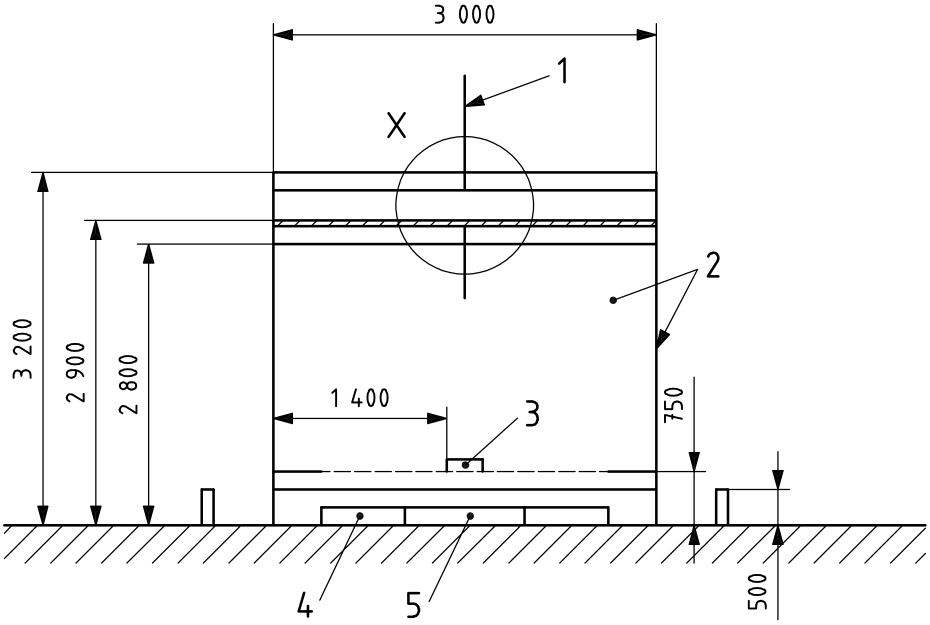
Key

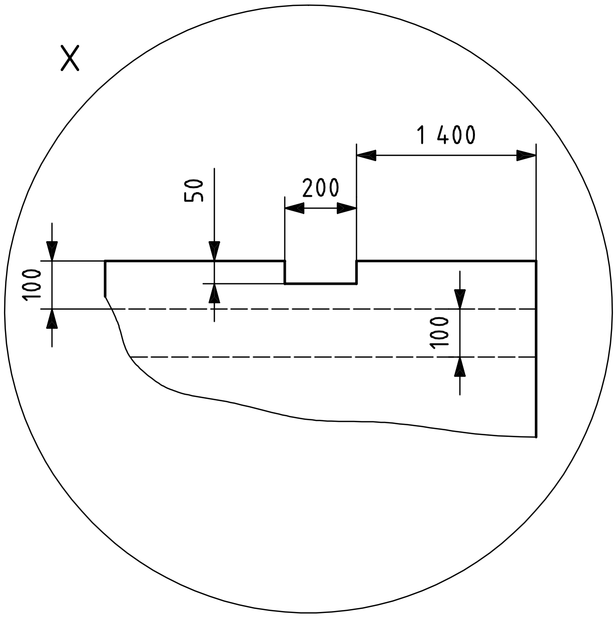
1 concealed spray
2 tray (0,1 m²)
3 steel plate (4 mm)
4 tray (0,4 m²)
5 tray (0,5 m²)
6 steel plate (2 mm)
7 solid steel plate
8 steel plate (300 mm × 600 mm × 50 mm)
9 top tray (3 m²)
10 solid bilge plates (4 000 mm × 6 000 mm outside dimensions)

[a] 100 mm gap between engine mock-up and inside perimeter of bilge plates.

Figure 3 — Engine mock-up and engine mock-up side view

Dimensions in millimetres





Key

1 obstruction rod (15 mm × 1 000 mm)

2 steel plate (thickness 5 mm)

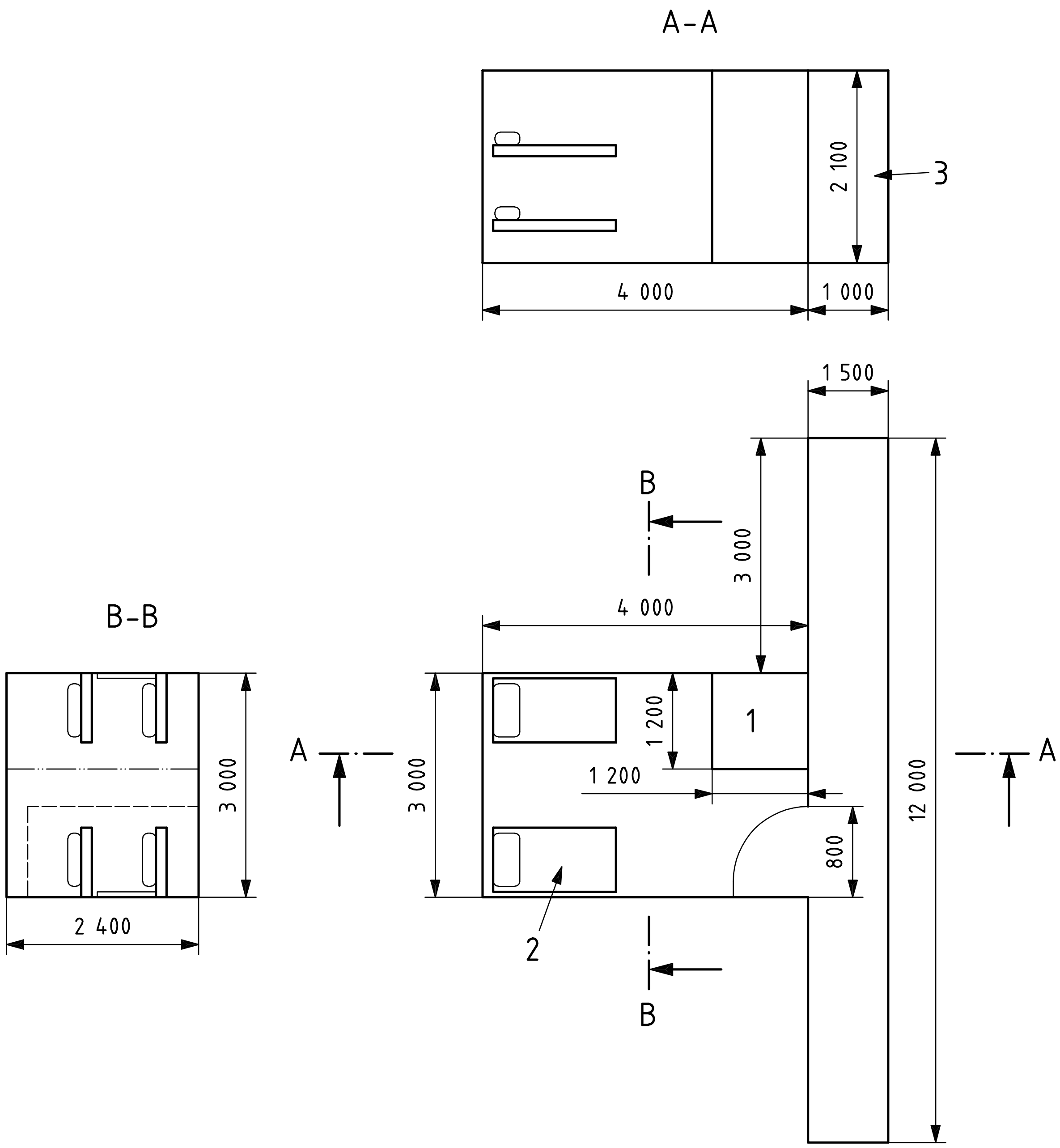
3 tray (0,1 m^2)

4 tray (0,4 m^2)

5 tray (0,5 m^2)

Figure 4 — Engine mock-up detail

Dimensions in millimetres



Key

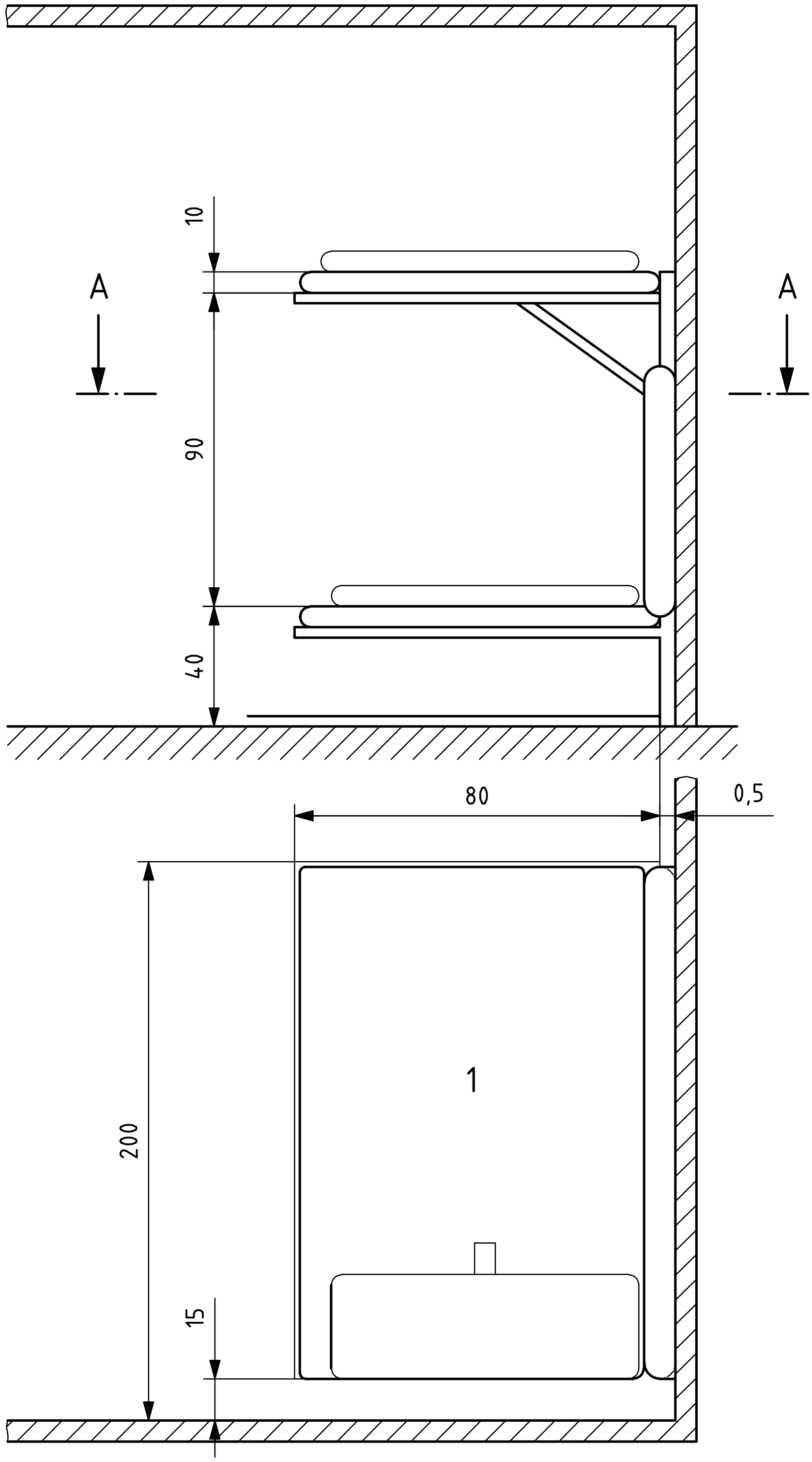
1 lavatory

2 ignition point

3 corridor

Figure 5 — 12 m^2 cabin and corridor details

Dimensions in centimetres

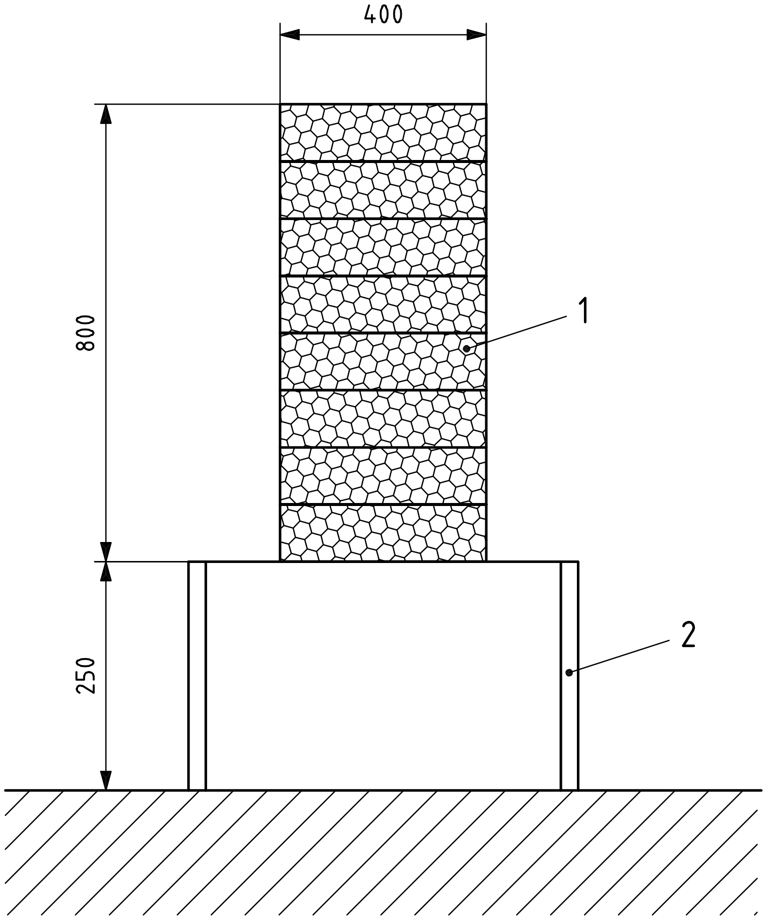


Key

1 ignition source

Figure 6 — Bunk bed arrangement

Dimensions in millimetres



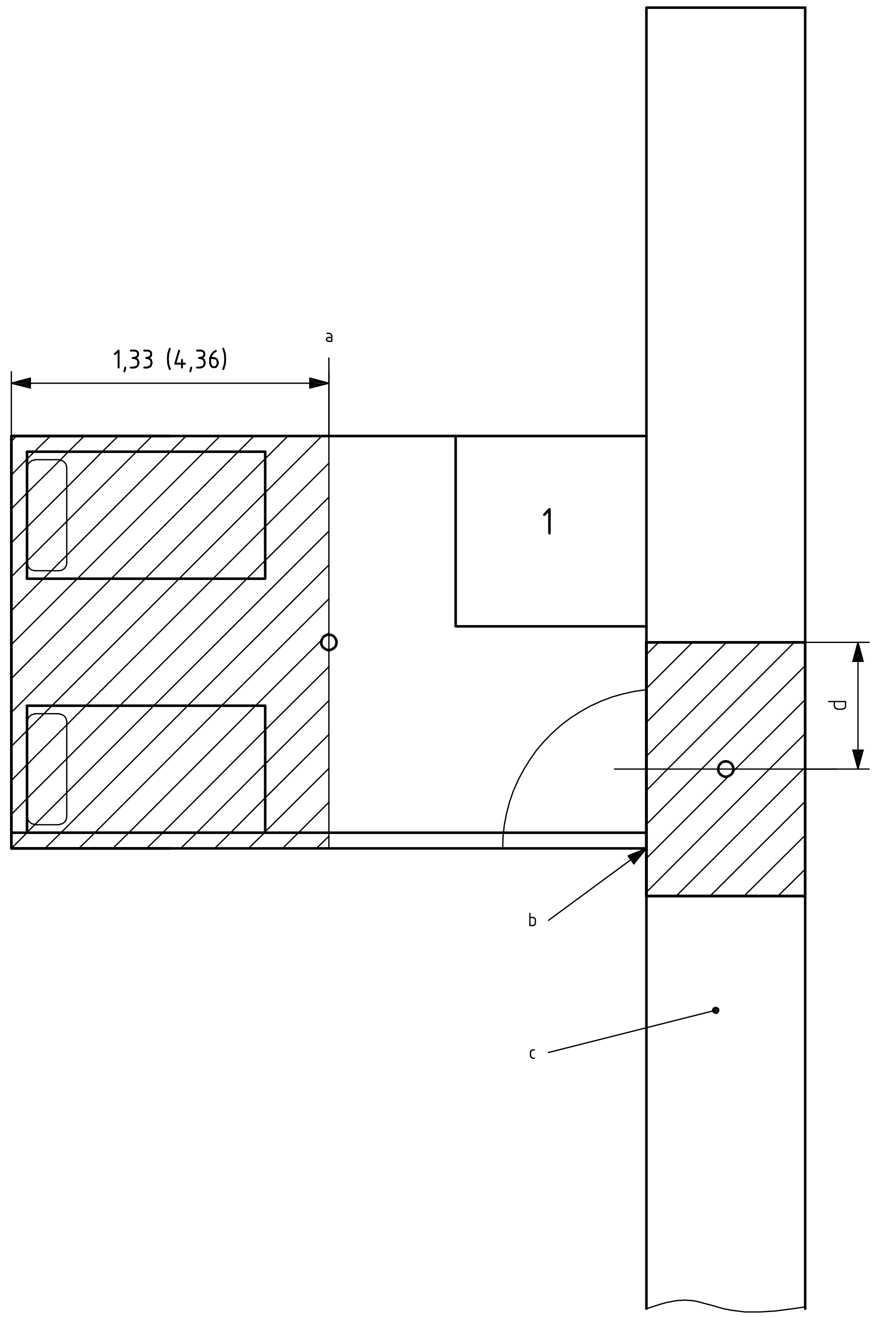
Key

1 8 piled mattresses (400 mm × 400 mm)

2 stand

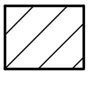
Figure 7 — Corridor fire fuel package

Dimensions in metres (feet)



Key

1 lavatory

 restricted area for location of nozzle

a Thermocouples in the centre of the cabin should be placed so that they are not directly affected by water.

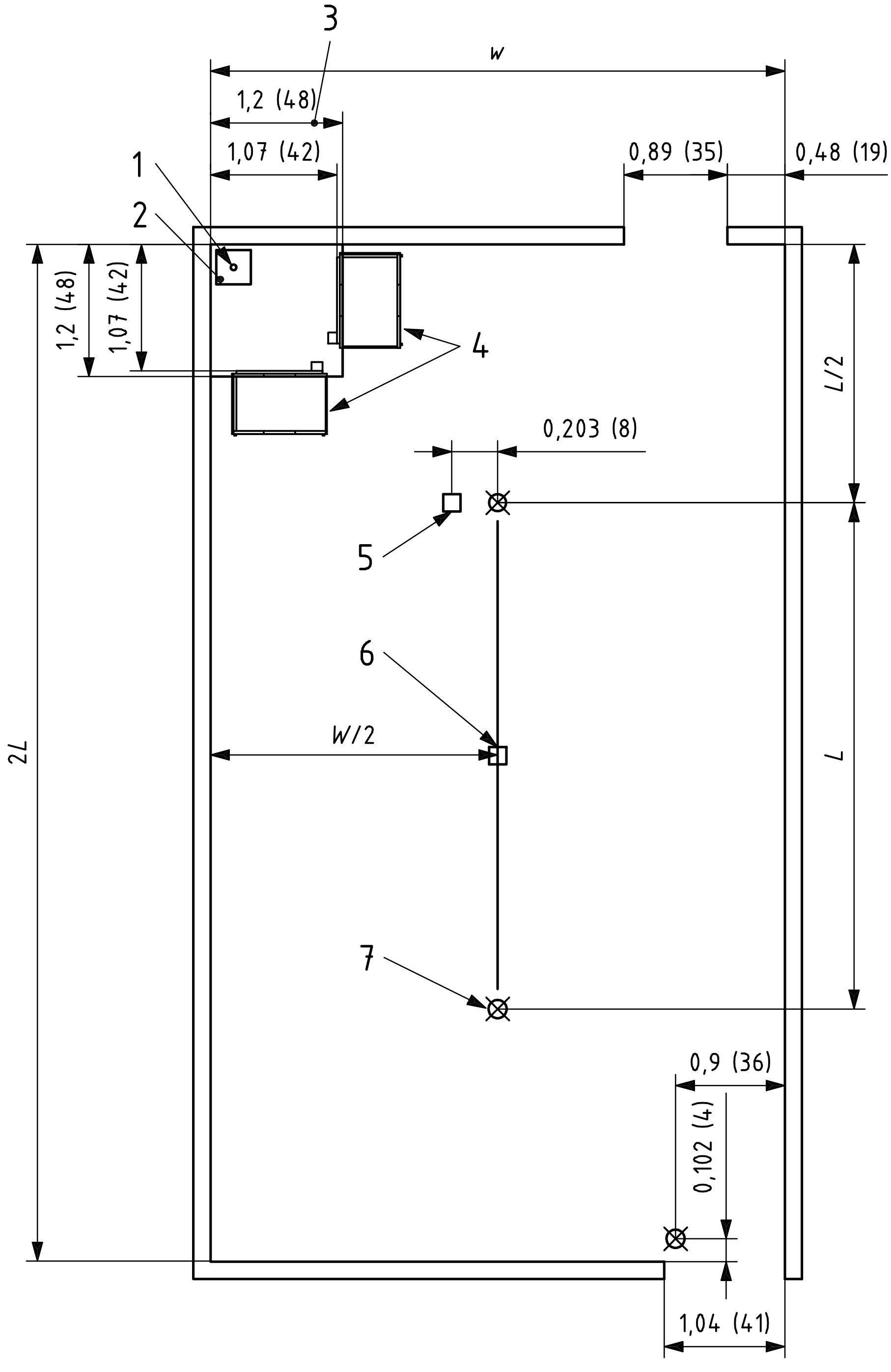
b Thermocouples located opposite doorway.

c Thermocouples should be placed between two nozzles.

d 1/2 × spacing between nozzles.

Figure 8 — Location of thermocouples in the cabin/corridor and areas restricted for location of nozzles

Dimensions in metres (inches)



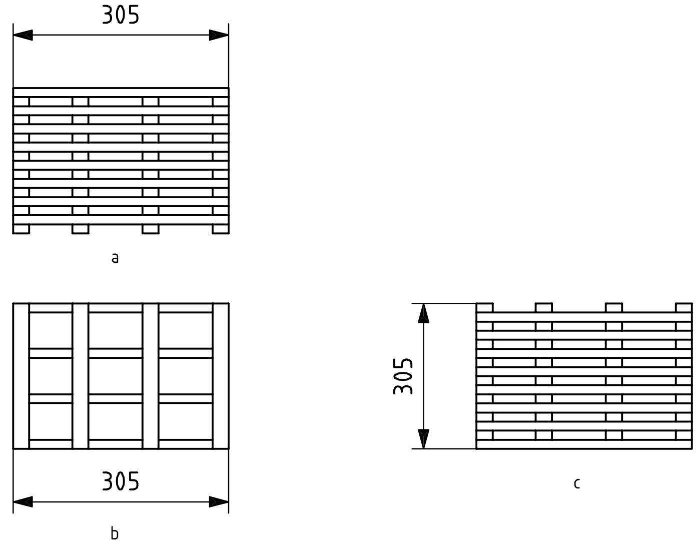
Key

1 thermocouple 6,3 mm (0,25 in) above ceiling 254 mm (10 in) diagonally from corner
2 wood crib
3 plywood
4 simulated furniture
5 thermocouples 76,2 mm (3 in) below ceiling and 1,6 m (63 in) above floor
6 thermocouple 76,2 mm (3 in) below ceiling (room centre)
7 sprinkler (typical)

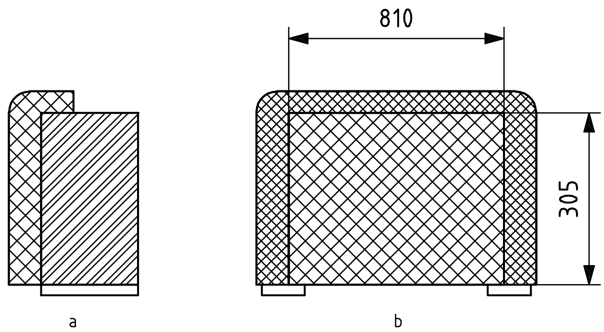
L = coverage length
W = coverage width

Figure 9 — 24 metres square and larger cabin fire test arrangement

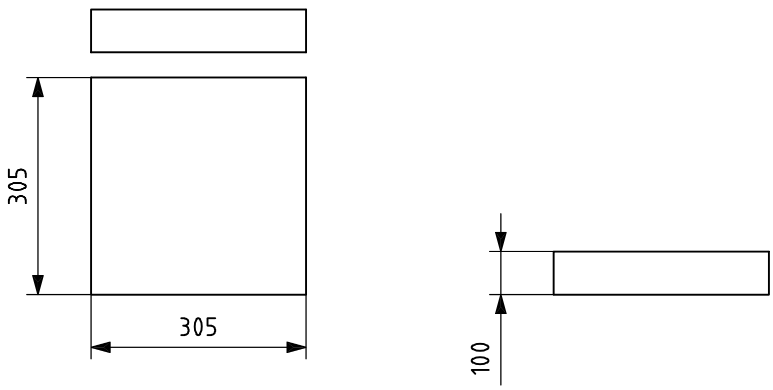
Dimensions in millimetres



a) Wood crib



b) Simulated furniture



c) Test pan

Key

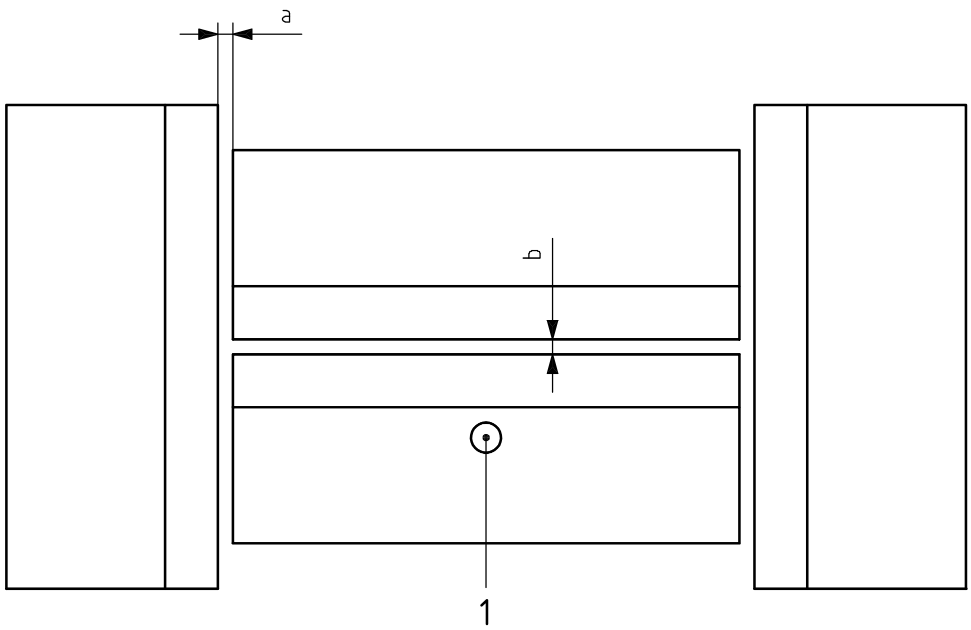
a Side elevation.

b Plan.

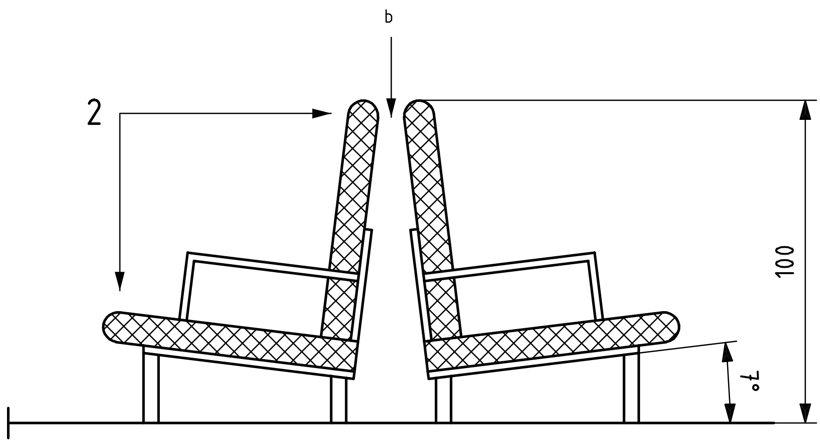
c Front elevation.

Figure 10 — Cabin fire test crib and simulated furniture fuel package

Dimensions in centimetres



a) Top view



b) Side view of centre sofas

Key

1 fire source

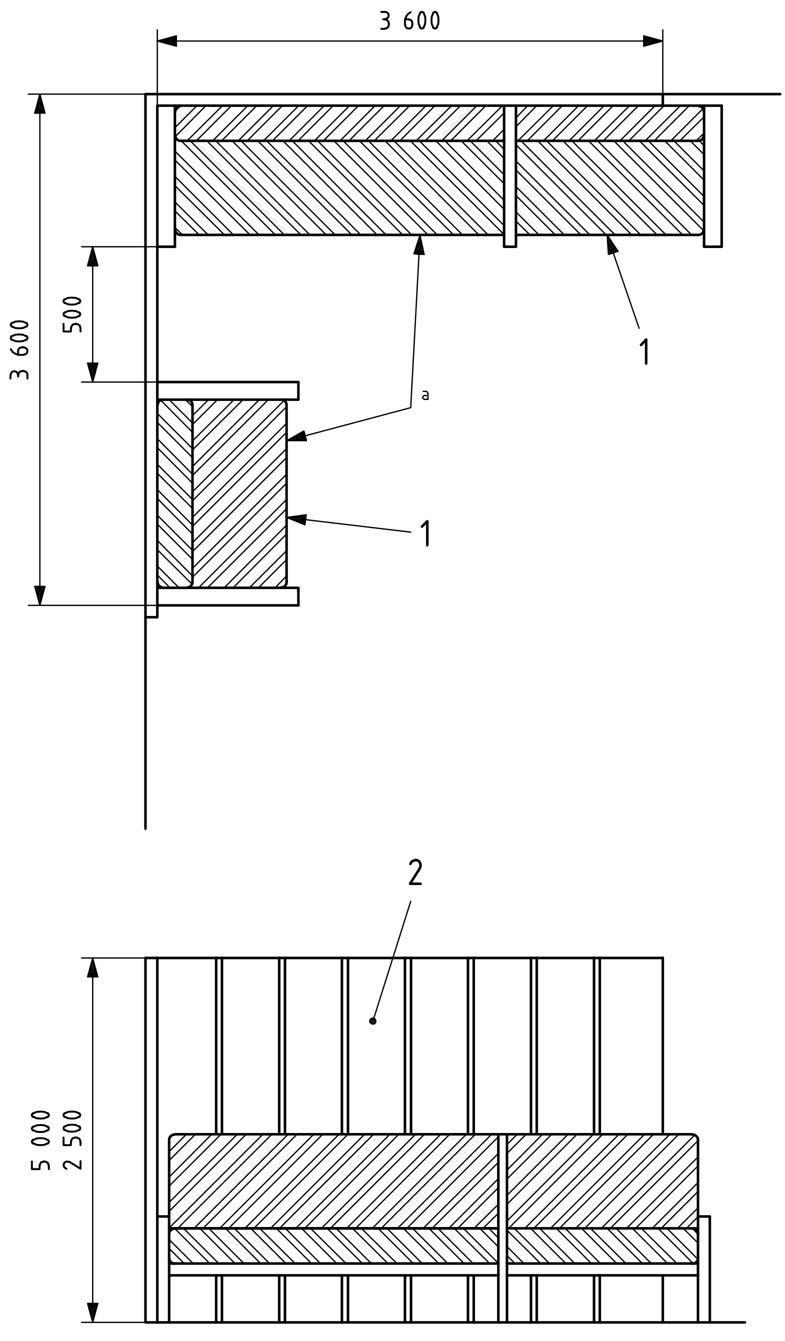
2 mattresses (200 cm × 80 cm × 10 cm)

[a] 2 cm to 3 cm gap between top back edge of outer sofa to the respective edge of the inner sofa's mattresses (2 places).

[b] 2 cm to 3 cm gap between top back edge of sofas.

Figure 11 — Public space fire test arrangement

Dimensions in millimetres



Key

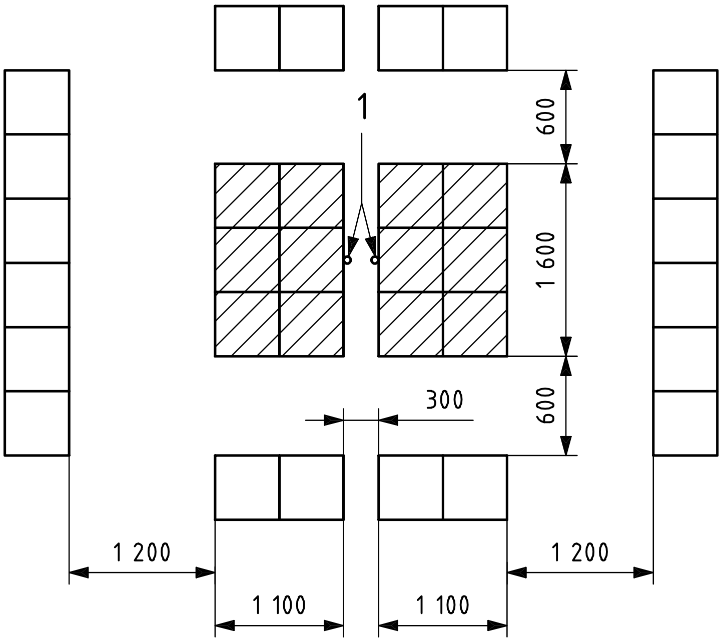
1 1/2 sofa (target)

2 decorative plywood wood panels

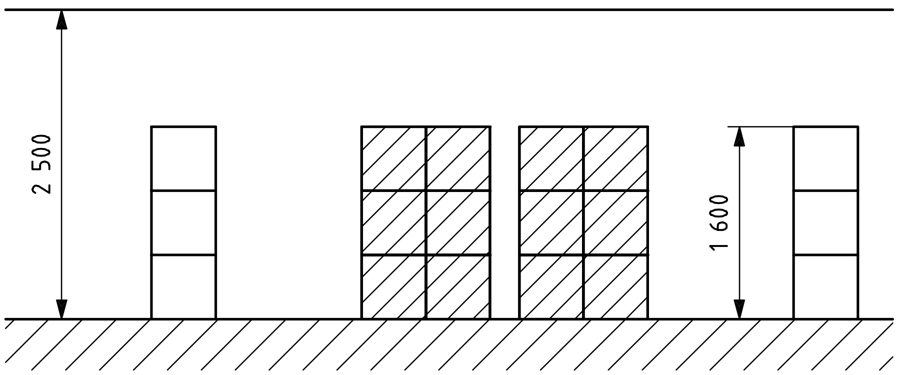
[a] Sofas placed 25 mm from walls.

Figure 12 — Public space corner fire test arrangement

Dimensions in millimetres



a) Plan view



b) Front view

Key

1 ignitors

(hatched)	cardboard cartons packed with polystyrene plastic cups
(empty)	empty cardboard boxes as target arrays

Figure 13 — Public space ordinary hazard test arrangement

Annex A
(normative)

Tolerance limit calculation methods

A.1 General

The calculation methods for determining compliance with the tolerance limit requirements specified in 7.7.1 are described in A.2 to A.4.

A.2 Unbiased standard deviation

The sample unbiased standard deviation is calculated from the formula:

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n-1}}$$

where

X is the sample mean;

X_i is the individual value of each sample tested;

n is the number of samples tested;

s is the unbiased sample standard deviation.

A.3 Determination of constant

Determine K, where K is a factor selected from Table A.1.

A.4 Procedure

The steps to complete the comparison with the requirements specified in 7.7.1 are to be performed as indicated in Table A.2.

Table A.1 — Table for K factors for one-sided tolerance limits for normal distributions

Number of samples n	**Strength of heat-responsive element test for frangible bulb types** (see 7.7.1) $\Gamma = 0{,}99$ $P = 0{,}99$ (99 % of samples)
10	5,075
11	4,828
12	4,633
13	4,472
14	4,336
15	4,224
16	4,124
17	4,038
18	3,961
19	3,893
20	3,832
21	3,776
22	3,727
23	3,680
24	3,638
25	3,601
30	3,446
35	3,334
40	3,250
45	3,181
50	3,124

Table A.2 — Tolerance limit worksheet for strength of heat-responsive element test for frangible bulb types (see 7.7.1)

Sample bulb strength values N	**Nozzle assembly load values** N

$\overline{X_1}$ is the mean bulb strength, in N;

$\overline{S_1}$ is the sample unbiased standard deviation for X_1, in N;

$\overline{X_2}$ is the mean assembly load, in N;

S_2 is the sample unbiased standard deviation for X_2;

K_1 is the bulb strength factor from Table A.1 for $\Gamma = 0{,}99$ and $P = 0{,}99$);

K_2 is the assembly load factor from Table A.1 for $\Gamma = 0{,}99$ and $P = 0{,}99$);

$L_{\text{tol},1}$ is the lower tolerance limit for bulb strength $= X_1 - K_1 S_1$)

$L_{\text{tol},2}$ is the upper tolerance limit for nozzle assembly load $= X_2 + K_2 S_2$)

The sample data are ACCEPTABLE if

$$L_{\text{tol},1} > 2L_{\text{tol},2}$$

Annex B
(informative)

Analysis of the strength test for fusible elements

The formula given in 8.9.2.1 is based on the intention of providing fusible elements that are not susceptible to failure caused by creep stresses during a reasonable period of service. As such, the duration of 876 600 h (100 years) was selected only as a statistical value with an ample safety factor. No other significance is intended, as many other factors govern the useful life of a nozzle.

Loads causing failure by creep, and not by an unnecessarily high initial distortion stress, are applied and the times noted. The given requirement then approximates to the extrapolation of the full logarithmic regression curve by means of the following analysis.

The observed data is used to determine, by means of the method of least squares, the load at 1 h, L_0, and the load at 1 000 h, L_M. One way of stating this is that, when plotted on full logarithmic paper, the slope of the line determined by L_M and L_0 shall be greater than or equal to the slope determined by the maximum design load at 100 years, L_d, and L_0 or

$$(\ln L_M - \ln L_0) \geqslant \ln 1\,000^3 (\ln L_d - \ln L_0)/\ln 876\,600$$

This is then reduced as follows:

$$\ln L_M \geqslant \left(\ln L_d - \ln L_0\right) \frac{\ln 1\,000}{\ln 876\,600} + \ln L_0$$

$$\geqslant 0{,}504\,8 \left(\ln L_d - \ln L_0\right) + \ln L_0$$

$$\geqslant 0{,}504\,8 \ln L_d + \ln L_0 \left(1 - 0{,}504\,8\right)$$

$$\geqslant 0{,}504\,8 \ln L_d + 0{,}495\,2 \ln L_0$$

With an error of approximately 1 %, the formula may be approximated by

$$\ln L_M \geqslant 0{,}5 \left(\ln L_d + \ln L_0\right)$$

or, compensating for errors

$$\ln L_M \geqslant \sqrt{0{,}99\, L_d\, L_0}$$

or

$$L_d \geqslant 1{,}02 \frac{{L_M}^2}{L_0}$$

Annex C
(informative)

Nozzle response sample calculations

C.1 Calculation of C-factor (see 8.6.2.2.1)

EXAMPLE

The mean nozzle operating temperature obtained from tests described in 8.6.1 was 72 °C. Sequential tests were conducted as described above. In the first test, $u_L = 0,288$ m/s and $T_m = 20,3$ °C. The actual air temperature was 125 °C. Actuation did not occur in 15 min. In the second test, $u_H = 0,342$ m/s and $T_m = 20$ °C and the actual air temperature was 127 °C. Actuation occurred at 350 s.

$$(u_H/u_L)^{0,5} = (0,342/0,288)^{0,5} \leqslant 1,1$$

therefore

$$C_L = [(125-20,3)/(72-20,3)-1](0,288)^{0,5}$$

$$C_L = 0,55\ (\text{m/s})^{0,5}$$

$$C_H = [(127-20)/(72-20)-1](0,342)^{0,5}$$

$$C_H = 0,62\ (\text{m/s})^{0,5}$$

$$C = 0,5\ (0,55 + 0,62) = 0,59\ (\text{m/s})^{0,5}$$

C.2 Calculations of RTI

C.2.1 Example

Assume a response time in the plunge test (t_r) equal to 10 s for a nozzle. Also assume the following:

a) The mean liquid bath operating temperature of the nozzle is 72 °C.

b) Ambient temperature is 20 °C.

c) The actual air temperature in the test section is 197 °C.

d) The actual air velocity in the test section is 2,56 m/s.

e) The conductivity factor for this nozzle was determined to be 0,59 (m/s)^{0,5} as described in 8.6.2.2.

$$\text{RTI} = \frac{-10(2,56)^{0,5}\left[1 + 0,59/(2,56)^{0,5}\right]}{\ln\left[1-(72-20)\left[1+0,59/(2,56)^{0,5}\right]/(197-20)\right]}$$

$$\text{RTI} = 43\ (\text{m}\cdot\text{s})^{0,5}$$

C.2.2 Example

In connection with the example in 8.6.2.3, assume a response time in the worst-case orientation of 20 s. Let this RTI be denoted RTI_{wc}:

$$RTI_{wc} = \frac{-20(2{,}56)^{0{,}5}\left[1+0{,}59\left(RTI_{wc}/2{,}56\right)^{0{,}5}\right]}{\ln\left\{1-(72-20)\left[1+0{,}59\left(RTI_{wc}/43\right)/(2{,}56)^{0{,}5}\right]/(197-20)\right\}}$$

The iterative solution is:

$RTI_{wc} = 80\ (m \cdot s)^{1/2}$

Annex D
(normative)

Tolerances

Unless otherwise stated, the following tolerances shall apply:

a) angle ± 2°

b) frequency (Hz) ± 5 % of value

c) length ± 2 % of value

d) volume ± 5 % of value

e) pressure ± 3 % of value

f) temperature ± 5 % of value

g) time $^{5}_{0}$ s

$^{0,1}_{0}$ min

$^{0,1}_{0}$ h

$^{0,25}_{0}$ d

Bibliography

[1] ISO 49, *Malleable cast iron fittings threaded to ISO 7-1*

[2] IEC 60751, *Industrial platinum resistance thermometer sensors*

ICS 13.220.20

Price based on 60 pages