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Fire protection — Automatic sprinkler systems —

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

Protection contre l'incendie — Systèmes d'extinction automatiques du type sprinkler —

Partie 7: Prescriptions et méthodes d'essai des sprinklers de type «extinction précoce/réaction rapide»

Reference number
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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 6182-7 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 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*

The following parts are under preparation:

- *Part 8: Requirements and test methods for pre-action dry alarm valves*
- *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 requirements and test methods for early suppression fast response (ESFR) sprinklers.

Fire protection — Automatic sprinkler systems —

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

1 Scope

This part of ISO 6182 specifies performance requirements, test methods and marking requirements for fusible element and glass-bulb early suppression fast response (ESFR) sprinklers. It is applicable to ESFR sprinklers with flow constants of 202 ± 8.

NOTE 1 Requirements for ESFR sprinklers with flow constants other than 202 ± 8 are in preparation.

NOTE 2 All pressure data in this part of ISO 6182 are also given as gauge pressure in bar. The correct SI unit for pressure is the pascal (Pa) (1 bar = $10^5 N/m^2$ = 0,1 MPa).

2 Normative reference

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 7-1:1994, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

3 Terms and definitions

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

3.1 General

3.1.1
sprinkler
thermosensitive device designed to react at a predetermined temperature by automatically releasing a stream of water and distributing it in a specified pattern and quantity over a designated area

3.1.2
conductivity factor
C
measure of the conductance between the sprinkler's heat responsive element and the fitting

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

3.1.3
response time index
RTI
measure of sprinkler sensitivity

$$\text{RTI} = \tau\sqrt{u}$$

where

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

u is the gas velocity, expressed in meters per second

NOTE 1 The response time index is expressed in units of $(\text{m}\cdot\text{s})^{0,5}$.

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

3.1.4
orientation A
orientation with the airflow perpendicular to both the waterway axis and the plane of the frame arms and with the heat responsive element upstream of the frame arms

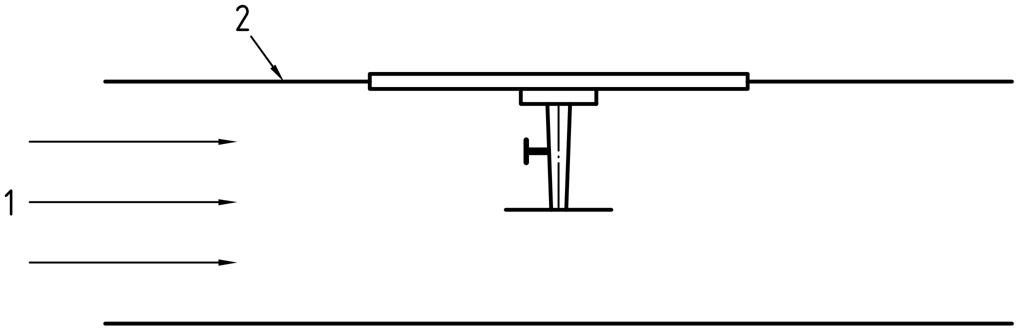
See Figure 1.

3.1.5
orientation B
orientation with the airflow perpendicular to both the waterway axis and the plane of the frame arms and with the heat responsive element downstream of the frame arms

See Figure 1.

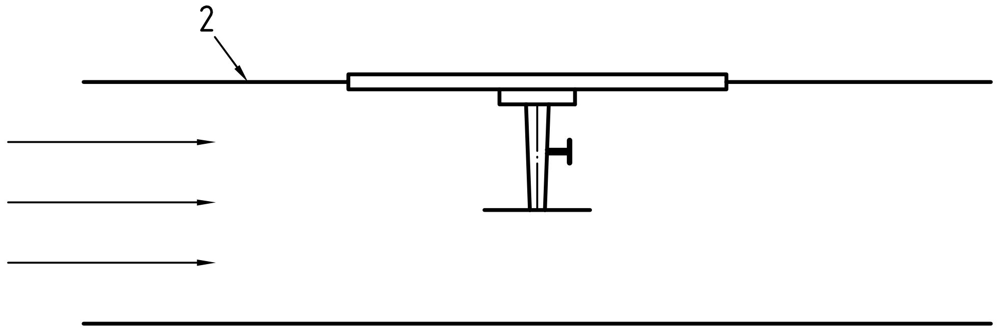
3.1.6
orientation C
⟨head on⟩ orientation with the axis of the sprinkler inlet parallel to the airflow and the deflector perpendicular to the airflow

See Figure 1.

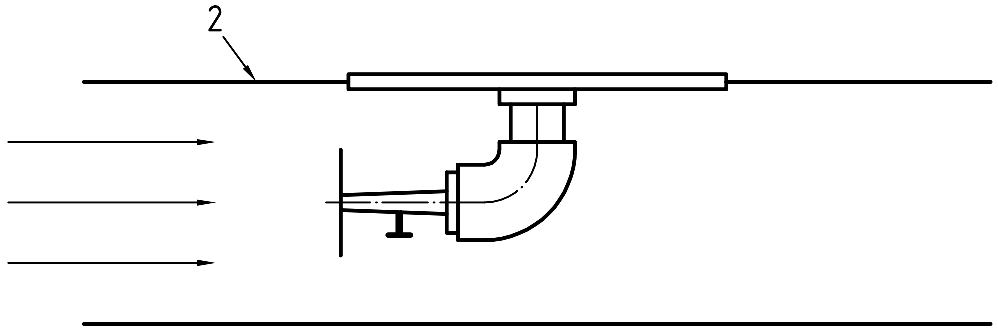


a) Orientation A

Figure 1 — Orientations A, B and C



b) Orientation B



c) Orientation C

Key

1 air flow

2 tunnel test section (elevation view)

NOTE If the sprinkler has a symmetrical heat responsive element and frame, Orientation A would be the same as Orientation B. Testing in both positions is not required.

Figure 1 (*continued*)

3.1.7
actual delivered density

ADD

rate at which water is deposited from an operating sprinkler onto the top horizontal surface of a simulated burning combustible array

3.1.8
early suppression

sprinkler system performance whereby the first few sprinklers, which operate, are able to provide sufficient water to the fire early enough so as to reduce the fire to an acceptable level, if not extinguished

3.1.9
early suppression fast response automatic sprinkler

ESFR

thermosensitive device designed to react at a predetermined temperature by automatically releasing a stream of water and distributing it in a specified pattern and density over a designated area so as to provide early suppression of a fire when installed on the appropriate sprinkler piping

3.1.10
assembly load

force exerted on the sprinkler at 0 MPa (0 bar) hydraulic pressure at the inlet

3.1.11

design load

force exerted on the sprinkler at the service load of the sprinkler

3.1.12

service load

combined force exerted on the sprinkler body by the assembly load of the sprinkler and the equivalent force of a 1,2 MPa (12 bar) hydraulic pressure of the inlet

3.1.13

average design strength

⟨axial⟩ glass-bulb suppliers specified and assured lowest average design strength of any batch of 50 bulbs

3.2 Sprinklers classified according to type of heat responsive element

3.2.1

fusible element sprinkler

sprinkler that opens under the influence of heat by the melting of a component

3.2.2

glass-bulb sprinkler

sprinkler that opens under the influence of heat by the bursting of the glass bulb caused by the increased pressure resulting from expansion of the fluid enclosed therein

3.3 Sprinklers classified according to position

3.3.1

pendent sprinkler

P

sprinkler that is arranged in such a way that the water stream is directed downwards against the distribution plate

3.3.2

upright sprinkler

U

sprinkler that is arranged in such a way that the water stream is directed upwards against the distribution plate

4 Product consistency

It shall be the responsibility of the manufacturer to implement a quality control programme to ensure that production continuously meets the requirements of this part of ISO 6182 in the same manner as the originally tested samples.

Every manufactured sprinkler shall pass a leak resistance test equivalent to a hydrostatic pressure of at least 3,4 MPa (34 bar) for at least 2 s.

5 Product assembly

All sprinklers shall be designed and manufactured in such a way that they cannot be readily adjusted, dismantled or reassembled.

6 Requirements

6.1 Dimensions

6.1.1 Sprinklers shall have a nominal thread size of R 3/4.

6.1.2 Nominal thread sizes shall be suitable for fittings threaded in accordance with ISO 7-1.

The dimensions of all threaded connections should conform to International Standards where applied. National standards may be used if International Standards are not applicable.

6.1.3 All sprinklers shall be constructed so that a sphere of diameter 8 mm can pass through each water passage in the sprinkler.

6.2 Nominal operating temperatures (see 7.7)

The nominal operating temperature of ESFR sprinklers shall be as indicated in Table 1.

The nominal operating temperatures of all sprinklers shall be specified in advance by the manufacturer and verified in accordance with 6.3. They shall be determined as a result of the operating temperature test (see 7.7.1). Nominal operating temperatures shall be within the ranges specified in Table 1.

The nominal operating temperature that is to be marked on the sprinkler shall be that determined when the sprinkler is tested in accordance with 7.7.1, taking into account the specifications of 6.3.

Table 1 — Nominal operating temperature and colour coding

Values in degrees Celsius

Glass-bulb sprinklers		Fusible element sprinklers	
Nominal operating temperature	**Liquid colour code**	**Nominal operating temperature**	**Yoke arm colour code**
68 to 74	red	68 to 74	uncoloured
93 to 104	green	93 to 104	white

6.3 Operating temperatures (see 7.7.1)

Sprinklers shall open within a temperature range of

$$T \pm (0{,}035T + 0{,}62) \tag{1}$$

where T is the nominal operating temperature, expressed in degrees Celsius.

6.4 Water flow and distribution

6.4.1 Flow constant (see 7.11)

The flow constant, K, for sprinklers is given by the formula

$$K = \frac{q_V}{\sqrt{p}} \tag{2}$$

where

p is the pressure, expressed in bars;

q_V is the flow rate, expressed in litres per minute (l/min).

The flow constant for ESFR sprinklers shall have values of 202 ± 8 when determined by the test method of 7.11. All values tested shall be within the acceptable range and the standard deviation divided by the average value of the flow constant shall be less than 2 %.

6.4.2 Water distribution (see 7.12)

6.4.2.1 To demonstrate the required coverage of the protected area allotted to it, the sprinkler shall be subjected to the tests specified in 7.12.

6.4.2.2 Ten collection pans, as specified in 7.12.1, shall be utilized on a rotating table to measure the distribution from a single sprinkler. All pan collection rate values shall be recorded. The tenth pan shall have a collection rate not exceeding 0,80 mm/min.

6.4.2.3 Three samples, or sets of samples, shall be tested to the requirements of Table 2 in accordance with 7.12.2.

Table 2 — Sprinkler water distribution measurements

Number of sprinklers under the water-collection system	Sprinkler spacing m	Pipe spacing m	Ceiling clearance to water-collection pans m	Pressure [a, b] MPa (bar)	Minimum 16-pan average density[c] mm/min	Minimum flue space (4 pans) average[c] mm/min	Minimum 20-pan average density[c] mm/min	Minimum non-flue 10-pan average density[c,d] mm/min	Minimum single non-flue pan density[c] mm/min
1	0	0	3,04	0,34 (3,4)	21,22	40,80	NR	NR	NR
1	0	0	4,42	0,34 (3,4)	19,58	36,31	NR	NR	NR
1	0	0	4,42	0,51 (5,1)	NR	69,36	37,13	20,40	10,61
2	3,04	0	1,27	0,34 (3,4)	24,48	NR	NR	NR	NR
2	3,04	0	3,04	0,34 (3,4)	22,03	NR	NR	NR	NR
2	0	3,04	1,27	0,34 (3,4)	23,66	NR	NR	NR	NR
2	0	3,04	3,04	0,34 (3,4)	23,26	NR	NR	NR	NR
2	3,66	0	1,27	0,34 (3,4)	17,95	NR	NR	NR	NR
2	0	3,66	1,27	0,34 (3,4)	18,36	NR	NR	NR	NR
2	3,04	0	1,27	0,51 (5,1)	NR	NR	31,42	24,48	8,16
2	0	3,04	1,27	0,51 (5,1)	NR	NR	31,42	24,48	8,16
4	3,04	3,04	1,27	0,34 (3,4)	27,74	NR	NR	NR	NR
4	3,04	3,04	3,04	0,34 (3,4)	35,09	NR	NR	NR	NR
4	2,44	3,6	1,27	0,34 (3,4)	26,93	NR	NR	NR	NR
4	3,04	3,04	1,27	0,51 (5,1)	NR	NR	28,97	24,48	15,10

[a] All 0,34 MPa (3,4 bar) tests are performed on a system fed from both directions (double feed).

[b] All 0,51 MPa (5,1 bar) tests are performed on a system fed from one direction (single feed), except for the two-sprinklers, single-pipe tests which are performed on a double-feed system.

[c] NR = No requirement (see Figures 8 to 13).

[d] Average of the ten non-flue pans with the lowest water collection.

6.5 Ability to function (see 7.6)

6.5.1 When tested in accordance with 7.6.1, all operating parts shall clear the sprinkler within 10 s or shall comply with the requirements of 6.4.2.

6.5.2 The deflector and its supporting parts shall not sustain significant damage as a result of the deflector strength test specified in 7.6.2 and shall meet the requirements of 6.4.2.

NOTE In most instances, visual examination of the sprinkler is sufficient to establish conformity with the requirements of 6.5.1 and 6.5.2.

6.6 Strength of sprinkler body (see 7.4)

The sprinkler body shall not show permanent elongation of more than 0,2 % between the load-bearing points of the sprinkler body after being subjected to twice the average service load as measured in 7.4.

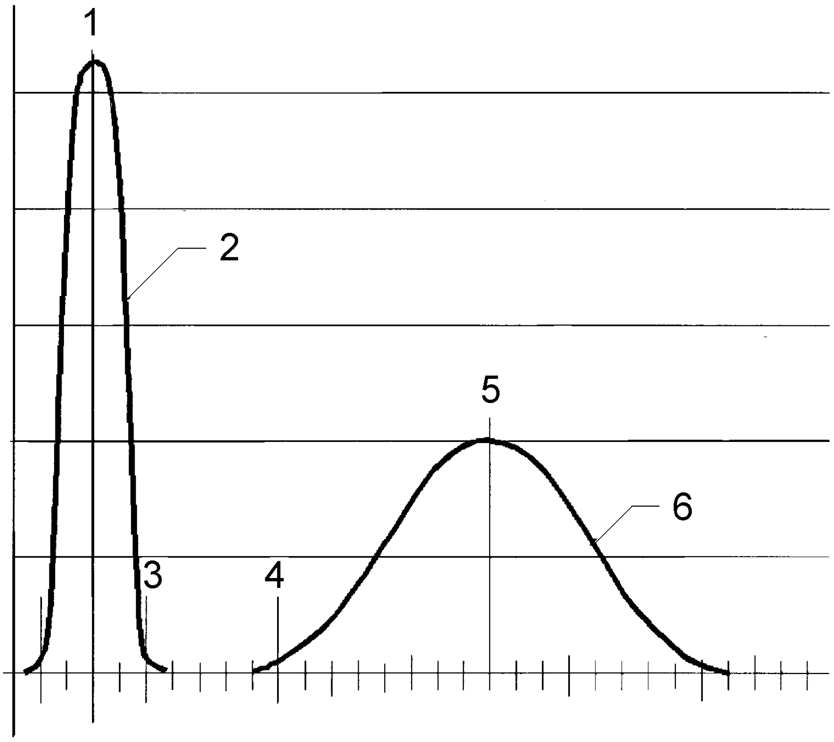
6.7 Strength of release element (see 7.10)

6.7.1 When tested in accordance with 7.10.1, the elements of glass bulbs shall

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

b) have a design strength lower tolerance limit (L_{TL}) on the strength distribution curve of at least two times the upper tolerance limit (U_{TL}) of the service load distribution curve based on calculations with a degree of confidence (y) of 0,99 for 99 % of samples (n).

Calculations will be based on a normal or Gaussian distribution, except where other distributions can be shown to be more applicable due to manufacturing of designing factors. See Figure 2 and Annex A.



Key

1 average service load
2 service load curve
3 U_{TL}
4 L_{TL}
5 average design strength
6 design strength curve

Figure 2 — Strength curve

6.7.2 Fusible heat-responsive elements shall sustain the design load when tested in accordance with 7.10.2.

6.8 Leak resistance and hydrostatic strength (see 7.5)

6.8.1 A sprinkler shall not show any sign of leakage when tested by the method specified in 7.5.1.

6.8.2 A sprinkler shall not rupture, operate, or release any parts when tested by the method specified in 7.5.2.

6.9 Heat exposure (see 7.8)

6.9.1 Glass-bulb type ESFR sprinklers

There shall be no damage to the elements of the glass bulb when the sprinkler is tested by the method specified in 7.8.1.

6.9.2 All ESFR sprinklers

ESFR sprinklers shall withstand exposure to increased ambient temperature without evidence of weakness or failure when tested by the method specified in 7.8.2.

6.10 Thermal shock (see 7.9)

Glass-bulb type ESFR sprinklers shall not be damaged when tested by the method specified in 7.9.

6.11 Corrosion

6.11.1 Stress corrosion (see 7.13.1)

When tested in accordance with 7.13.1, each sprinkler shall show no cracks, delaminations, or failures which can possibly affect its ability to satisfy other requirements. Following exposure, half the sprinkler samples shall be tested to requirements of 6.8.1. The remaining samples shall have an RTI of $(28 \pm 8)\ (\mathrm{m \cdot s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.11.2 Moist sulfur-dioxide/carbon-dioxide corrosion (see 7.13.2)

ESFR sprinklers shall be resistant to sulfur-dioxide/carbon-dioxide saturated with water vapour when conditioned in accordance with 7.13.2. Following exposure, the sprinklers shall meet the requirements of 6.8.1 at 1,20 MPa (12,0 bar). Half the samples shall meet the requirements of 6.3 and the remaining samples shall have an RTI of $(28 \pm 8)\ (\mathrm{m \cdot s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.11.3 Moist hydrogen-sulfide corrosion (see 7.13.3)

ESFR sprinklers shall be resistant to hydrogen sulfide saturated with water vapour when conditioned in accordance with 7.13.3. Following exposure, the sprinklers shall meet the requirements of 6.8.1 at 1,20 MPa (12,0 bar). Half the samples shall meet the requirements of 6.3 and the remaining samples shall have an RTI of $(28 \pm 8)\ (\mathrm{m \cdot s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.11.4 Salt-spray corrosion (see 7.13.4)

ESFR sprinklers shall be resistant to salt spray when conditioned in accordance with 7.13.4. Following exposure, the sprinklers shall be tested at 1,20 MPa (12,0 bar) in accordance with 6.8.1 and have an RTI of $(28 \pm 8)\ (\mathrm{m \cdot s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.11.5 Moist-air exposure (see 7.13.5)

Sprinklers shall be resistant to moist-air exposure when tested in accordance with 7.13.5. Following exposure, the sprinklers shall operate as intended when tested in accordance with 7.6.2.

6.12 Water hammer (see 7.15)

Sprinklers shall not leak when subjected to pressure surges from 0,4 MPa to 3,4 MPa (4 bar to 34 bar). They shall show no signs of mechanical damage when tested in accordance with 7.15. Following the water-hammer test, the samples shall not leak when tested in accordance with 7.5.1 and shall operate as intended when tested in accordance with 7.6.2.

6.13 Dynamic heating (see 7.7.2)

6.13.1 See also the references in the Bibliography.

6.13.2 ESFR sprinklers shall meet the RTI limits of (28 ± 8) $(\text{m}\cdot\text{s})^{0,5}$ when tested in orientations A and B as described in 7.7.2. The RTI value shall not exceed 138 % of the original value when tested in orientation C as described in 7.7.2. The conductivity factor, C, is not required for this calculation in this part of ISO 6182.

6.13.3 The conductivity factor (C) shall not exceed 1,0 $(\text{m/s})^{0,5}$ when determined using the prolonged plunge test (see 7.7.3.2) or the prolonged exposure ramp test (see 7.7.3.3).

6.14 Resistance to heat (see 7.14)

Open sprinklers shall be resistant to high temperatures when tested in accordance with 7.14. After exposure, the sprinkler shall not show visual deformation or fracture.

6.15 Resistance to vibration (see 7.16)

Sprinklers shall be able to withstand the effects of vibration without deterioration when tested in accordance with 7.16. After the vibration test of 7.16, sprinklers shall show no visible deterioration and shall meet the requirements of 6.8.1 and shall have an RTI of (28 ± 8) $(\text{m}\cdot\text{s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.16 Resistance to impact (see 7.17)

ESFR sprinklers shall have adequate strength to withstand impacts associated with handling, transport and installation without deterioration of performance or reliability. These sprinklers shall show no fracture or deformation, shall meet the leak resistance requirement of 6.8.1 and the dynamic heating test requirement of 6.13.3 after the impact test of 7.17.1. If the sprinkler is deformed during testing, water distribution testing (6.4.2) shall be required.

6.17 Lateral discharge (see 7.18)

When tested in accordance with 7.18, there shall be no direct impingement or dripping of water from the target.

6.18 Thirty-day leakage resistance (see 7.19)

When tested in accordance with 7.19 sprinklers shall not leak, sustain distortion, or suffer any other mechanical damage when subjected to 2 MPa (20 bar) water pressure for 30 d.

6.19 Vacuum resistance (see 7.20)

Sprinklers shall not exhibit distortion or mechanical damage and shall meet the leakage requirements of 6.8.1 after being subjected to the test in 7.20.

6.20 Resistance to low temperatures (see 7.21)

Sprinklers shall be resistant to low temperatures when tested in accordance with 7.21. After exposure, the sprinkler shall either be visibly damaged, leak subsequent to thawing, or not be damaged. Sprinklers not visibly damaged shall be subjected to the requirements of 6.8 and shall have an RTI of (28 ± 8) $(\mathrm{m \cdot s})^{0,5}$ when tested in accordance with 7.7.2.2.

6.21 Actual delivered density (see 7.22)

ESFR sprinklers shall meet the minimum average densities shown in Table 3 when measured in accordance with 7.22.

Table 3 — ADD measurements

Number of sprinklers under the ADD apparatus	Sprinkler spacing m	Pipe spacing m	Ceiling clearance to water-collection pans m	Freeburn convective heat release kW	Pressure MPa (bar)	Direction of feed flow	Minimum 16-pan average ADD mm/min	Minimum flue space (4 pans) average [a] mm/min
1	0	0	4,57	1 318	0,34 (3,4)	Double	19,18	60,38
1	0	0	4,57	2 636	0,34 (3,4)	Double	9,79	20,40
2	3,66	0	1,22	2 636	0,34 (3,4)	Single	11,83	NR
2	0	3,66	1,22	2 636	0,34 (3,4)	Double	14,28	NR
4	2,44	3,66	1,22	2 636	0,34 (3,4)	Double	26,11	NR

[a] NR = No requirement.

6.22 Thrust force measurements (see 7.23)

ESFR sprinklers shall meet the minimum thrust force requirements shown in Table 4 when tested in accordance with 7.23.

Table 4 — Thrust

Pressure MPa (bar)	Direction of feed flow	Ceiling clearance to thrust plate m	Minimum required thrust Pa (mbar)
0,34 (3,4)	Double	1,2	0,71 (0,71)
0,34 (3,4)	Double	2,1	0,44 (0,44)
0,51 (5,1)	Single	2,1	0,99 (0,99)

6.23 Reaction force test (see 7.24)

ESFR sprinklers shall meet the minimum reaction force requirements shown in Table 5 when tested in accordance with 7.24.

Table 5 — Reaction force

Pressure MPa (bar)	Minimum required reaction force[a] N
0,34 (3,4)	57
0,51 (5,1)	85

[a] This is 35 % of the maximum force of a K 202 nozzle 476 N/MPa × 0,35 = 167 N/MPa (47,6 N/bar × 0,35 = 16,7 N/bar).

7 Test methods

7.1 General conditions

Carry out the following tests for each type of sprinkler. Before testing, precise drawings of parts and the assembly shall be submitted together with the appropriate specifications (using SI units). Carry out tests at a room temperature of (20 ± 5) °C, unless other temperatures are indicated. Test sprinklers with all the components required by their design and installation. A suggested test programme is illustrated in Figure 3 for guidance.

7.2 Preliminary examination

Examine the construction to ensure that it complies with the requirements of Clause 4 and Clause 5.

7.3 Visual examination

Before testing, examine the sprinklers visually with respect to the following points:

a) marking,

b) conformity of the sprinklers with the manufacturer's drawings and specifications, and

c) obvious defects.

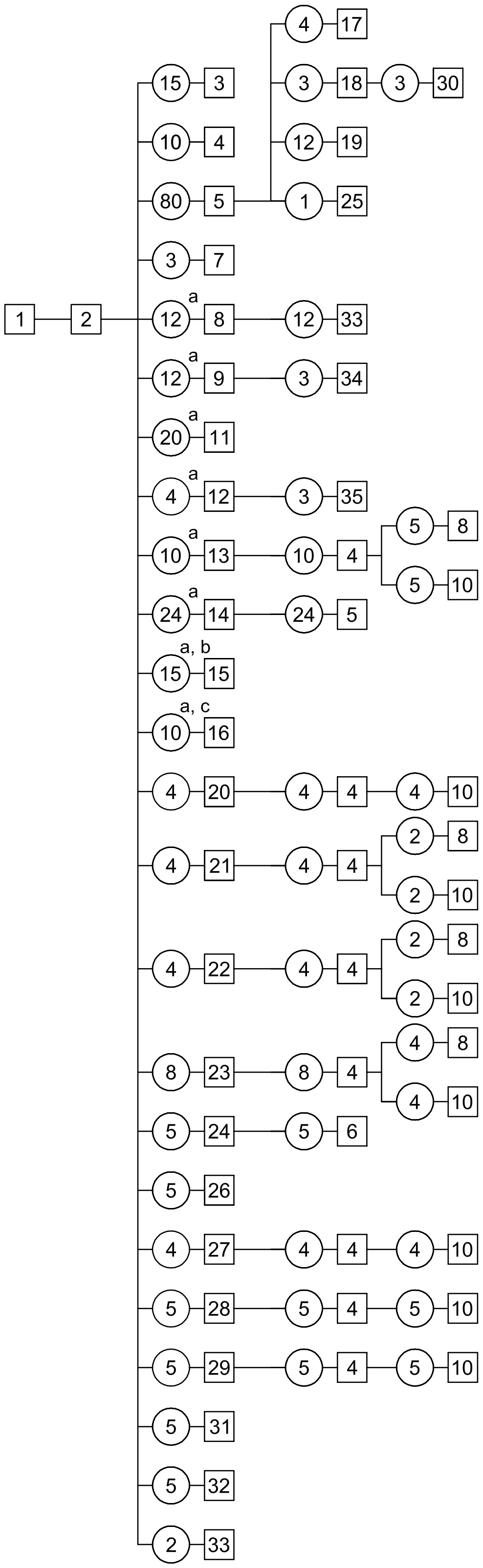
7.4 Body strength test (see 6.6)

7.4.1 Measure the service load for 15 sprinklers by securely installing each sprinkler, at room temperature, in a tensile/compression test machine and applying an equivalent of a hydraulic pressure of 1,2 MPa (12 bar) at the inlet.

Use an indicator capable of reading deflection to an accuracy of 0,01 mm to measure any change in length of the sprinkler between its load bearing points. Movement of the sprinkler shank thread in the threaded bushing of the test machine shall be avoided or taken into account.

Release hydraulic pressure, or equivalent force, and remove the heat responsive element of the sprinkler by a suitable method. When the sprinkler is at room temperature, make a second measurement using the indicator.

Apply an increasing mechanical load to the sprinkler, at a rate not exceeding 500 N/min, until the indicator reading at the deflector end of the sprinkler returns to the initial value achieved as assembled and under hydrostatic, or equivalent, load. The mechanical load necessary to achieve this shall be recorded as the service load. Calculate the average service load. See Annex C.



Key

○ number of sprinklers required

☐ test programme number

Test programme

1	Preliminary examination (7.2)
2	Visual examination (7.3)
3	Body strength (7.4)
4	Leak resistance and hydrostatic strength (7.5)
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24	Moist air exposure (7.13.5)
25	Heat resistance (7.14)
26	Water hammer (7.15)
27	Vibration (7.16)
28	Impact (7.17.1)
29	Tumble (7.17.2)
30	Lateral discharge (7.18)
31	Thirty-day leakage (7.19)
32	Vacuum (7.20)
33	Freezing (7.21)
34	ADD (7.22)
35	Thrust force (7.23)
36	Reaction force (7.24)

Unless otherwise stated, the tolerances given in Annex B shall apply.

[a] Number of samples for each temperature rating

[b] Glass bulb with seating parts only

[c] Fusible elements only

Figure 3 — Test programme for ESFR sprinklers

7.4.2 Increase the applied load progressively at a rate not exceeding 500 N/min on each of the ten specimens until twice the average service load has been applied. Maintain this load for (15 ± 5) s.

Remove the load and compare the permanent elongation with the requirement of 6.6 and compare it to the strength of element determined in 7.10.

7.5 Leak resistance and hydrostatic strength test (see 6.8)

7.5.1 Subject 20 sprinklers to a water pressure of 3,4 MPa (34 bar). Increase the pressure from 0 MPa to 3,4 MPa (0 bar to 34 bar) at a rate of (0,1 ± 0,025) MPa/s [(1 ± 0,25) bar/s]. Maintain the pressure at 3,4 MPa (34 bar) for a period of 3 min and then allow it to fall to 0 MPa (0 bar). After the pressure has dropped to 0 MPa (0 bar), increase it to 0,05 MPa (0,5 bar) in not more than 5 s. Maintain this pressure for 15 s and then increase it to 1 MPa (10 bar) at a rate of increase of (0,1 ± 0,025) MPa/s [(1 ± 0,25) bar/s] and maintain it for 15 s.

7.5.2 Following the test of 7.5.1, subject 20 sprinklers to a water pressure of 4,8 MPa (48 bar). Fill the sprinkler inlet with water at (20 ± 5) °C and vent any air. Increase the pressure to 4,8 MPa (48 bar) at a rate of (0,1 ± 0,025) MPa/s [(1 ± 0,25) bar/s]. Maintain the pressure at 4,8 MPa (48 bar) for 1 min.

7.6 Lodgement, ability-to-function and deflector strength test (see 6.5.1)

7.6.1 Lodgement test

Heat the sprinklers using a suitable heat source. Continue heating until the sprinkler operates. Test 10 sprinklers in their normal mounting position at each of the following inlet pressures.

0,03 MPa (0,35 bar)

0,17 MPa (1,70 bar)

0,34 MPa (3,40 bar)

0,51 MPa (5,10 bar)

0,68 MPa (6,80 bar)

0,85 MPa (8,50 bar)

1,02 MPa (10,2 bar)

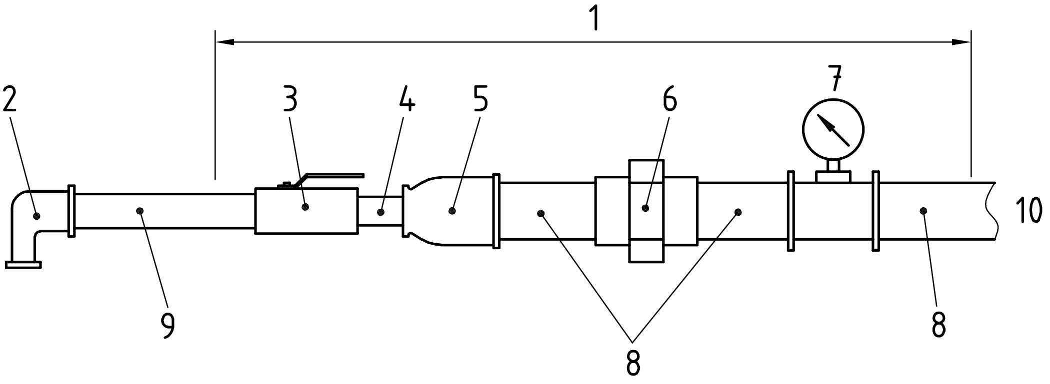
1,20 MPa (12,0 bar)

When installed on appropriate pipe and fitting, the flowing pressure shall be at least 75 % of the initial operating pressure as measured within 0,5 m upstream of the sprinkler. A typical piping configuration is shown in Figure 4.

7.6.2 Deflector strength test

In order to check the strength of the deflector (6.5.2), subject three sprinklers to the ability-to-function test in the normal mounting position at a pressure of 1,4 MPa (14 bar). Allow the water to flow at a running pressure of 1,4 MPa (14 bar) for a period of 30 min.

Dimensions in millimetres



Key

1	typical assembly
2	elbow (32 × 20)
3	full port ball valve
4	pipe (∅ 32)
5	reducer (32 × 50)
6	union (50)
7	gauge tee (50)
8	long steel pipe (50 × 150)
9	long steel pipe (32 × 300)
10	supply pipe

All dimensions shown are nominal pipe diameters.

The discharge coefficient of test apparatus shall exceed 170 when discharging through an orifice with nominal K of 202.

Figure 4 — Lodgement test apparatus

7.7 Operating temperature test (see 6.3)

7.7.1 Test of static operation

Heat 50 glass-bulb sprinklers or 10 fusible element sprinklers from a temperature of (20 ± 5) °C to a temperature of (20^{+2}_{0}) °C below their nominal operating temperature at a rate not exceeding 20 °C/min. Maintain this temperature for 10 min. Then increase the temperature at a rate of (0,5 ± 0,1) °C/min until the sprinkler operates.

Determine the nominal operating temperature using equipment capable of measuring to within ± 0,25 % of the nominal temperature rating.

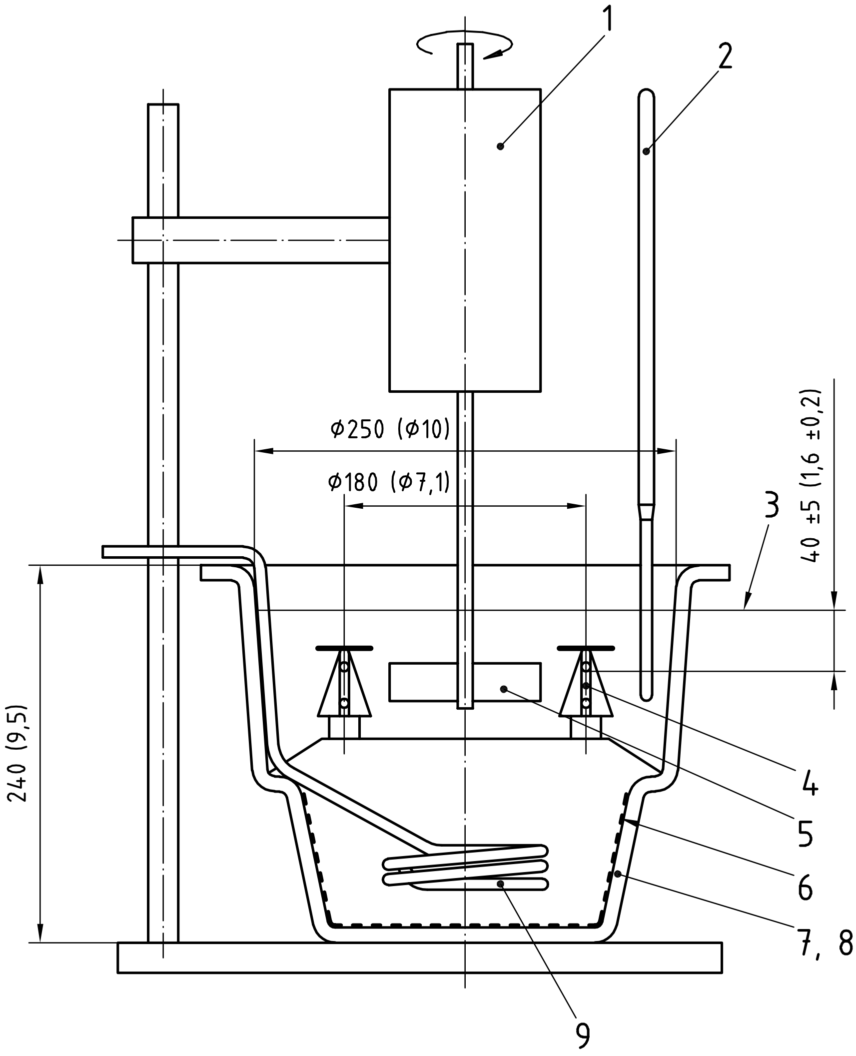
Carry out the test in a liquid bath. Test sprinklers having nominal operating temperatures less than or equal to 80 °C in a bath containing demineralized water. Test sprinklers with higher rated elements in a bath containing glycerine, vegetable oil or synthetic oil.

Position the sprinklers in the liquid bath in a vertical position and so as to immerse totally and cover the sprinklers with the liquid to a depth of (5^{+3}_{0}) mm. Locate the measurement zone at a distance, below the liquid surface, level with the geometric centre of the glass-bulb or fusible elements.

The measurement zone shall be at, if possible, but no less than, (40 ± 5) mm below the liquid surface level. The temperature deviation within the measurement zone shall be within ± 0,25 °C.

Any rupture of a glass bulb within the prescribed temperature rate constitutes an operation. If partial fracture of the glass bulb does not result in sprinkler operation, perform an additional ability-to-function test (see 6.5.1). Figure 5 gives an example of a standardized liquid bath. Use a laboratory temperature-measuring device, calibrated to a depth of 40 mm immersion, to determine temperatures of liquids in the bath tests as well as operation temperature. Hold the temperature-sensing element level with the sprinkler operating parts using a support member. To control the temperature in the thermal bath a PT-100 DIN EN 60751 can be used.

Dimensions in millimetres
(Dimensions in inches)



Key

1 speed agitator (150 r/min)
2 thermometer calibrated for 40 mm (1,6 in) immersion and PT-100
3 liquid level
4 ring to support 10 sprinklers (3/4 in) or 15 sprinklers (1/2 in)
5 double wing [100 mm × 20 mm (3,9 in × 0,8 in)]
6 mesh screen
7 standard glass vessel
8 desiccator ∅250 (10 in), liquid volume about 7 l
9 immersion heater

Figure 5 — Liquid bath

7.7.2 Dynamic heating test (see 6.13.2)

7.7.2.1 Plunge test

Subject 12 sprinklers in each nominal temperature rating to the plunge test in orientations A, B and C in accordance with 7.7.2.3. Calculate the RTI as described in 7.7.2.4 for each orientation.

7.7.2.2 Exposure verification for plunge test

Subject the sprinklers to the plunge test in orientation A or B, whichever produces the higher RTI value when tested in accordance with 7.7.2.3.

7.7.2.3 Test conditions

Conduct the plunge tests using a brass sprinkler mount. Apply 1 wrap to 1,5 wraps of PTFE sealant tape to the sprinkler threads of the sprinkler under test. Screw the sprinkler into a mount to a torque of (15 ± 3) N·m. Mount each sprinkler on a tunnel test section cover and maintain the sprinkler and its cover in a conditioning chamber for a period of no less than 30 min so as to reach ambient temperature.

Test all sprinklers with the inlet end of each sample connected to a source of air pressure at (0,034 ± 0,005) MPa [(0,34 ± 0,05) bar].

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

Use a tunnel with air velocity and temperature conditions at the test section (sprinkler location) selected from the appropriate range of conditions shown in Table 6. Select the tunnel conditions so as to limit maximum anticipated equipment error to 3 % (see reference [2] in the Bibliography).

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. A suggested method for determining radiation effects is by conducting comparative plunge tests on a blackened (high emissivity) metallic test specimen and a polished (low emissivity) metallic test specimen.

Table 6 specifies the range of permissible tunnel operating conditions. Maintain the selected operating conditions for the duration of the test with the tolerances as specified by the footnotes in Table 6.

Table 6 — Range of plunge test conditions at test section (sprinkler location)

Nominal operating temperatures °C	Air temperature [a]	Air velocity [b]
	Early suppression fast response sprinklers °C	Early suppression fast response sprinklers m/s
68 to 74	197	2,56
93 to 104	197	2,56

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

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

7.7.2.4 Calculation of RTI value

Determine the RTI value using equation (3):

$$\mathrm{RTI} = \frac{-t_\mathrm{r}\sqrt{u}}{\ln\left(1-\Delta T_\mathrm{ea}/\Delta T_\mathrm{g}\right)} \tag{3}$$

where

t_r is the response time, expressed in seconds, of the sprinkler;

u is the actual air velocity, expressed in metres per second (m/s), in the test section of the tunnel taken from Table 6;

ΔT_ea is the temperature difference, expressed in degrees Celsius (°C), between the mean liquid-bath operating temperature of the sprinkler and the ambient temperature;

ΔT_g is the temperature difference, expressed in degrees Celsius (°C), between the actual air temperature in the test section, corrected for radiation effects on the temperature sensing device, and the ambient temperature.

7.7.3 Determination of conductivity factor (C)

7.7.3.1 General

Determine the conductivity factor (C) using the prolonged plunge test (see 7.7.3.2) or the prolonged exposure ramp test (see 7.7.3.3).

7.7.3.2 Prolonged plunge test

The prolonged plunge test is an iterative process to determine C and may require up to 20 sprinkler samples. Use a new sprinkler sample for each test in this clause even if the test sample does not operate during the prolonged plunge test.

Determine the conductivity factor for sprinklers of each nominal temperature rating in either the “A” or “B” orientation, whichever produces the larger RTI value in 6.13.2.

Apply 1 wrap to 1,5 wraps of PTFE sealant tape to the sprinkler threads of the sprinkler under test. Screw the sprinkler into a mount to a torque of (15 ± 3) N·m. Mount each sprinkler on a tunnel test section cover and maintain the sprinkler and its cover in a conditioning chamber for a period of no less than 30 min so as to reach ambient temperature.

Introduce at least 25 ml of water, conditioned to ambient temperature, into the sprinkler inlet prior to testing.

Test all sprinklers with the inlet end of each sample connected to a source of pressure at 0,05 MPa (0,5 bar).

Using a timer accurate to ± 0,01 s, measure the response time of the sprinkler, i.e. the time it takes the sprinkler to begin operating from the time it is first plunged into the tunnel.

Maintain the mount temperature at (20 ± 0,5) °C for the duration of each test. Maintain the air velocity in the tunnel test section at the sprinkler location with ± 2 % of the selected velocity. Select the appropriate air temperature as specified in Table 7 and maintain this temperature during the entire test.

Table 7 specifies the range of permissible tunnel operating conditions. Maintain the selected operating conditions for the duration of the test keeping within the tolerances also specified in Table 7.

To determine C, immerse the sprinkler in the test stream at various air velocities for a maximum of 15 min. Choose the velocity so as to keep the actuation between two successive test velocities. Establish the lower velocity (u_L) so as to ensure the sprinkler does not actuate within the 15 min test interval but that it does actuate at the next higher velocity (u_H), within the 15 min time limit. If the sprinkler does not operate at the highest velocity, select an air temperature from Table 7 for the next higher temperature rating.

Table 7 — Range of test conditions for conductivity factor (C) determination at testsection (sprinkler location)

Nominal operating temperature °C	Air temperature °C	Maximum variation of air temperature during test from selected temperatures °C
58 to 77	124 to 130	± 1,0
78 to 107	193 to 201	± 3,0

Select the test velocity so as to ensure that

$$\sqrt{\frac{u_H}{u_L}} \leqslant 1{,}1 \qquad (4)$$

Calculate the value of the test conductivity factor, C, which is equal to the average of the values calculated at each of the two velocities using the following equation:

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

where

ΔT_g is the temperature difference, expressed in degrees Celsius (°C), between the actual gas (air) temperature and the mount temperature (T_m);

ΔT_{ea} is the temperature difference, expressed in degrees Celsius (°C), between the mean liquid-bath operating temperature and the mount temperature (T_m);

u is the actual air velocity, expressed in metres per second (m/s).

Determine the value of the sprinkler conductivity factor, C, by repeating the bracketing procedure three times and calculating the numerical average of the three C values.

7.7.3.3 Prolonged exposure ramp test

Carry out the prolonged exposure ramp test for the determination of the conductivity factor in the test section of a wind tunnel according to the temperature requirements given for the sprinkler mount as described for the dynamic heating test. It is not necessary to precondition the sprinklers.

Test 10 sprinklers of each nominal temperature rating. Position all sprinklers in either the “A” or “B” orientation, whichever produces the larger value of RTI in 6.13.2. Plunge the sprinklers in an air stream of a constant velocity of (1 ± 0,1) m/s and an air temperature at the nominal operating temperature of the sprinkler at the beginning of the test.

Increase the air temperature at a rate of (1 ± 0,25) °C/min until the sprinkler begins to operate. Control the air temperature, velocity and mount temperature from the initial rate of increase and measure and record them at sprinkler operation.

Determine the C value as the average of the 10 test values using Equation (5).

7.8 Heat exposure test (see 6.9)

7.8.1 Glass-bulb sprinklers (see 6.9.1)

Heat four glass-bulb sprinklers whose nominal release temperatures are less than or equal to 80 °C in a demineralized water bath from a temperature of (20 ± 5) °C to a temperature of (20 ± 2) °C below their nominal operating temperatures. Ensure the rate of temperature increase does not exceed 20 °C/min. Use glycerine, vegetable oil, or synthetic oil for higher rated release elements.

Increase the temperature 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, make sure the pointed end of the glass bulb (seal end) is pointed downwards. Perform the test four times on each of four sprinklers.

7.8.2 All ESFR sprinklers (see 6.9.2)

Expose 10 sprinklers for a period of 90 d to a high ambient temperature as shown in Table 8. After exposure, subject all of the sprinklers to the requirements of 6.8.1, five sprinklers to the requirements of 6.13.3, and five to the requirements of 6.3.

Table 8 — Test temperatures for ESFR sprinklers

Nominal operating temperature	Sprinkler test temperature
68 °C to 74 °C	52 °C
93 °C to 104 °C	79 °C

7.9 Thermal shock test for glass-bulb sprinklers (see 6.10)

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

Test sprinklers whose nominal operating temperatures are less than or equal to 80 °C in a bath of demineralized water. Test sprinklers having higher rated elements in a bath of glycerine, vegetable oil or synthetic oil. Maintain the temperature of the bath at (10 ± 0,5) °C below the lower limit of the tolerance range of the operating temperature of the sprinklers. After 5 min, remove the sprinklers from the bath and immerse them immediately in another bath of liquid (demineralized water), keeping the bulb seal pointed downwards, at a temperature of (10 ± 0,5) °C. Then test the sprinklers in accordance with 6.5.1.

7.10 Strength test for release elements (see 6.7)

7.10.1 Position at least 55 glass bulbs of the same design of each bulb type individually in a test fixture using the sprinkler seating parts. Subject each bulb to a uniform increasing force at a rate of (250 ± 25) N/s in the test machine until the glass bulb fails.

Conduct each test with bulbs mounted in new seating parts. The seating parts may be reinforced externally or can be manufactured from hardened steel (Rockwell Hardness C44 ± 6) in accordance with the specifications of the sprinkler manufacturer to prevent collapse, but in a manner which does not interfere with bulb failure. Record the crush force for each bulb.

Using the lowest 50 measured bulb strength results, calculate the average strength and the lower tolerance limit (L_{TL}) for bulb strength (see Annex A). Using the values of service load recorded in 7.4.1, calculate the upper tolerance limit (U_{TL}) for the sprinkler release element service load (see Annex A). Verify compliance with 6.7.1.

7.10.2 For fusible elements, determine compliance with the requirements of 6.7.2 by subjecting fusible heat-responsive elements to loads in excess of the maximum design load F_d, which will produce failure within and after 1 000 h (see Annex C). Subject at least 10 samples to different loads up to 15 times the maximum design load. Plot a full logarithmic regression curve (time-to-link failure as a function of load) using the method of least squares, and from this calculate the load at 1 h, F_{1h}, and the load at 1 000 h, F_{1000h}, where

$$F_d \leqslant \frac{1{,}02\, F_{1000h}^2}{F_{1h}} \qquad (6)$$

where F_{1h} is the load at 1 h.

Conduct these tests at an ambient temperature of (20 ± 3) °C.

7.11 Water flow test (see 6.4.1)

Mount the sprinkler with a pressure gauge on a supply pipe as shown in Figure 6. Test four sprinklers individually. The frame arms and deflector may be removed to facilitate testing. Insert each sprinkler into the test fixture and hand-tighten them. Then further tighten them one half turn. Measure the water flow at pressures from 0,1 MPa to 1 MPa (1 bar to 10 bar) in 0,1-MPa (1-bar) increments.

In one series of tests, increase the pressure and in the other series, decrease the pressure. Calculate the flow constant for each flowing pressure and average the flow constant for each series of readings. Each calculated flow constant and the average flow constant for each series shall be within the limits specified in 6.4.1. During the test, correct the pressure for differences in height between the gauge and the outlet orifice of the sprinkler.

7.12 Water distribution tests (see 6.4.2)

7.12.1 Single sprinkler distribution (see 6.4.2.2)

Place 10 collection pans, measuring (300 ± 5) mm × (300 ± 5) mm, in line on a table which rotates at 1 r/min to 4 r/min as shown in Figure 7. Collect water discharged at a sprinkler discharge pressure of 0,34 MPa (3,4 bar) measured using a calibrated gauge located at the end of the sprinkler piping opposite the supply end and at a distance of at least 1,5 m from the sprinkler. The purpose of this test is to provide a simple measure of the performance of a sprinkler for use in future re-examinations by the testing laboratory.

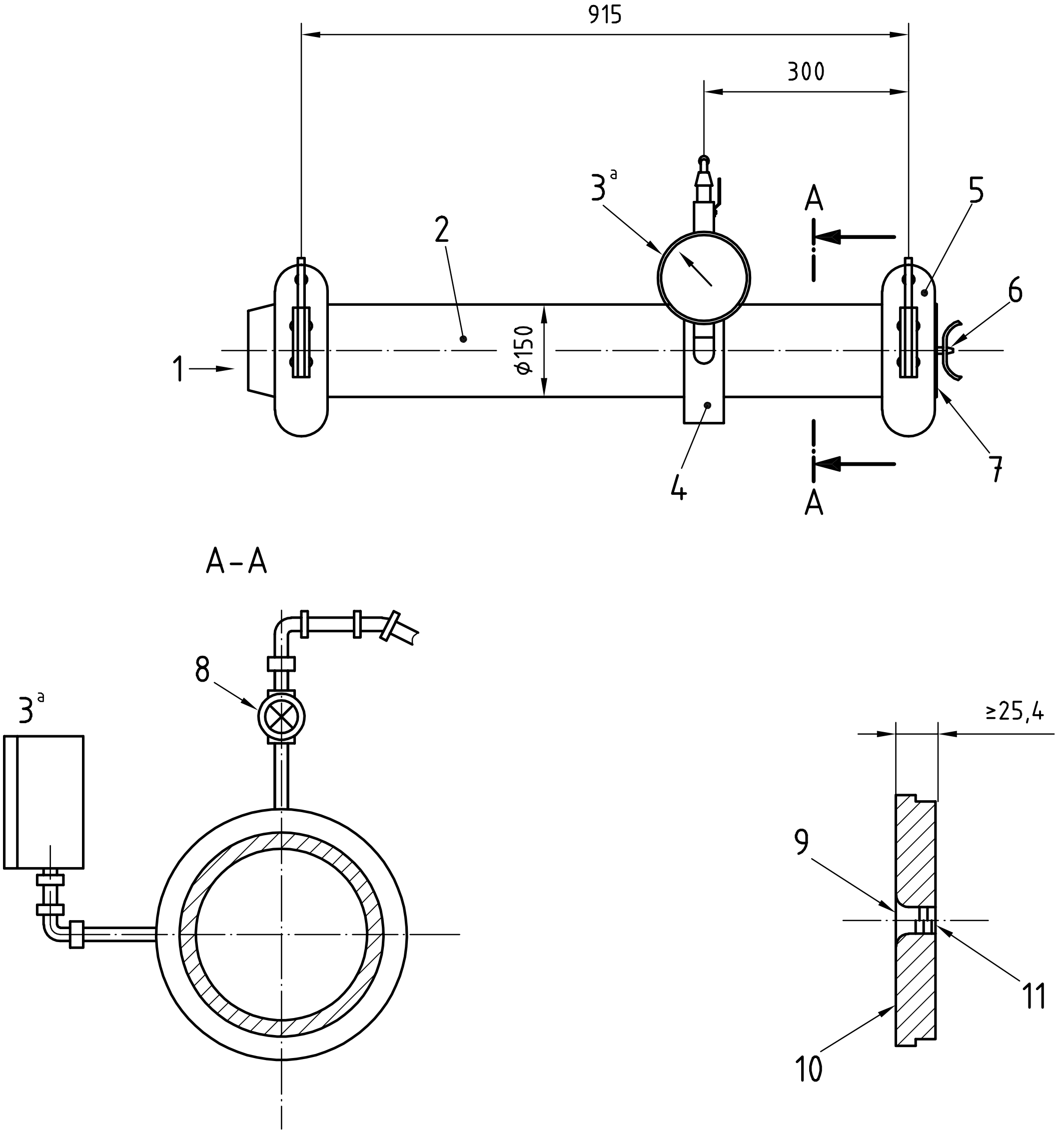
Test duration shall be 3 min.

Install the sprinkler on an appropriately sized side outlet of a standard mass threaded “tee” with run ends connected to 50 mm steel piping. The minimum distance from the “tee” fitting to the supply connection shall be 1,5 m.

Record all pan collection values.

Repeat the tests again at pressures of 0,7 MPa (7,0 bar), 1 MPa (10,0 bar) and 1,2 MPa (12,0 bar) and record the water collected in the tenth pan only.

Dimensions in millimetres



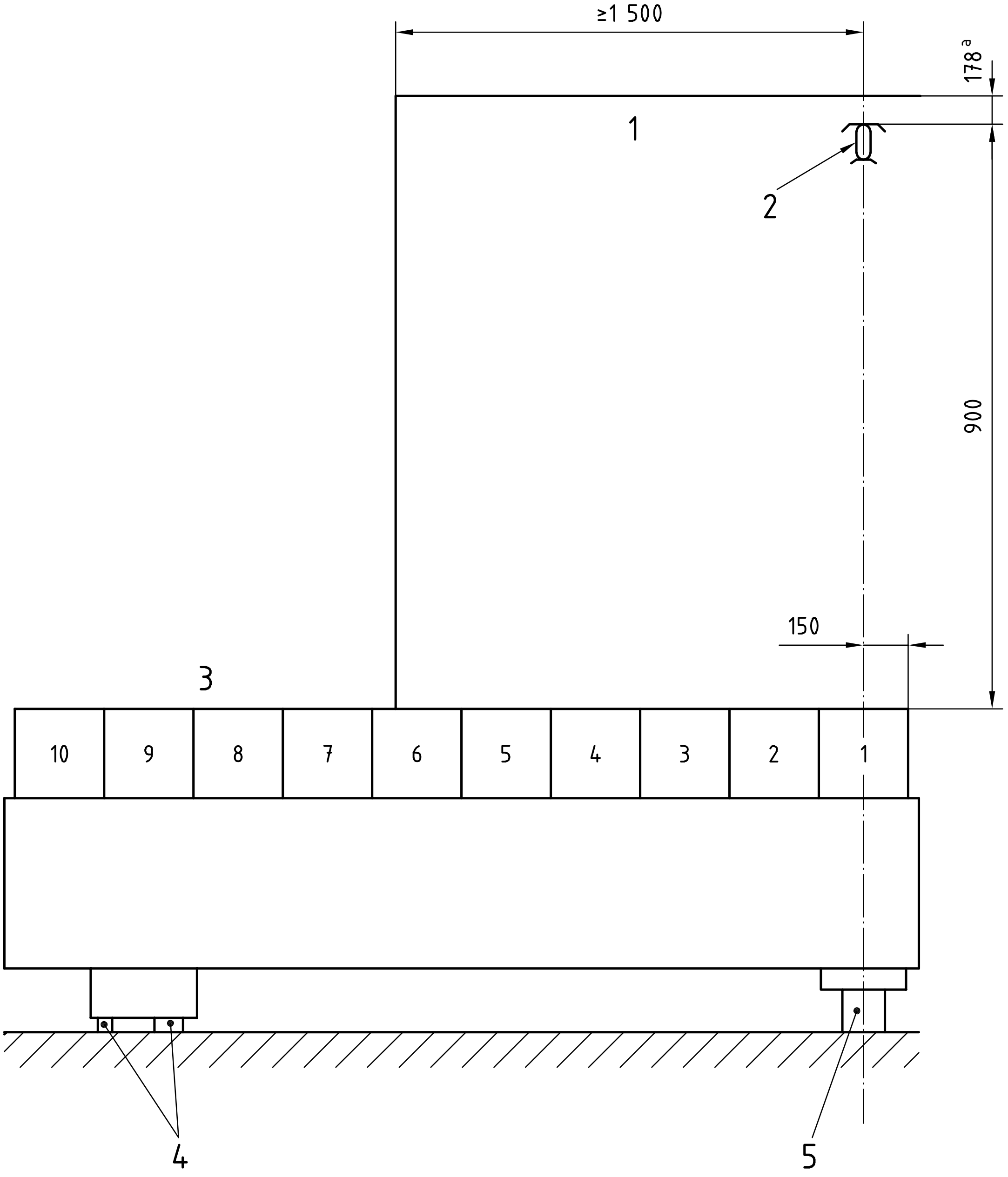
Key

1 water source inlet
2 pipe
3 gauge
4 piezometer ring
5 flexible coupling (typical)
6 sprinkler butt
7 grooved end cap
8 valve for air relief
9 inlet of tapped hole with generous radius
10 flat surface of end cap
11 appropriate tapped hole

[a] Full range: 0 MPa to 1,4 MPa (0 bar to 14 bar)
Accuracy: 0,007 MPa subdivisions (0,07 bar subdivisions)

Figure 6 — Water-flow test apparatus

Dimensions in millimetres



Key

1 ceiling (3 m × 3 m minimum)
2 test sprinkler
3 deep pans (300 × 300 × 300)
4 wheels
5 pivot

Table rotates at 1 r/min to 4 r/min.

[a] Deflector to "ceiling" clearance is equal to 178 mm for both upright and pendent sprinkler designs.

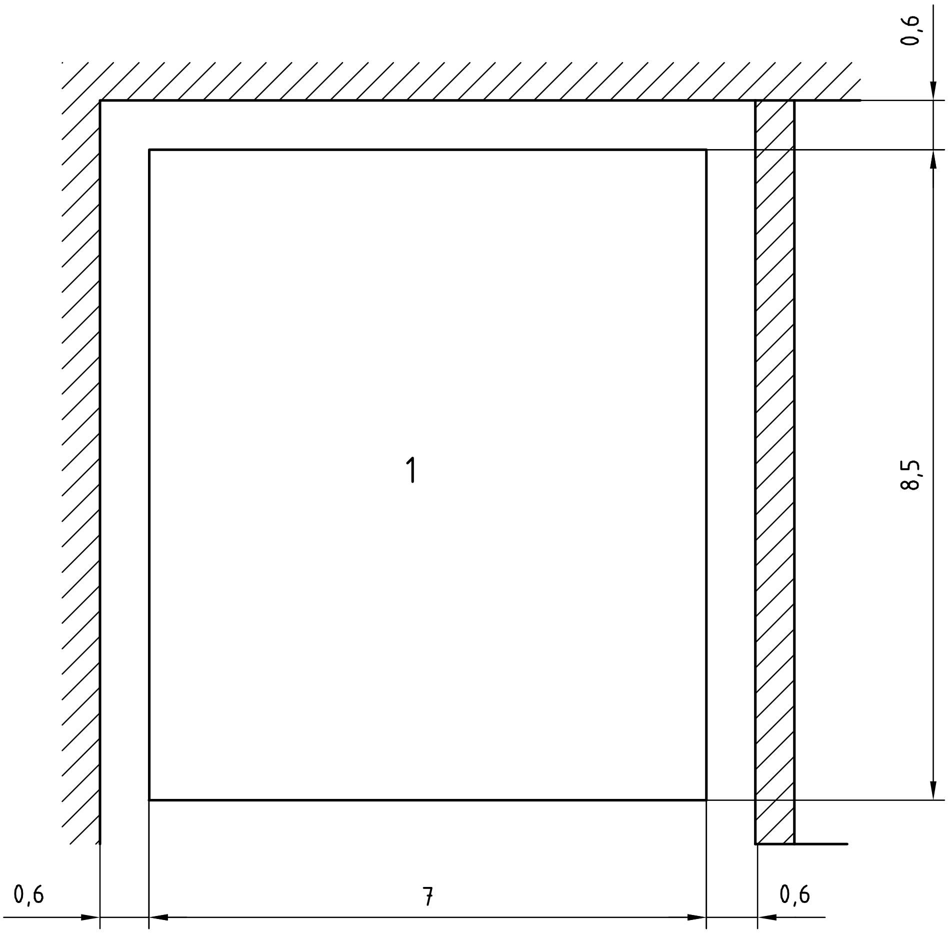
Figure 7 — Water-distribution-collection apparatus (rotating table)

7.12.2 Multiple sprinkler distribution (see 6.4.2.3)

Test three samples, or sets of samples, to the requirements given in Table 2. Operate all samples by applying a heat source to remove the heat-sensitive element. The sprinkler test area shall be designed as shown in Figures 8, 9, 10, 11 and 12. Construct the water-collection apparatus in accordance with the specifications given in Figure 13. Locate the test apparatus in a room of sufficient volume so as to minimize the entrainment of additional water spray. Prevent any drafts or other air movement from entering, or leaving, the test area.

Cover the water-collection system, Figure 13, until the required pressure has been obtained. At that time, quickly remove the cover in such a manner as to not cause water collected on top of the cover to be deposited into the collection pans. Conduct this test for a period of 5 min. At the conclusion of the test, immediately place the cover over the collection pans to prevent any further water from being collected in the pans.

Dimensions in metres

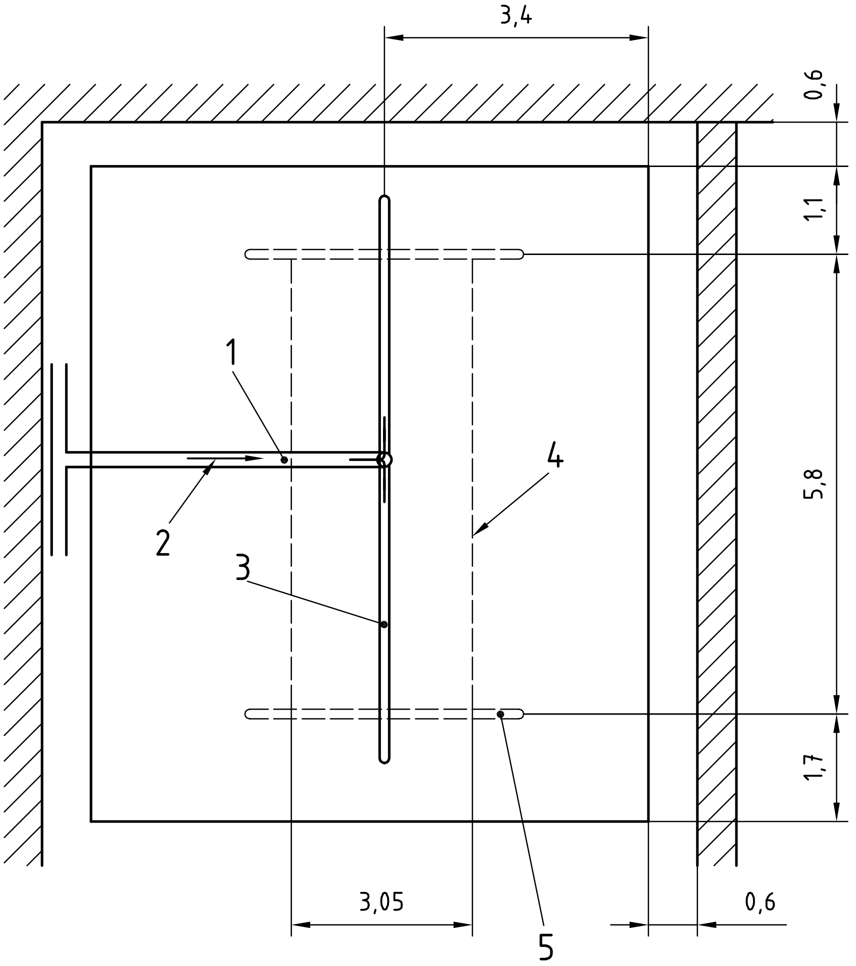


Key

1 suspended ceiling

Figure 8 — Minimum dimensions of the water-distribution-collection apparatus

Dimensions in metres



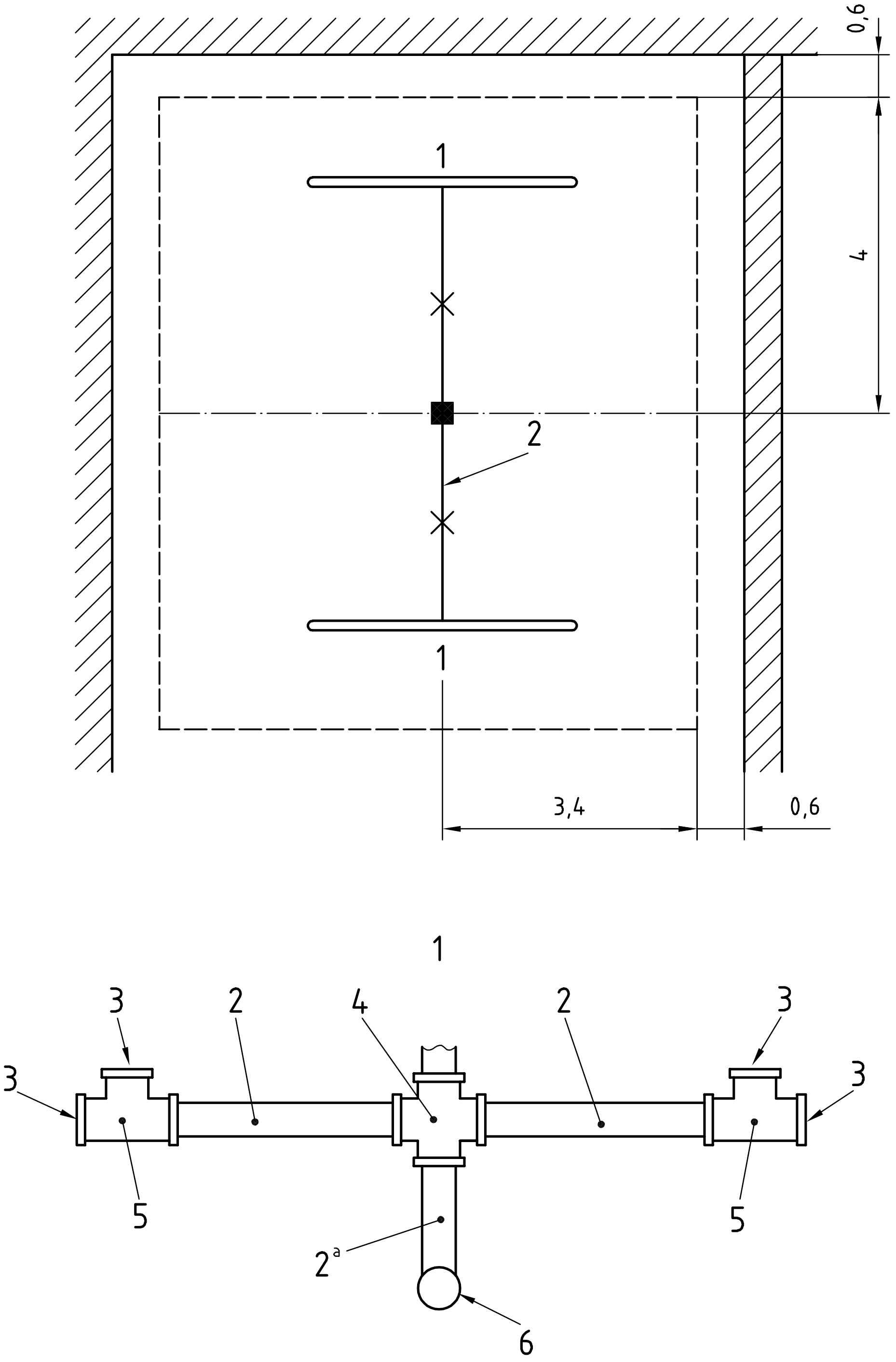
Key

— — — Indicates piping located below the ceiling (see Figures 10 and 11)

1 pipe [∅ 100 nom. (mm)]
2 water flow
3 pipe [∅ 75 nom. (mm)]
4 sprinkler pipe (∅ 50 mm)
5 manifold under ceiling (50 mm)

Figure 9 — Overhead piping configuration for water-distribution-collection apparatus

Dimensions in metres



Key

1 pipe manifold
2 pipe [∅ 50 nom. (mm)]
3 pipe plug
4 threaded cross (50 mm × 50 mm × 50 mm)
5 threaded tee (50 mm × 50 mm × 50 mm)
6 nominal feed line from above the ceiling with reducer (∅ 75 mm)

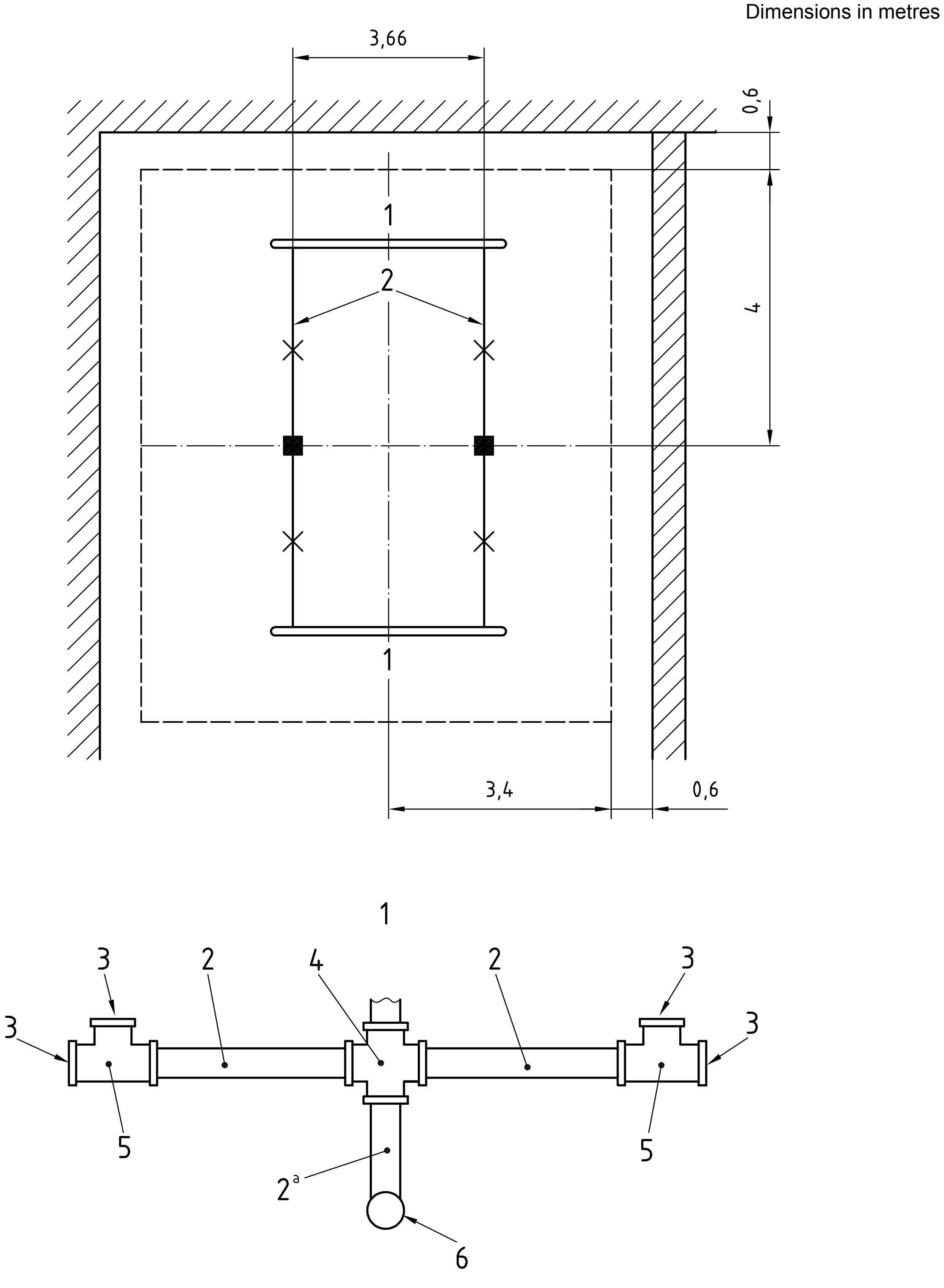
■ sprinkler location — single sprinkler test

× sprinkler location — two-sprinkler test

NOTE See Table 2 for pipe spacing.

[a] 300 mm minimum length.

Figure 10 — Single sprinkler piping configuration for the water-distribution-collection apparatus



Key

1 pipe manifold
2 pipe [∅ 50 nom. (mm)]
3 pipe plug
4 threaded cross (50 mm × 50 mm × 50 mm)
5 threaded tee (50 mm × 50 mm × 50 mm)
6 nominal feed line from above the ceiling with reducer (∅ 75 mm)

■ sprinkler location — two sprinkler test

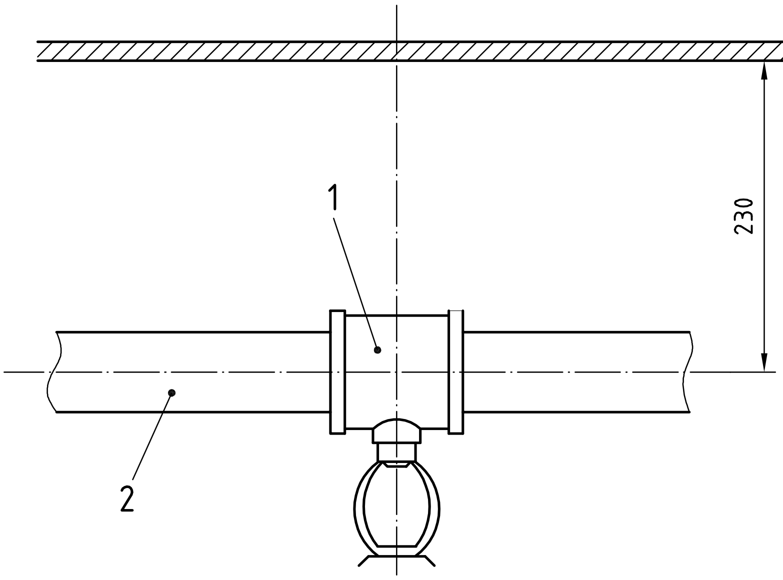
× sprinkler location — four-sprinkler test

NOTE See Table 2 for pipe spacing.

[a] 300 mm minimum length

Figure 11 — Multiple-sprinkler piping configuration for the water-distribution-collection apparatus

Dimensions in millimetres

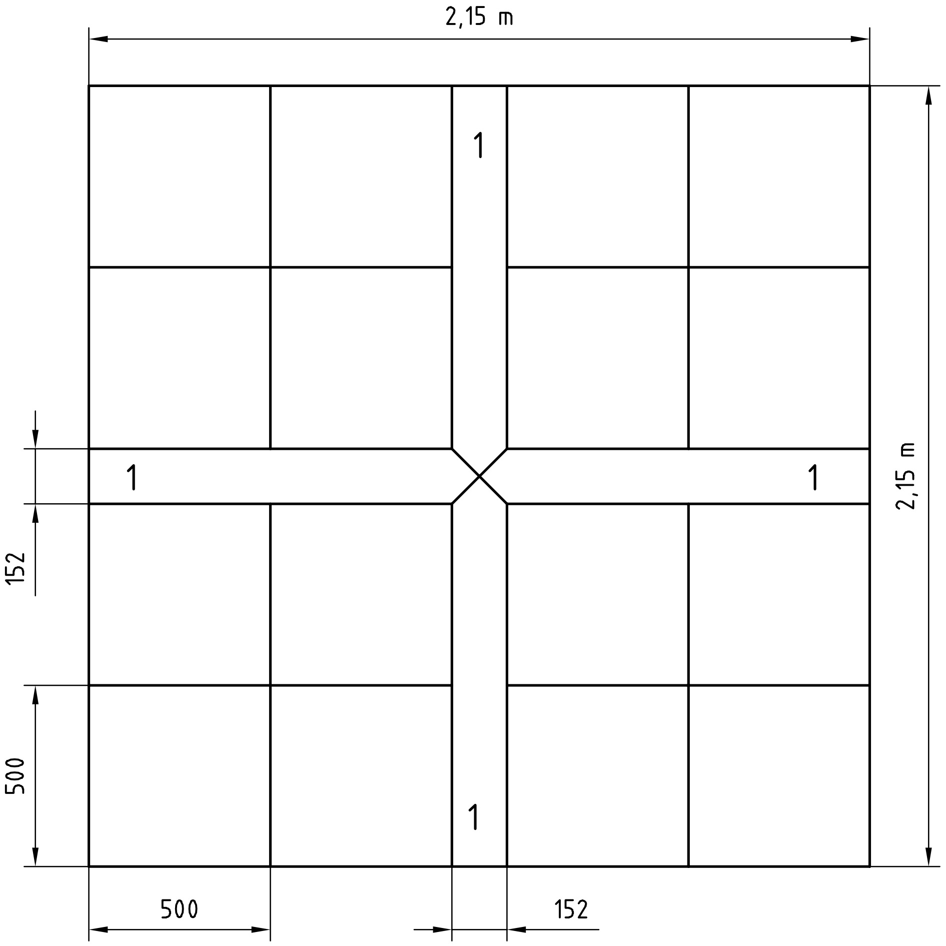


Key

1 threaded tee	2 pipe [∅ 50 nom. (mm)]

Figure 12 — Piping detail for the water-distribution-collection apparatus

Dimensions in millimetres



Key

1 flue space

Top surface of collection pans to be ⩾ 1 m above solid floor surface

Figure 13 — Collection pan assembly for water-distribution-collection apparatus

7.13 Corrosion tests

7.13.1 Stress corrosion test with aqueous ammonia solution (see 6.11.1)

Subject four sprinklers to the following aqueous ammonia test. Fill the inlet of each sample with water and seal it with a non-reactive cap, e.g. plastic.

Remove all non-production coatings from the samples to be tested and then expose them for 10 d to a moist ammonia-air mixture in a glass container of volume (0,02 ± 0,01) m^3.

Maintain an aqueous ammonia solution, having a density of 0,94 g/cm^3, 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 per cubic centimetre of the volume of the container will give approximately the following atmospheric concentrations: 35 % ammonia, 5 % water vapour, and 60 % air.

Maintain the moist ammonia-air mixture as closely as possible to atmospheric pressure and under uniform heat at a temperature of (34 ± 2) °C. Make provision to vent the chamber using a capillary tube to avoid the build-up of pressure. Shield specimens from condensate drippage.

After exposure, rinse and dry the sprinklers, and carry out a detailed examination. Subject all sprinklers to a leak resistance test at 1,2 MPa (12 bar) for 1 min and to the sensitivity test. See 6.8 and 6.13.3.

Sprinklers shall not show signs of cracking, delamination, or failure of any part.

7.13.2 Moist sulfur-dioxide/carbon-dioxide corrosion test (see 6.11.2)

Subject four ESFR sprinklers to the following moist sulfur-dioxide/carbon-dioxide corrosion test. Fill the inlet of each sample with water and seal it with a non-reactive cap, e.g. plastic.

Use test equipment consisting of a vessel made of heat-resistant glass, with a corrosion-resistant lid of such a shape as to prevent condensate dripping on the sprinklers. Regulate the heating of the vessel so as to maintain the temperature inside the glass vessel at (25 ± 3) °C. Shield specimens from condensate drippage.

Suspend the sprinklers to be tested in their normal mounting position under the lid inside the vessel. Sulfur dioxide and carbon dioxide are to be supplied to the test chamber from commercial cylinders. Introduce an amount of sulfur dioxide equivalent to 1 % of the volume of the test chamber, and an equal volume of carbon dioxide, into the chamber each working day. Maintain a small amount of potable or demineralized water at the bottom of the chamber.

Conduct the test for a period of 10 d. After a total of 10 d, remove the samples from the container and allow them to dry for 1 d to 5 d at a temperature not exceeding 35 °C with a relative humidity no greater than 70 %.

After the drying period, test all of the sprinklers at 1,2 MPa (12 bar) in accordance with 6.8.1. Subject two of the sprinklers to the dynamic heating test in accordance with 6.13.3 and the other two to the temperature test specified in 6.3.

7.13.3 Moist hydrogen-sulfide corrosion test (see 6.11.3)

Subject four ESFR sprinklers to the following moist hydrogen-sulfide corrosion test. Fill the inlet of each sample with water and seal it with a non-reactive cap, e.g. plastic.

Use test equipment consisting of a vessel made of heat-resistant glass, with a corrosion-resistant lid of such a shape as to prevent condensate dripping on the sprinklers. Regulate the heating of the vessel so as to maintain the temperature inside the glass vessel at (25 ± 3) °C. Shield specimens from condensate drippage.

Suspend the sprinklers to be tested in their normal mounting position under the lid inside the vessel. Hydrogen sulfide is to be supplied to the test chamber from a commercial cylinder. Introduce an amount of hydrogen sulfide equivalent to 1 % of the volume of the test chamber into the chamber each working day. Maintain a small amount of water at the bottom of the chamber.

Conduct the test for a period of 10 d. After a total of 10 d, remove the samples from the container and allow them to dry for 1 d to 5 d at a temperature not exceeding 35 °C with a relative humidity no greater than 70 %.

After the drying period, test all of the sprinklers at 1,2 MPa (12 bar) in accordance with 6.8.1. Subject two of the sprinklers to the dynamic heating test in accordance with 6.13.3 and the other two to the temperature test specified in 6.3.

7.13.4 Salt-spray corrosion test (see 6.11.4)

Expose eight sprinklers to a salt spray within a fog chamber.

During the corrosive exposure, seal the inlet thread orifice with a plastic cap after having first filled the sprinklers with water. Use a salt solution having a mass fraction of 20 % sodium chloride in demineralized 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. Provide a suitable means of controlling the atmosphere in the chamber. Suspend the specimens in their normal operating position and expose them to the salt spray (fog) in a chamber having a volume of at least 0,43 m^3. Maintain the exposure zone at a temperature of (35 ± 2) °C. Record the temperature at least once per day, at intervals at least 7 h apart (except weekends and holidays when the chamber normally would not be opened). Salt solution shall be supplied from a recirculation reservoir through air-aspirating nozzles, at a pressure between 0,07 MPa (0,7 bar) and 0,17 MPa (1,7 bar). Collect salt solution runoff from exposed samples making sure that it is not returned to the reservoir for recirculation. Shield specimens from condensate drippage.

Collect fog from at least two points in the exposure zone to determine the rate of application and salt concentration. For each 80 cm^2 of collection area of the fog, collect 1 ml to 2 ml of solution per hour over a 16-h period while maintaining the mass fraction of the salt concentration at (20 ± 1) %.

Expose the sprinklers to the salt spray for a period of 10 d. After this period, remove the sprinklers from the fog chamber and allow them to dry for 2 d to 4 d at a temperature not exceeding (20 ± 5) °C in an atmosphere having a relative humidity no greater than 70 %. After the drying period, test all of the sprinklers at 1,2 MPa (12 bar) only in accordance with 6.8.1. Subject four of the sprinklers to the dynamic heating test in accordance with 6.13.3 and the other four to the temperature test specified in 6.3.

7.13.5 Moist-air exposure (see 6.11.5)

Expose five sprinklers to a high temperature-humidity atmosphere consisting of a relative humidity of (98 ± 2) % and a temperature of (95 ± 1,1) °C.

Install the sprinklers on a pipe manifold containing 50 % demineralized water. Place the entire manifold in the high temperature humidity enclosure for 90 d. After this period, remove the sprinklers from the high temperature-humidity enclosure and allow them to dry for 4 d to 7 d at a relative humidity no greater than 70 %. Following the drying period, test all sprinklers for their ability-to-function in accordance with 6.5.1 at only 0,034 MPa (0,34 bar).

NOTE 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.

7.14 Heat-resistance test (see 6.14)

Heat one sprinkler body in an oven at 800 °C for a period of 15 min. Remove the sprinkler body, holding it by the threaded inlet, and promptly immerse it in a water bath at a temperature of 15 °C.

7.15 Water-hammer test (see 6.12)

Connect five sprinklers to the test equipment. After purging the air from the sprinklers and the test equipment, subject the sprinklers to 100 000 cycles of pressure varying from (0,4 ± 0,05) MPa [(4 ± 0,5) bar] to (3,4 ± 0,05) MPa [(34 ± 0,5) bar]. Increase the pressure from 4 bar to 34 bar at a rate of (10 ± 1,0) MPa/s [(100 ± 10) bar/s]. Perform the test at a rate of at least 6 cycles of pressure per minute with a cycle period of (5 ± 4) s.

Visually examine each sprinkler for leakage during the test.

7.16 Vibration test (see 6.15)

7.16.1 Fix four sprinklers vertically to a vibration table. Subject them to sinusoidal vibrations at room temperature with the direction of the vibration along the axis of the connecting thread.

7.16.2 Vibrate the sprinklers continuously at an amplitude of 0,38 mm at a varying frequency from 30 Hz to 60 Hz for 25 h and at an amplitude of 1,27 mm at a varying frequency from 10 Hz to 30 Hz for 25 h. Amplitude shall be defined as the maximum displacement of sinusoidal motion from the point of rest to one-half the total table displacement. Each half-cycle period (e.g. 10 Hz to 30 Hz or 30 Hz to 10 Hz) shall be (25 ± 5) s. If one or more resonant points are detected, vibrate the sprinklers at each of these resonant frequencies for 50 h divided by the number of resonances.

7.17 Impact and tumble tests (see 6.16)

7.17.1 Impact test

Test five sprinklers for impact by dropping a mass onto the deflector end of the sprinkler along the axial centre line of the waterway. Test sprinklers provided with shipping caps, intended for removal only after completion of the sprinkler installation, for impact 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 sprinkler dropped from a height of 1 m (see Figure 14). Prevent the dropped mass from being impacted more than once upon each sample.

7.17.2 Tumble test

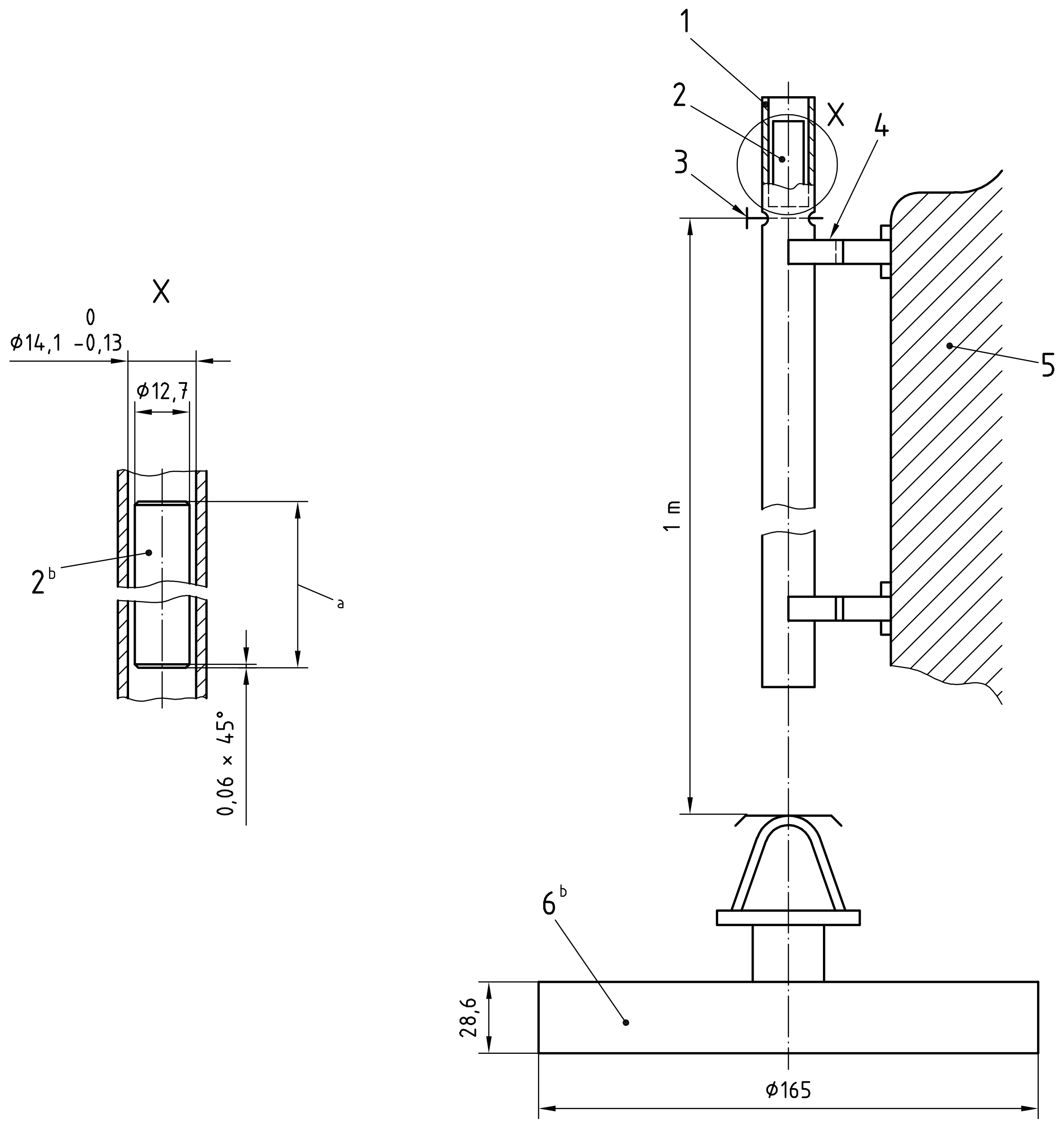
Test five sprinklers for impact by individually subjecting them to a tumbling test for 3 min. Test sprinklers provided with shipping caps, which are intended for removal only after completion of the sprinkler installation, for impact with the caps in place. Place each sample in a vinyl-lined right-hexagonal-prism-shaped drum designed to provide a tumbling action. The drum shall have a length along the axis of rotation of 254 mm. The distance between two opposite and parallel sides of each hexagonal-shaped-drum end plate shall be 305 mm. For each test, the drum shall contain one sprinkler and five wood blocks. The blocks shall be 38,1 mm cubes made of hardwood. Rotate the drum at a rate of 1 r/s about its longitudinal axis. Following the test, visually examine each sprinkler. The sprinkler shall reveal no cracks, breaks, or other evidence of impending failure.

7.18 Lateral discharge test (see 6.17)

Install an open sprinkler on the same piping used for 7.12.1.

In addition, place a target having the same width and height as the maximum plan area of the sprinkler at a point 2,1 m from the discharging sprinkler at a height 17,8 mm below the ceiling. Discharge water from the sprinkler for 3 min at pressures of 0,35 MPa (3,5 bar), 0,7 MPa (7,0 bar), 1,0 MPa (10,0 bar), and 1,20 MPa (12,0 bar). Make observations for wetting and water impingement of the tag.

Dimensions in millimetres



Key

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

[a] Length to be determined (length of required weight).

[b] Cold finished steel.

Figure 14 — Impact test apparatus

7.19 Thirty-day leakage test (see 6.18)

Install five sprinklers on a water-filled test line maintained under a constant pressure of 2,0 MPa (20 bar) for 30 d.

Visually inspect the sprinklers at least weekly for leakage. Following completion of this 30-day test, examine all samples to verify that there is no evidence of distortion or other mechanical damage.

7.20 Vacuum test (see 6.19)

Subject three sprinklers to a gradually increasing vacuum of 660 mm Hg applied to the sprinkler inlet and maintained for 1 min. Following this test, examine each sample to verify that no distortion or mechanical damage has occurred.

7.21 Freezing test (see 6.20)

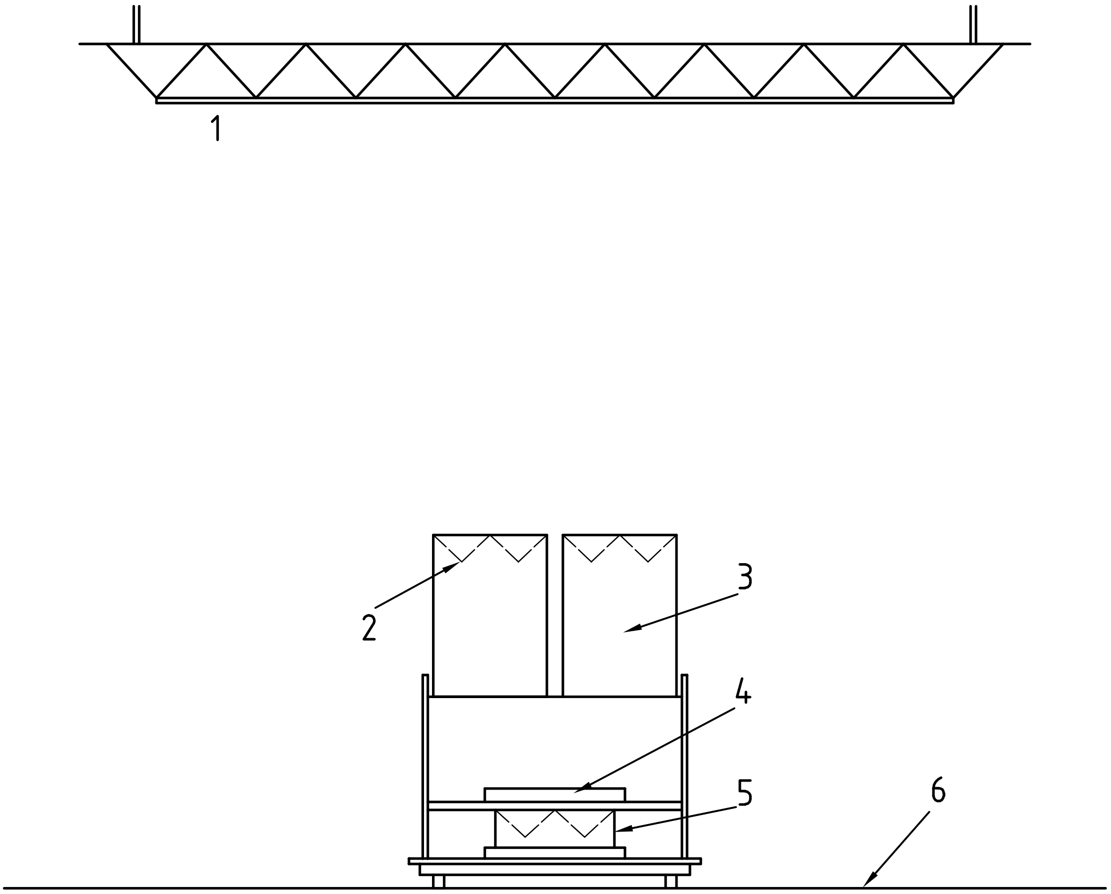
Attach five samples individually to the end of 100-mm lengths of 5 mm nominal diameter steel pipe using an appropriate fitting. Attach pipe coupling to the opposite end of each pipe. Fill each assembly to capacity with water and seal it using a pipe plug. Expose the assemblies to a temperature of (– 30 ± 5) °C for a period of 24 h.

7.22 Actual delivered density (ADD) test (see 6.21)

Take measurements of the actual delivered density (ADD) on three samples or sets of samples, using a test apparatus as shown in Figure 15. Calibrate the apparatus prior to use using a fire-products collector. The ADD apparatus shall consist of two major components: a fire source and a simulated commodity. Use a fire source containing a number of spray nozzles equally spaced on the circumference of a circle. Use heptane as the fuel for the fire. Above the fire source, place a simulated commodity which approximates the geometry and size of a single tier rack-storage commodity of two pallet loads deep and two pallet loads wide, with a 15,2 cm flue space between the pallets. Install 16 water-collection pans on the top surface of the simulated commodity to collect water that reaches the top surface. Install four additional pans under the fire source to collect water delivered to the flue space. Channel water collected by the pans to the collectors of the ADD apparatus. Suspend a flat horizontal ceiling with a minimum dimensions of 11,13 m × 10,21 m above the ADD apparatus. Locate the test apparatus in a room of sufficient volume to minimize the entrainment of additional water spray. Do not allow any drafts or other air movement to enter, or leave, the test area.

Install the sprinkler(s) in the same way as the non-fire measurements, i.e. with the deflector 35 cm below the ceiling with the frame arms parallel to the sprinkler piping. Locate the sprinkler piping centreline 23 cm below the ceiling. Use sprinkler piping having a minimum nominal diameter of 50 mm.

Prior to each measurement, ignite the heptane sprays. Adjust the heptane spray so as to obtain the convective heat release required. Stabilize the heptane flow at the selected flow rate corresponding to the required heat release. Once the fuel flow rate has been stabilized, discharge the water. Run the test for a minimum of 10 min in accordance with the test programme specified in Table 3.



Key

1	ceiling level
2	collection pans (16)
3	simulated commodity
4	fire source
5	collection pans (4) for flue space
6	floor level

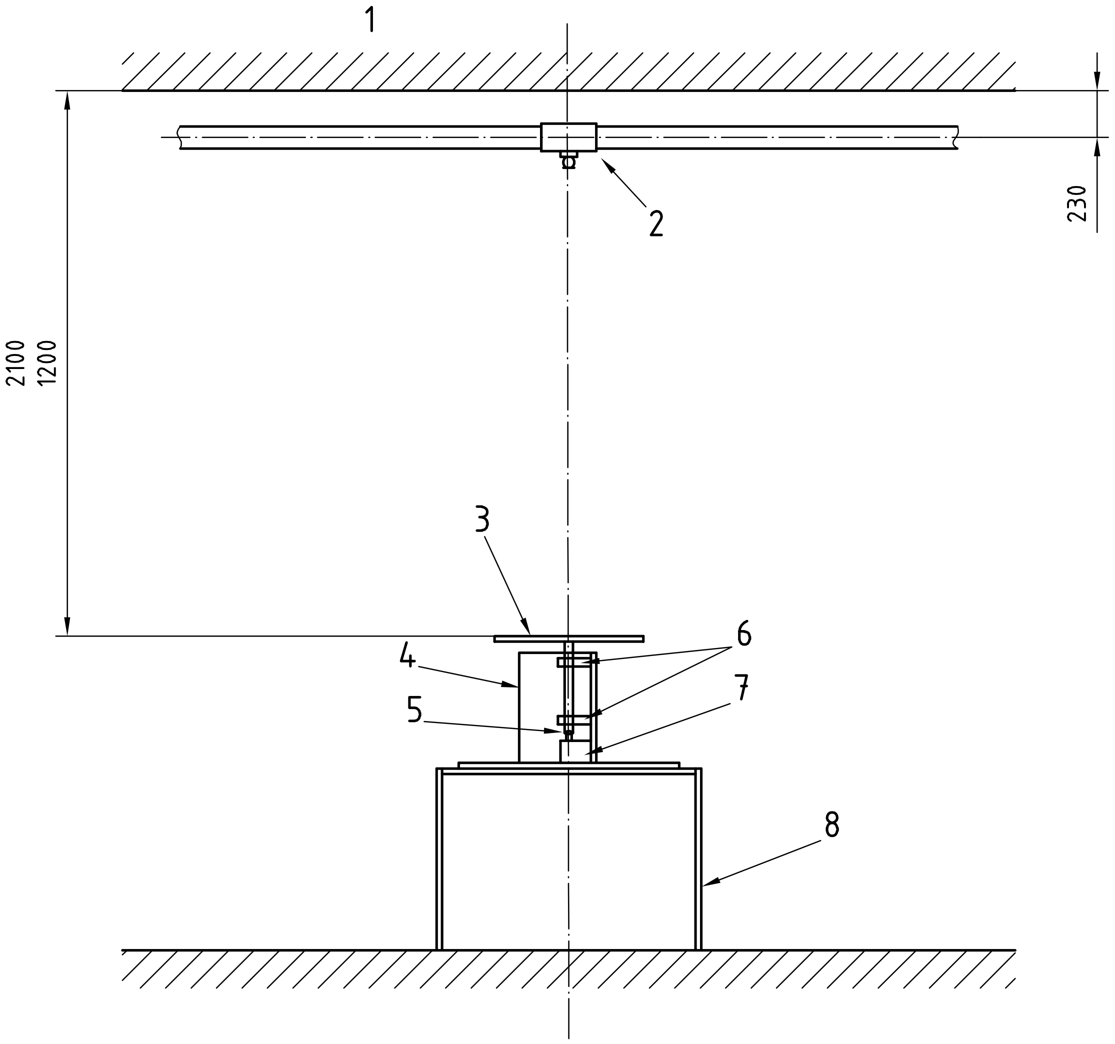
NOTE For a typical test apparatus see Table 3.

Figure 15 — Actual delivered density (ADD) test apparatus

7.23 Thrust force test (see 6.22)

Install the sprinkler in the thrust force apparatus as shown in Figure 16. Measure and record the thrust at the pressures specified in Table 4. Repeat the test two more times with different sprinklers.

Dimensions in millimetres



Key

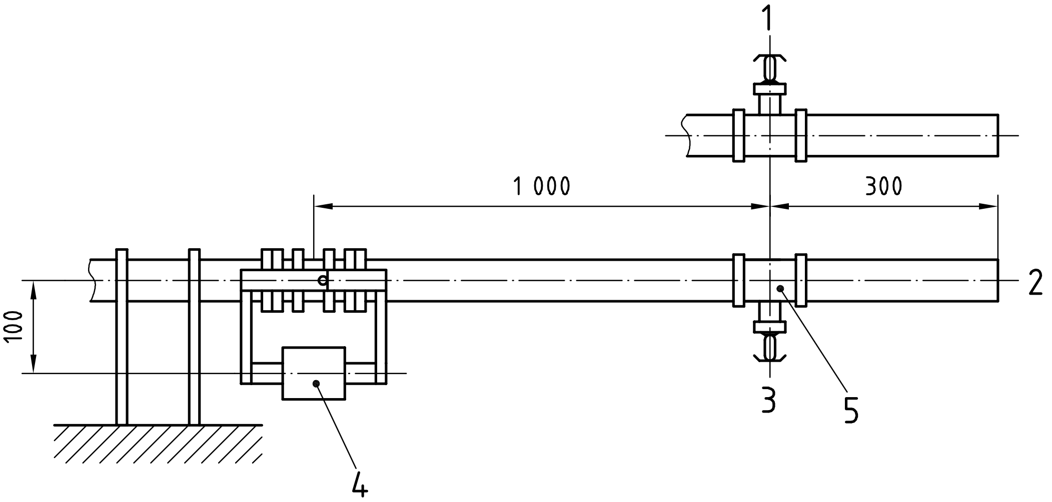
1	suspended ceiling
2	threaded tee (50 mm × 50 mm × 50 mm)
3	thrust plate (∅ 343 ± 1)
4	waterproof casing
5	strainless steel ball
6	slide ball bearing
7	load cell transducer
8	platform

Figure 16 — Thrust force measurement test apparatus

7.24 Reaction force test (see 6.23)

Install the sprinkler in a reaction force apparatus as shown in Figure 17. Measure and record the reaction force at pressures of 3,4 bar and 5,1 bar. Repeat the test two more times with different sprinklers.

Dimensions in millimetres



Key

1 sprinkler in upright position
2 pipe (DN 50)
3 pendent position
4 load cell
5 threaded tee (50 × 50 × 50)

Figure 17 — Reaction force test apparatus

8 Marking of sprinklers

Each sprinkler complying with the requirements of this part of ISO 6182 shall be permanently marked as follows:

a) trademark or manufacturer's name;

b) identification of model;

c) manufacturer's factory identification (if the manufacturer has more than one sprinkler manufacturing facility);

d) the words “EARLY SUPPRESSION FAST RESPONSE” or the letters “ESFR”;

e) the word “pendent” (or the letter “P”) or the word “upright” (or the letter “U”), as appropriate;

f) the nominal flow constant;

g) nominal year of manufacture, which may include the last three months of the preceding year and the first six months of the following year;

h) nominal operating temperature, the range of which shall be colour-coded on the sprinkler to identify the nominal rating. The colour code shall be visible on the yoke arms holding the distribution plate for fusible element sprinklers and shall be indicated by the colour of the liquid in glass bulbs. All sprinklers shall be stamped, cast, engraved or colour-coded in such a way that the nominal temperature rating is recognizable even if the sprinkler has operated. This shall be in accordance with Table 1.

Sprinklers using glass bulbs from more than one supplier shall have permanently coded marking on a non-operating part of the sprinkler to identify the individual supplier of the glass bulb used in that specific sprinkler.

Annex A
(informative)

Tolerance limit calculation method

The calculation method for determining compliance with the statistical tolerance limit requirements specified in 6.7.1 and 7.10.1 is described below.

Calculate the mean and unbiased standard deviation for the glass-bulb design load and glass-bulb strength. The sample unbiased standard deviation (s) is calculated from the formula:

$$s_n = \sqrt{\sum_{i=0} \left(x_i - x\right)^2 \Big/ \left(n - 1\right)} \tag{A.1}$$

where

x is the sample mean;

x_i is the individual value of each sample tested;

n is the number of samples tested.

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

Upon accumulation of data points for glass-bulb design load and glass-bulb strength and the selection of the appropriate respective values for K, verify

$$L_{\text{TL}} > 2U_{\text{TL}} \tag{A.2}$$

where

L_{TL} is the lower tolerance limit for glass-bulb strength and is equal to

$$L_{\text{TL}} = \bar{x}_1 - K\, s_1 \tag{A.3}$$

where

$\bar{x}_1$ is the mean glass-bulb strength;

K is the statistical factor taken from Table A.1;

s_1 is the sample unbiased standard deviation for the glass bulb;

U_{TL} is the upper tolerance limit for glass-bulb design load and is equal to

$$U_{\text{TL}} = \bar{x}_2 + K\, s_2 \tag{A.4}$$

where

$\bar{x}_2$ is the mean glass-bulb design load;

s_2 is the sample unbiased standard deviation for the glass-bulb design load;

K is the statistical factor taken from Table A.1.

Table A.1 — Table for K-factor values for one-side tolerance limits for normal distributions

n	K for response test of ceiling type sprinklers (including concealed flush, and recessed) [a]
10	3,981
11	3,852
12	3,747
13	3,659
14	3,585
15	3,520
16	3,463
17	3,415
18	3,370
19	3,331
20	3,295
21	3,262
22	3,233
23	3,206
24	3,181
25	3,158
30	3,064
35	2,994
40	2,941
45	2,897
50	2,863

[a] y = 0,95 (degree of confidence)

p = 0,99 (for 99 % of samples)

Annex B
(normative)

Tolerances

Unless otherwise stated, the following tolerances shall apply:

1	Angle	± 2°
2	Frequency (Hz)	± 5 % of value
3	Length	± 2 % of value
4	Volume	± 5 % of value
5	Pressure	± 3 % of value
6	Temperature	± 5 % of value
7	Time	$^{+5}_{\ 0}$ s
		$^{+0,1}_{\ \ 0}$ min
		$^{+0,1}_{\ \ 0}$ h
		$^{+0,25}_{\ \ 0}$ d

Annex C
(informative)

Analysis of the strength test for release elements

The Equation (6) given in 7.10.2 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 sprinkler.

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 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, $F_{1\text{h}}$, and the load at 1 000 h, $F_{1000\text{h}}$. One way of stating this is that, when plotted on full logarithmic paper (time-to-link failure as a function of the load), the slope of the line determined by $F_{1000\text{h}}$ and $F_{1\text{h}}$ shall be greater than, or equal to, the slope determined by the maximum design load at 100 years, F_d, and $F_{1\text{h}}$ or:

$$\frac{\ln F_{1000\text{h}} - \ln F_{1\text{h}}}{\ln 1\,000} \geqslant \frac{\ln F_\text{d} - \ln F_{1\text{h}}}{\ln 876\,600} \qquad \text{(C.1)}$$

This is then reduced as follows:

$$\ln F_{1000\text{h}} \geqslant \left(\ln F_\text{d} - F_{1\text{h}}\right)\frac{\ln 1\,000}{\ln 876\,600} + \ln F_{1\text{h}} \qquad \text{(C.2)}$$

$$\geqslant 0{,}504\,8\left(\ln F_\text{d} - \ln F_{1\text{h}}\right)\ln F_{1\text{h}} \qquad \text{(C.3)}$$

$$\geqslant 0{,}504\,8 \ln F_\text{d} + \ln F_{1\text{h}}\left(1 - 0{,}504\,8\right) \qquad \text{(C.4)}$$

$$\geqslant 0{,}504\,8 \ln F_\text{d} + 0{,}495\,2 \ln F_{1\text{h}} \qquad \text{(C.5)}$$

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

$$\ln F_{1000\text{h}} \geqslant 0{,}5\left(\ln F_\text{d} + \ln F_{1\text{h}}\right) \qquad \text{(C.6)}$$

or, compensating for errors

$$F_{1000\text{h}} \geqslant 0{,}99\sqrt{F_\text{d} F_{1\text{h}}} \qquad \text{(C.7)}$$

or

$$F_\text{d} \leqslant \frac{1{,}02\, F_{1000\text{h}}^2}{F_{1\text{h}}} \qquad \text{(C.8)}$$

Bibliography

References on the dynamic heating test (i.e. the plunge test and prolonged plunge test) are described in the following documents:

[1] HESKESTAD G. and BILL R.G.JR. *Conduction Heat Loss Effects on Thermal Response of Automatic Sprinklers*. Factory Mutual Research Corporation, September 1987.

[2] HESKESTAD G. and SMITH H.F. *Plunge test for Determination of Sprinkler Sensitivity*. Factory Mutual Research Corporation, December 1980.

[3] HESKESTAD G. and SMITH H.F. *Investigation of a New Sprinkler Sensitivity Approval Test: The Plunge Test.* Factory Mutual Research Corporation, December 1973.

[4] Doc. ISO/TC 21/SC 5/WG 1 N 157 (VdS Cologne, 1988).

[5] Doc. ISO/TC 21/SC 5/WG 1 N 186 (Job GmbH, 1990).

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