TECHNICAL SPECIFICATION

ISO/TS 7240-9

Second edition
2012-12-15

Fire detection and alarm systems —

Part 9: Test fires for fire detectors

Systèmes de détection et d'alarme d'incendie —

Partie 9: Essais sur foyers pour détecteurs d'incendie

Reference number
ISO/TS 7240-9:2012(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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 7240-9 was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 3, *Fire detection and alarm systems*.

This second edition cancels and replaces the first edition (ISO/TS 7240-9:2006) which has been technically revised.

ISO 7240 consists of the following parts, under the general title *Fire detection and alarm systems*:

— *Part 1: General and definitions*

— *Part 2: Control and indicating equipment*

— *Part 3: Audible alarm devices*

— *Part 4: Power supply equipment*

— *Part 5: Point-type heat detectors*

— *Part 6: Carbon monoxide fire detectors using electro-chemical cells*

— *Part 7: Point-type smoke detectors using scattered light, transmitted light or ionization*

— *Part 8: Carbon monoxide fire detectors using an electro-chemical cell in combination with a heat sensor*

— *Part 9: Test fires for fire detectors* [Technical Specification]

- *Part 10: Point-type flame detectors*
- *Part 11: Manual call points*
- *Part 12: Line type smoke detectors using a transmitted optical beam*
- *Part 13: Compatibility assessment of system components*
- *Part 14: Guidelines for drafting codes of practice for design, installation and use of fire detection and fire alarm systems in and around buildings* [Technical Report]
- *Part 15: Point type fire detectors using scattered light, transmitted light or ionization sensors in combination with a heat sensor*
- *Part 16: Sound system control and indicating equipment*
- *Part 17: Short-circuit isolators*
- *Part 18: Input/output devices*
- *Part 19: Design, installation, commissioning and service of sound systems for emergency purposes*
- *Part 20: Aspirating smoke detectors*
- *Part 21: Routing equipment*
- *Part 22: Smoke-detection equipment for ducts*
- *Part 23: Visual alarm devices*[1)]
- *Part 24: Sound-system loudspeakers*
- *Part 25: Components using radio transmission paths*
- *Part 27: Point-type fire detectors using a scattered-light, transmitted-light or ionization smoke sensor, an electrochemical-cell carbon-monoxide sensor and a heat sensor*
- *Part 28: Fire protection control equipment*

A part 29 dealing with video fire detectors is under development.

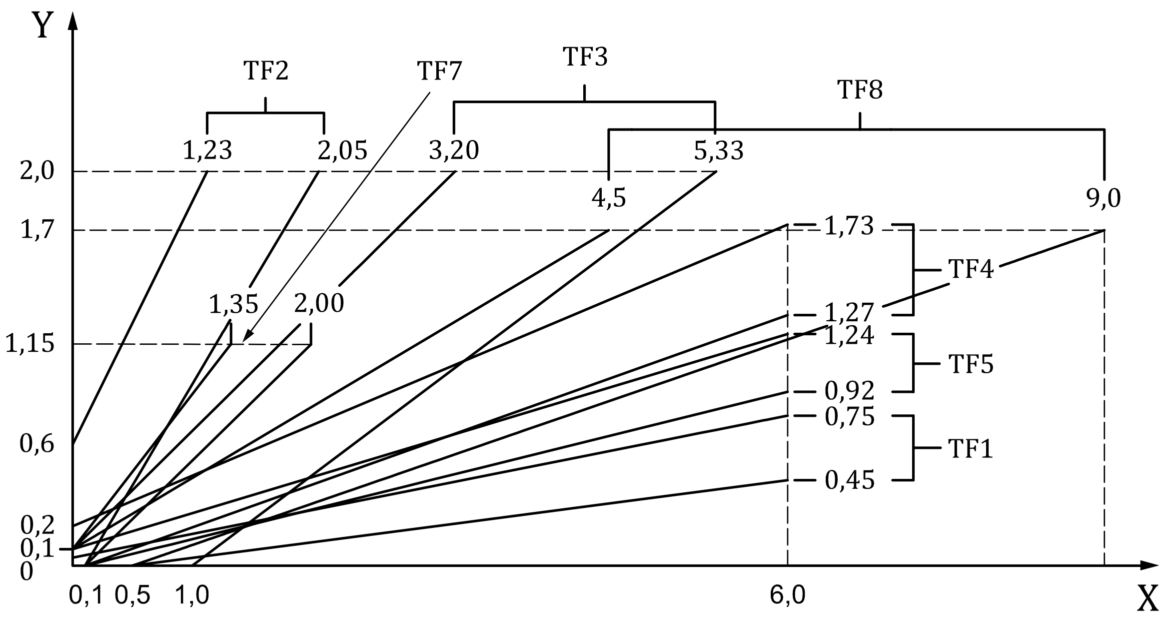
1) To be published.

Introduction

This part of ISO 7240 is based on ISO/TR 7240-9:2006. It provides a summary of the standard test fires defined in other parts of ISO 7240 and where they are used. It has been published to provide a convenient catalogue of fire tests but the formal definition and description of each fire remains within the individual parts of ISO 7240.

The combustibles selected represent a spectrum of large (*m*) and small (*y*) combustion particles for both grey and black smoke. These include burning liquids, plastics and cellulosic (wood) materials, and glowing and smouldering fabrics.

Figure 1 shows the limits of *m* vs *y* where they are defined for the relevant test fires. It illustrates how the test fires are designed to represent a reasonable cross–section of fire types and thus ensure that the response characteristics of the detectors being assessed are broadly capable of detecting the majority of common fires that may occur in practise.



Key

Y absorption index, m, dB/m

X MIC, y (dimensionless)

Figure 1 — Composite of ISO test fires TF1 to TF5, TF7 and TF8 profile curves: *m* versus *y*

The test fires in this part of ISO 7240 are intended to be applicable for the evaluation of all automatic fire detectors (smoke, heat, flame, etc.). They are employed on a selective basis for use in concert with a specified International Standard covering the particular type of detector. For example, test fire TF6, methylated spirits, is used to evaluate the response of heat detectors. Test fires TF1 through TF5 are selected to evaluate the response of system-connected smoke detectors. Test fire TF7 is selected in lieu of test fire TF2 to evaluate the response of smoke alarms intended primarily for installation in residential type occupancies. In view of the residential type application, smoke alarms are evaluated for compliance with test fire TF7 using a 3 m high rather than a 4 m high ceiling. Test fires TF2, TF3 and TF9 are suitable for testing the response of a detector to carbon monoxide. Carbon monoxide output curves are also shown for TF4, TF5 and TF8.

Fire detection and alarm systems —

Part 9:
Test fires for fire detectors

1 Scope

This Technical Specification describes methods of test using test fires to which fire detectors, such as smoke, heat, flame are subjected as specified in other parts of ISO 7240 for such detectors.

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 7240-1, *Fire detection and alarm systems — Part 1: General and definitions*

3 Terms, definitions and symbols

For the purposes of this document, the terms, definitions and symbols given in ISO 7240-1 and the following apply.

3.1
sensitivity
relative degree of response of a smoke detector

Note 1 to entry: A high sensitivity denotes response to a lower concentration of smoke particles than a low sensitivity under identical smoke build-up conditions.

4 Characteristics of test fires — Description

Fifteen test fires are described in Clause 7 and designated TF1 through TF9. Their characteristic features are shown in Table 1.

The test fires shall be carried out in accordance with the descriptions of Clause 7. It is permissible to vary slightly the quantities of fuel used, if necessary, to produce the required values of fire parameters.

Table 1 — Characteristics of test fires

Designation TF = Test fire	Type of fire	Develop-ment of heat	Up-current	Smoke	Aerosol spectrum	Visible portion	Carbon monoxide
TF1	Open cellulosic (wood)	Strong	Strong	Yes	Predominantly invisible	Dark	Very weak
TF2	Rapid smouldering pyrolysis (wood)	Weak	Weak	Yes	Predominantly visible	Light, high scattering	Yes
TF2a	Slow smouldering pyrolysis (wood)	Weak	Weak	Yes	Predominantly visible	Light, high scattering	Yes
TF2b	Smouldering pyrolysis (wood)	Weak	Weak	Yes	Predominantly visible	Light, high scattering	Yes
TF3	Glowing (fast smouldering) (cotton)	Weak	Very weak	Yes	Partially visible	Light, high scattering	Strong
TF3a	Glowing (slow smouldering) cotton	Weak	Very weak	Yes	Partially visible	Light, high scattering	Strong
TF3b	Glowing (smouldering) cotton	Weak	Very weak	Yes	Partially visible	Light, high scattering	Strong
TF4	Open plastics (polyurethane)	Strong	Strong	Yes	Partially invisible	Very dark	Weak
TF5	Liquid (*n*-heptane)	Strong	Strong	Yes	Predominantly invisible	Very dark	Weak
TF5a	Liquid (*n*-heptane) small	Strong	Strong	Yes	Predominantly invisible	Very dark	Weak
TF5b	Liquid (*n*-heptane) medium	Strong	Strong	Yes	Predominantly invisible	Very dark	Weak
TF6	Liquid (methylated spirit)	Strong	Strong	No	None	None	Very weak
TF7	Slow smouldering (pyrolysis) wood	Weak	Weak	Yes	Predominantly visible	Light, high scattering	Very weak
TF8	Low temperature black smoke (decalin) liquid	Weak	Weak	Yes	Predominantly visible	Dark	Very weak
TF9	Deep seated smouldering cotton	Weak	Weak	Yes	Predominantly visible	Light, high scattering	Yes

5 Test laboratory

5.1 Dimensions

The dimensions of the test room shall be within the following limits:

— length: 10 m ± 1 m;

— width: 7 m ± 1 m;

— height: 4 m ± 0,2 m for all tests except TF7 which specifies a 3 m ± 0,2 m ceiling height. This can be achieved by placing the hotplate on a 1 m high platform.

The ceiling and walls shall be flat with no obstructions between the fire source and the detectors and instrumentation. The fire source shall be centred as much as possible with respect to the four walls to minimize reflection of smoke and/or heat. Fire curtains may be employed to reduce the room size within specified limits, if needed.

5.2 Ambient test conditions

The following ambient conditions shall be established prior to conducting each test fire:

a) temperature: (15 to 35) °C. Recommend maximum 2 °C difference between ceiling and floor temperatures for smouldering tests TF2, TF3, TF3a, TF3b and TF7;

b) relative humidity: (25 to 75) %;

c) air pressure: (86 to 106) kPa;

d) air movement: negligible;

e) MIC reading: less than y = 0,05;

f) optical beam reading: less than m = 0,05 dB/m;

g) CO concentration: less than S = 5 µl/l

NOTE For improved consistency of test fires, the temperature can be controlled to (31 to 25) °C and the relative humidity can be controlled to (45 to 55) %.

5.3 Instruments

The measuring instruments or their specification employed during the test fires are described under the following annexes:

— optical measuring equipment (see Annex C);

— measuring ionization chamber (see Annex D);

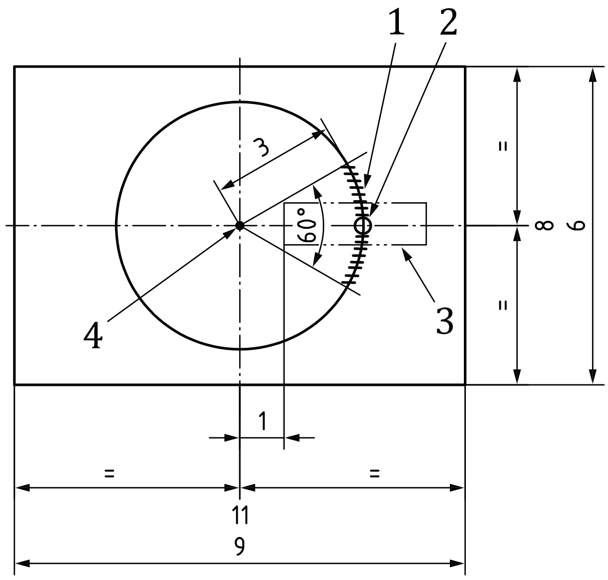
— spark generator (see Annex E).

6 Test method

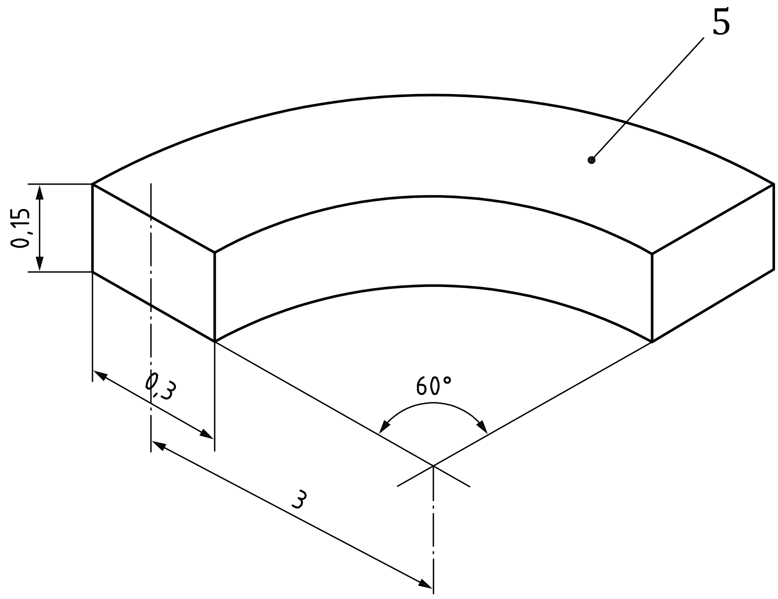
6.1 Arrangement

The location and arrangement of the detectors under test, smoke density, temperature and carbon monoxide level measuring instrumentation, and test fire location are illustrated in Figure 2.

For those tests that require ignition inside the test room, the personnel entrusted with the performance of the test shall leave the test room immediately after igniting the fuel, taking care to prevent air movement, which may affect the development of the test. All doors, windows, or other openings shall be kept closed during the test.



a) Plan view of fire test room



b) Mounting position for instruments and specimens

Key

1 specimens and measuring instruments [see Figure 2(b)]

2 optimum position of sampling point for aspirating smoke detectors

3 ventilation system for aspirating smoke detectors [see Figure 3]

4 position of test fire

5 ceiling

Figure 2 — Location of detectors, fire and measuring instruments

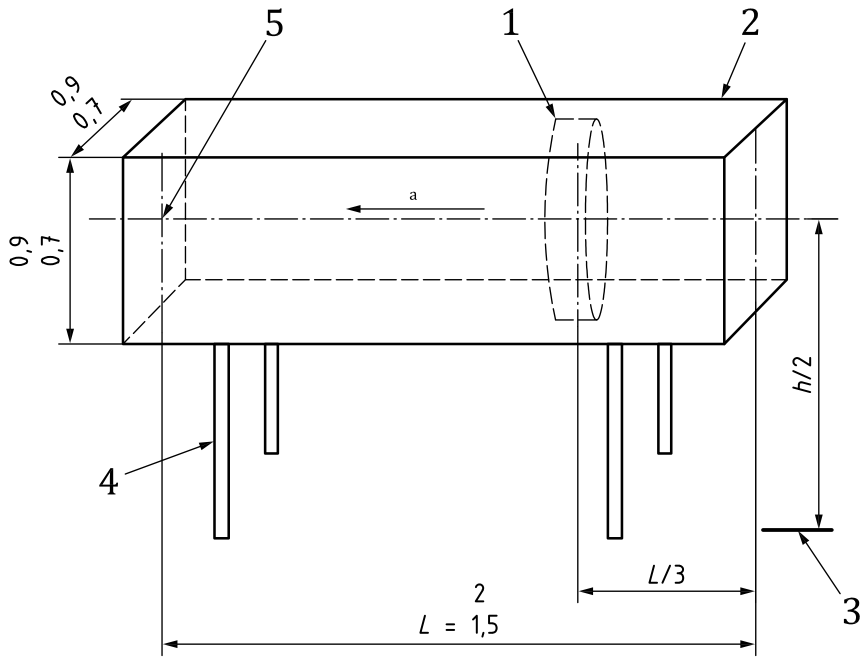
6.2 Ventilation system

As a consequence of the low quantity of aerosols generated by reduced fire tests, it is necessary, for the reduced fire tests TF2a, TF2b, TF3a, TF3b, TF5a and TF5b, to introduce in the fire test room a ventilation system to increase the homogeneity of the atmosphere close to the sampling points. The following specifies those characteristics of the ventilation system which are of primary importance.

The ventilation system consists of a square duct opened in both extremities (see Figure 3).

A fan is located in the duct as described in Figure 3. The diameter of the fan shall be as close as possible to the dimensions of the sides of the square section of the duct. At the location of the fan, the section of the duct not occupied by the fan shall be closed. The axis of the fan shall be the same as the axis of the square duct.

The ventilation system shall create an airflow at (1,0 ± 0,2) m/s at the output of the duct (the airflow direction is given in Figure 3). Conformity with this requirement shall be regularly verified during the fire tests by measurements at the centre of the duct output section (see key item 5 in Figure 3).



Key

1 fan
2 square duct
3 ground
4 stand
5 location of the flow velocity measurement
L length of the duct
h height of the fire test room [see Figure 2]
a Air flow.

Figure 3 — Ventilation system

6.3 Measurement parameters

During each test record the relevant test fire parameters listed in Table 2.

Table 2 — Test fire parameters

Parameter	Symbol	Unit
Temperature	T	°C
Temperature change	ΔT	°C
Time	t	seconds (s) or minutes (min) as required
Smoke density (optical)	m	dB/m
Smoke density (ionization)	y	dimensionless
Carbon monoxide concentration	S	µl/l

See Annexes A and B for tables of *m* values and *y* values.

6.4 End-of-test parameters

The values of the fire parameters at the end of the test (T_E, m_E, y_E, t_E, S_E) together with the profile curves are used as the control of the validity and reproducibility of the test fires. The test shall be considered finished when the specific limits for each test specified in Clause 7 is reached. If a detector responds after the specified end of test fire parameters have been reached, the detector shall be considered as having failed the test.

7 Test fires

7.1 General

This Clause contains a description of the 15 test fires, including type and amount of combustible material, illustration of 10 test setups, method of ignition, pre-conditioning of combustible material (if needed) and end-of-test parameters.

To permit more flexibility in conducting the tests and interpreting the results, the following guidelines may be followed. This should also result in a higher success rate for a valid test.

a) Because of variation in smoke build-up that frequently occurs, the build-up curve occasionally may drift out of the limits for a short interval or near the end of the test. The test is to be considered valid if the detectors being evaluated respond during the time interval when the build-up is within the limits.

b) The following exceptions would apply to the guidelines in a):

If the build-up curve drifted to the left of the *m* vs *y* limit, the test could be considered valid if ionization type detectors actuated during that interval since they respond worse to large particles.

c) The fuels specified are the preferred test materials. Alternate fuels may be used as substitutes because of the availability of national natural resources. The alternate fuel source shall exhibit the same characteristics as the preferred fuels, i.e. colour of smoke and particle size distribution (within the profile).

d) Where the detector under test does not contain a carbon monoxide sensor, the profile curves for CO concentration need not apply to the test fire.

7.2 Test fire TF1 — Open cellulosic (wood) fire

7.2.1 Fuel

Approximately 70 dried beechwood sticks, each stick having dimensions of 10 mm × 20 mm by 250 mm.

7.2.2 Conditioning

Dry the sticks in a heating oven so the moisture content is less than 3 %.

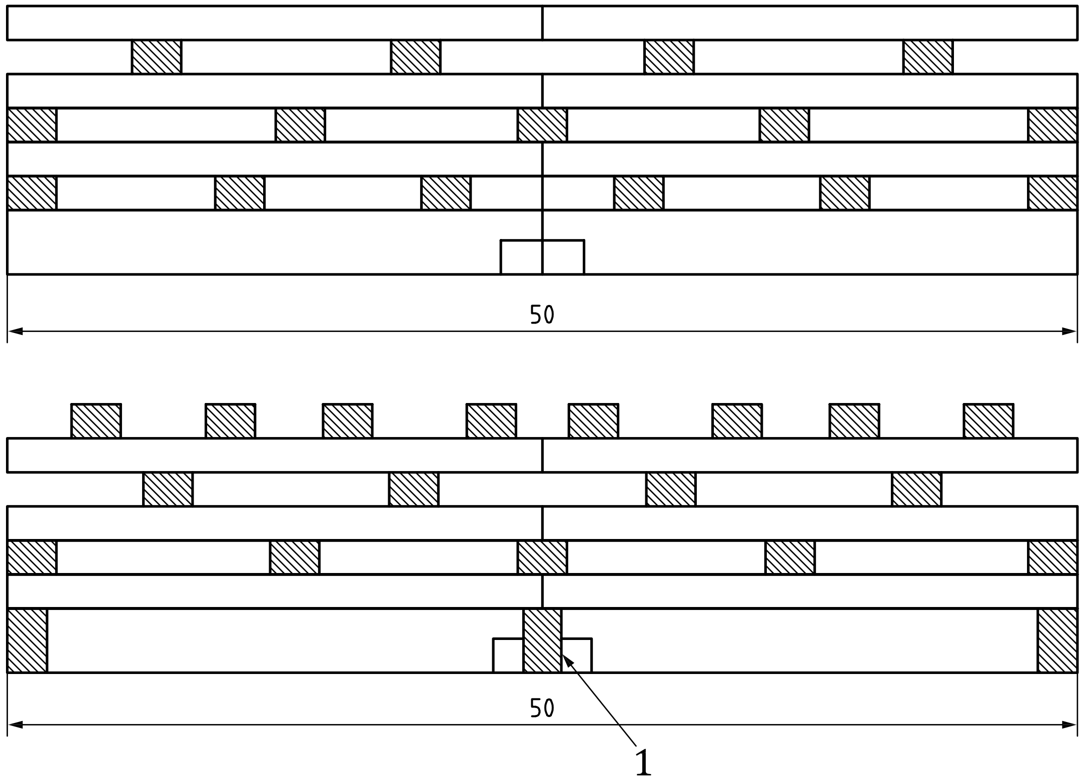
7.2.3 Preparation

If necessary, transport the sticks from the oven in a closed plastic bag and open the bag just prior to laying out the sticks in the test arrangement.

7.2.4 Arrangement

Superimpose seven layers on a base surface measuring approx. 50 cm wide × 50 cm long × 8 cm high; see Figure 4.

Dimensions in centimetres



Key

1 container for methylated spirits

Figure 4 — Wood arrangement for test fire TF1

7.2.5 Ignition

0,5 cm^3 methylated spirits in a bowl 5 cm in diameter. Locate the bowl in the centre of base surface.

7.2.6 Method of ignition

Ignite by flame or spark in the methylated spirits.

7.2.7 Test validity criteria

The development of the fire shall be such that the curves of *m* against *y*, and *m* against time, *t*, fall within the hatched areas shown in Figures 5 and 6, respectively. That is, 0,45 dB/m < *m* < 0,75 dB/m and 270 s < *t* < 370 s at the end-of-test condition y_E = 6,0.

For detectors using scattered or transmitted light, if the end of test condition, y_E = 6,0 is reached before all the specimens have responded, then the test is only considered valid if *m* ≥ 0,6 dB/m.

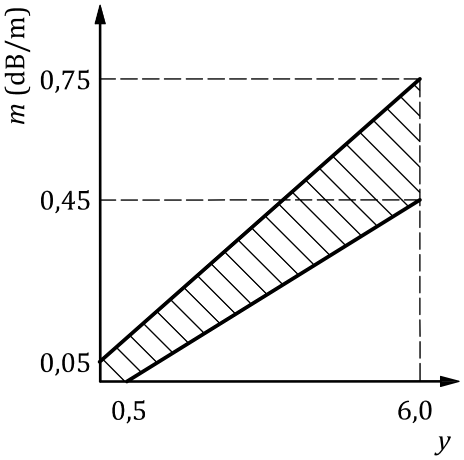


Figure 5 — Limits for *m* against *y*, Fire TF1

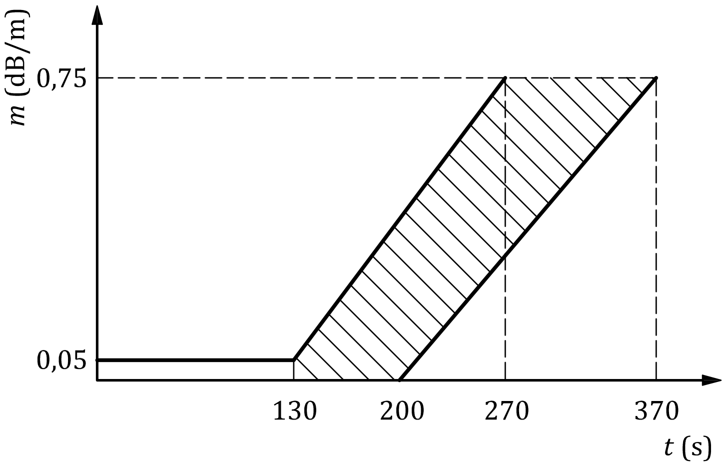


Figure 6 — Limits for *m* against time *y*, Fire TF1

7.2.8 Variables

The number of sticks may be varied in order for the test fire to remain within the profile curve limits.

7.2.9 End-of-test condition

The end-of-test condition shall be when

— y_E = 6;

— t_E > 370 s; or

— all the specimens have generated an alarm signal.

7.3 Test fire TF2 — Rapid smouldering pyrolysis (wood) fire

7.3.1 Fuel

Approximately 10 dried beechwood sticks, each stick having dimensions of 75 mm × 25 mm × 20 mm.

7.3.2 Conditioning

Dry the sticks in a heating oven so the moisture content is approximately 5 %.

7.3.3 Preparation

If necessary, transport the sticks from the oven in a closed plastic bag and open the bag just prior to laying out the sticks in the test arrangement.

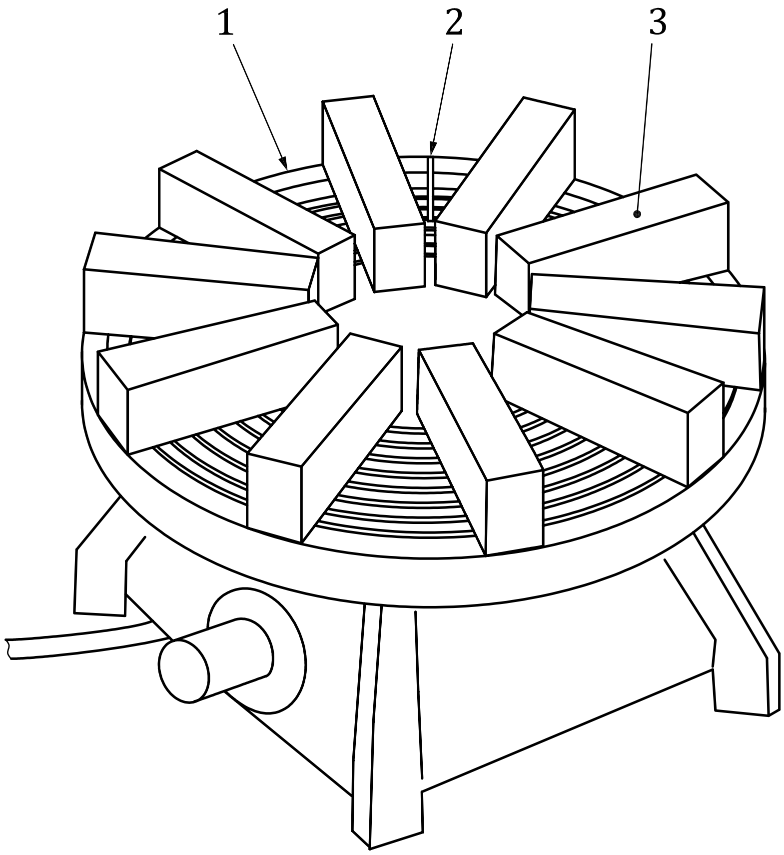
7.3.4 Hotplate

The hotplate shall have a 220 mm diameter grooved surface with eight concentric grooves with a distance of 3 mm between grooves. Each groove shall be 2 mm deep and 5 mm wide, with the outer groove 4 mm from the edge. The hotplate shall have a rating of approximately 2 kW.

Measure the temperature of the hotplate by attaching a sensor to the fifth groove, counted from the edge of the hotplate, and securing the sensor to provide a good thermal contact.

7.3.5 Arrangement

Arrange the sticks radially on the grooved hotplate surface, with the 20 mm side in contact with the surface such that the temperature sensor lies between the sticks and is not covered, as shown in Figure 7.



Key

1 grooved hotplate

2 temperature sensor

3 wooden sticks

Figure 7 — Arrangement of sticks on hotplate

7.3.6 Heating rate

Power the hotplate such that its temperature rises from ambient to 600 °C in approximately 11 min and is maintained for the duration of the test.

7.3.7 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* against *y*, *m* against time, *t*, and, for detectors incorporating carbon monoxide sensors, *S* against time, *t*, fall within the limits shown in Figures 8, 9 and 10, respectively. That is, $1,23 < y < 2,05$ and $570 \text{ s} < t < 840 \text{ s}$ at the end-of-test condition $m_E = 2$ dB/m and $45 \text{ µl/l} < S < 100 \text{ µl/l}$ at end-of-test condition $t = 840$ s.

For detectors using ionization, if the end of test condition, $m_E = 2$ dB/m, is reached before all the specimens have responded, then the test is only considered valid if a $y = \geq 1,6$.

For detectors incorporating carbon monoxide sensors, if the end of test condition, $m_E = 2$ dB/m is reached before all the specimens have responded, then the test is only considered valid if $S > 45$ µl/l.

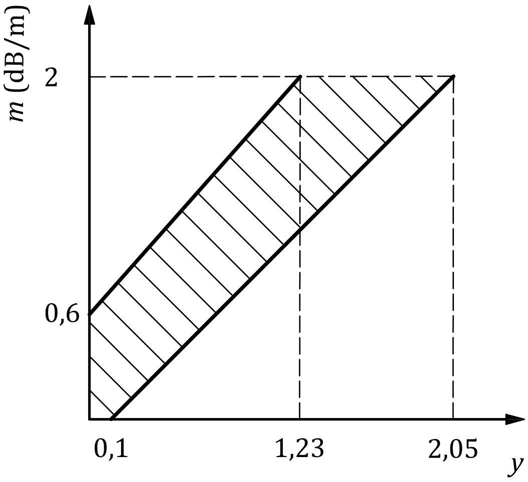


Figure 8 — Limits for *m* against *y*, Fire TF2

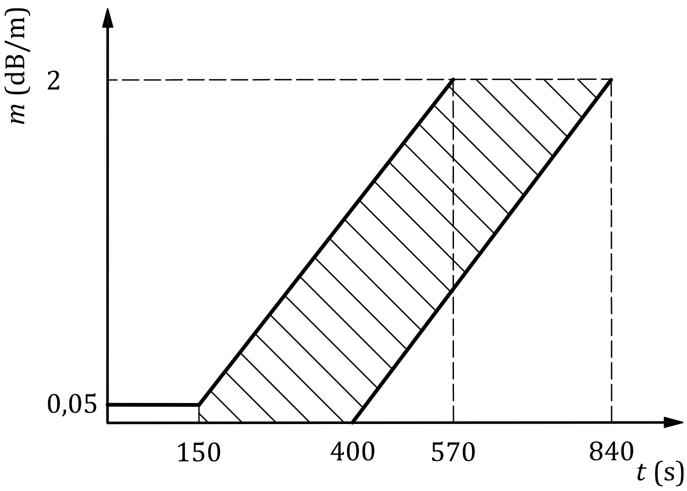


Figure 9 — Limits for *m* against time, *t*, Fire TF2

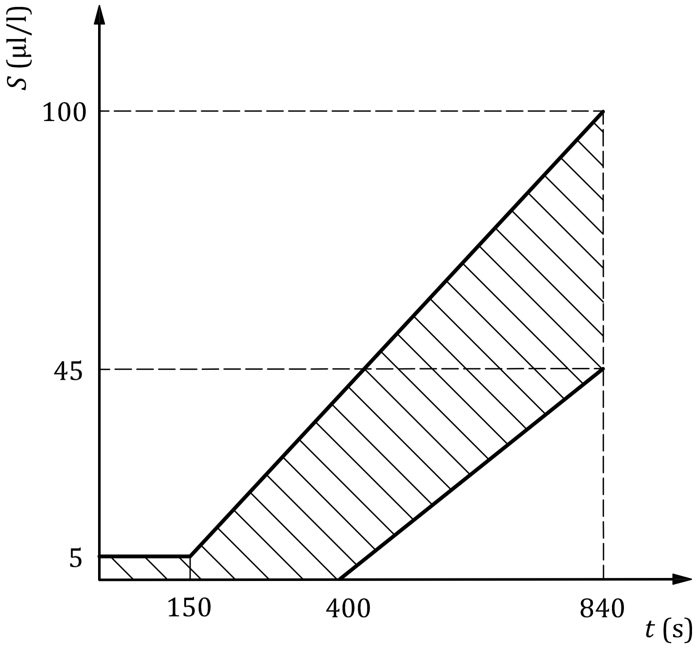


Figure 10 — Limits for *S* against time, *t*, Fire TF2

7.3.8 Variables

The number of sticks, the rate of temperature increase of the hotplate and the degree of conditioning of the wood may be varied in order for the test fire to remain within the profile curve limits.

7.3.9 End-of-test condition

The end-of-test condition shall be when

— m_E = 2 dB/m;

— t_E > 840 s;

— for detectors incorporating carbon monoxide sensors, *S* > 100 µl/l; or

— all the specimens have generated an alarm signal.

7.4 Test fire TF2a — Slow smouldering pyrolysis (wood) fire

7.4.1 Fuel

Approximately three dried beechwood sticks, each stick having dimensions of 75 mm × 25 mm × 20 mm.

7.4.2 Conditioning

Dry the sticks in a heating oven so the moisture content is approximately 5 %.

7.4.3 Preparation

If necessary, transport the sticks from the oven in a closed plastic bag and open the bag just prior to laying out the sticks in the test arrangement.

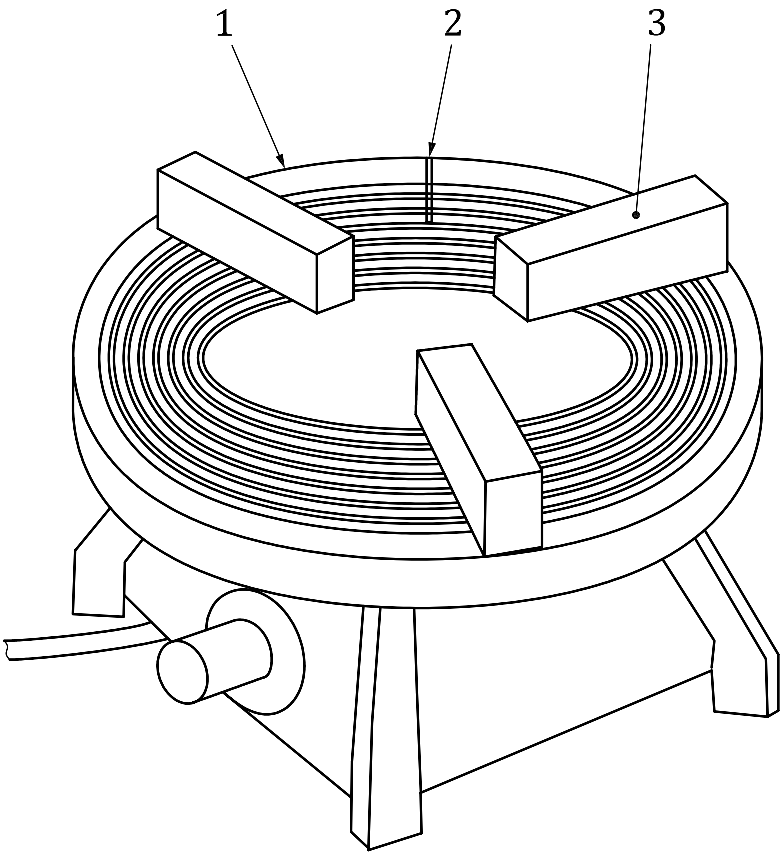
7.4.4 Hotplate

The hotplate shall have a 220 mm diameter grooved surface with eight concentric grooves with a distance of 3 mm between grooves. Each groove shall be 2 mm deep and 5 mm wide, with the outer groove 4 mm from the edge. The hotplate shall have a rating of approximately 2 kW.

Measure the temperature of the hotplate by attaching a sensor to the fifth groove, counted from the edge of the hotplate, and securing the sensor to provide a good thermal contact.

7.4.5 Arrangement

Arrange the sticks radially on the grooved hotplate surface, with the 20 mm side in contact with the surface such that the temperature sensor lies between the sticks and is not covered, as shown in Figure 11.



Key

1 grooved hotplate

2 temperature sensor

3 wooden sticks

Figure 11 — Arrangement of sticks on hotplate

7.4.6 Heating rate

Power the hotplate such that its temperature rises from ambient to 500 °C in approximately 11 min and is maintained for the duration of the test.

NOTE For TF2, the target temperature is 600 °C.

7.4.7 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* time, *t*, fall within the limits shown in Figure 12. That is, 960 s < *t* < 1440 s at the end-of-test condition m_E = 0,05 dB/m.

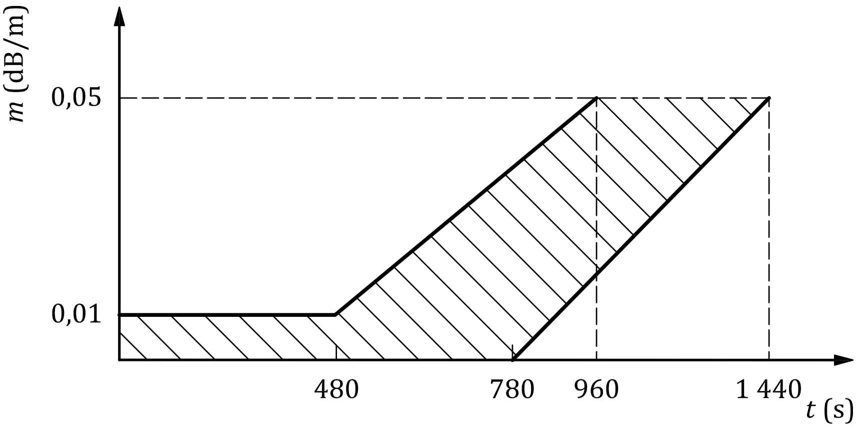


Figure 12 — Limits for *m* against time, *t*, Fire TF2a

7.4.8 Variables

The number of sticks, the rate of temperature increase of the hotplate and the degree of conditioning of the wood may be varied in order for the test fire to remain within the profile curve limits.

7.4.9 End-of-test condition

The end-of-test condition shall be when

— m_E = 0,05 dB/m;

— t_E > 960 s; or

— all the specimens have generated an alarm signal.

7.5 Test fire TF2b — Smouldering pyrolysis (wood) fire

7.5.1 Fuel

Approximately six dried beechwood sticks, each stick having dimensions of 75 mm × 25 mm × 20 mm.

7.5.2 Conditioning

Dry the sticks in a heating oven so the moisture content is approximately 5 %.

7.5.3 Preparation

If necessary, transport the sticks from the oven in a closed plastic bag and open the bag just prior to laying out the sticks in the test arrangement.

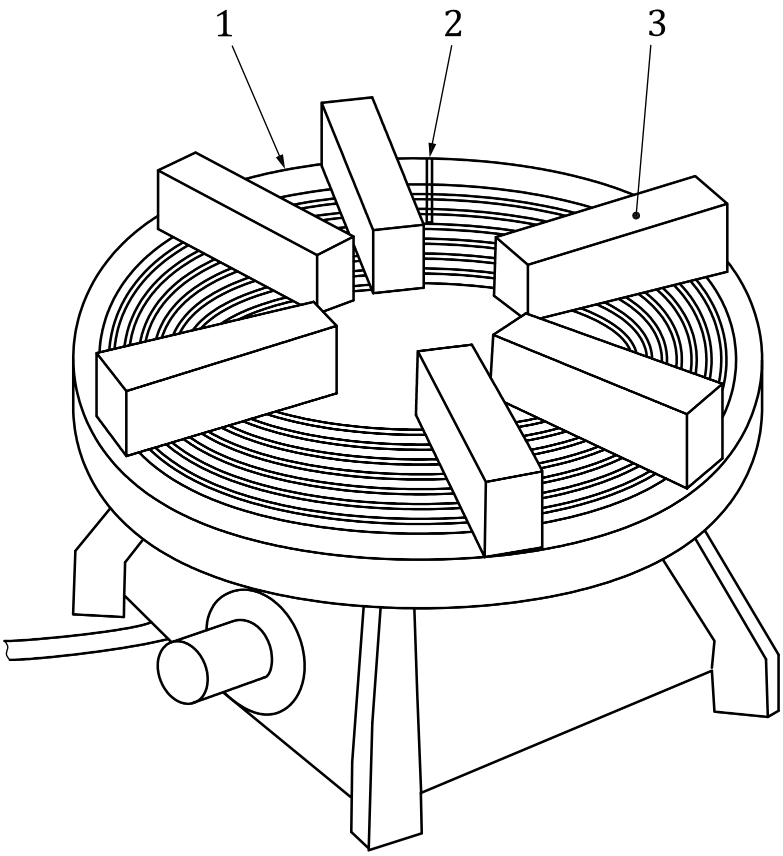
7.5.4 Hotplate

The hotplate shall have a 220 mm diameter grooved surface with eight concentric grooves with a distance of 3 mm between grooves. Each groove shall be 2 mm deep and 5 mm wide, with the outer groove 4 mm from the edge. The hotplate shall have a rating of approximately 2 kW.

Measure the temperature of the hotplate by attaching a sensor to the fifth groove, counted from the edge of the hotplate, and securing the sensor to provide a good thermal contact.

7.5.5 Arrangement

Arrange the sticks radially on the grooved hotplate surface, with the 20 mm side in contact with the surface such that the temperature sensor lies between the sticks and is not covered, as shown in Figure 13.



Key

1 grooved hotplate

2 temperature sensor

3 wooden sticks

Figure 13 — Arrangement of sticks on hotplate

7.5.6 Heating rate

Power the hotplate such that its temperature rises from ambient to 500 °C in approximately 11 min and is maintained for the duration of the test.

NOTE For TF2, the target temperature is 600 °C.

7.5.7 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* time, *t*, fall within the limits shown in Figure 14. That is, 1140 s < *t* < 2000 s at the end-of-test condition m_E = 0,15 dB/m.

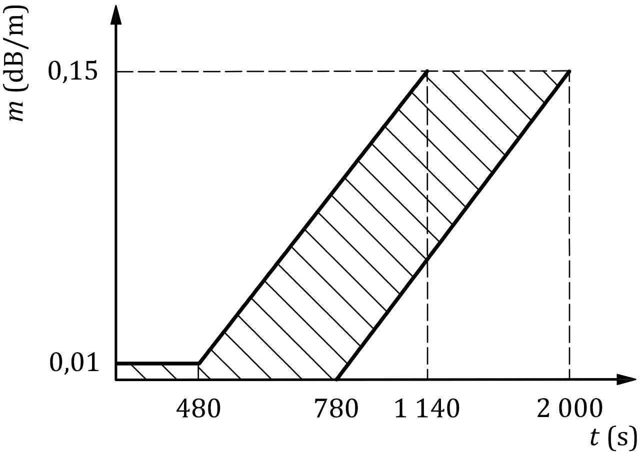


Figure 14 — Limits for *m* against time, *t*, Fire TF2b

7.5.8 Variables

The number of sticks, the rate of temperature increase of the hotplate and the degree of conditioning of the wood may be varied in order for the test fire to remain within the profile curve limits.

7.5.9 End-of-test condition

The end-of-test condition shall be when

— m_E = 0,15 dB/m;

— m_E > 1140 s; or

— all the specimens have generated an alarm signal.

7.6 Test fire TF3 — Glowing (fast smouldering) cotton fire

7.6.1 Fuel

Approximately 90 pieces of braided cotton wick, each of length approximately 80 cm and weighing approximately 3 g.

7.6.2 Conditioning

Wash and dry the wicks if they have a protected coating. Store the wicks in an environment of no more than 50 % humidity prior to being ignited.

7.6.3 Arrangement

Fasten the wicks to a ring approximately 10 cm in diameter and suspended approximately 1 m above a non-combustible plate as shown in Figure 15.

Dimension in metres

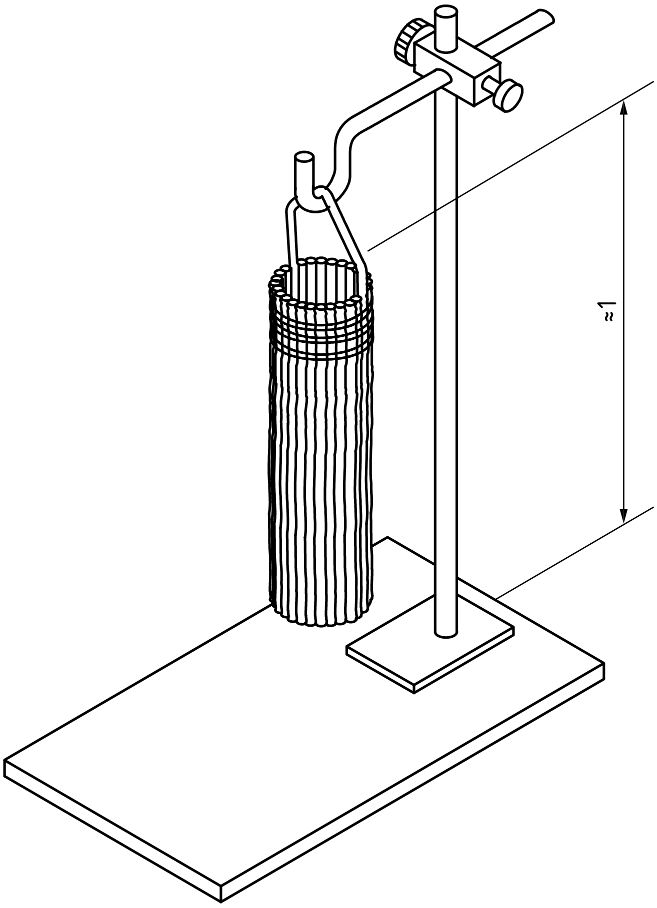


Figure 15 — Arrangement of cotton wicks

7.6.4 Ignition

Ignite the lower end of each wick so that the wicks continue to glow. Immediately blow out any flaming. Start the test time when all wicks are glowing.

7.6.5 Method of ignition

Ignite by match or torch.

7.6.6 Test validity criteria

The development of the fire shall be such that the curves of *m* against *y*, *m* against time, *t*, and, for detectors incorporating carbon monoxide sensors, *S* against time, *t,* fall within the limits shown in Figures 16, 17 and 18 respectively. That is, $3,2 < y < 5,33$ and $280 \text{ s} < t < 750 \text{ s}$ at the end-of-test conditions $m_E = 2$ dB/m or $S = 150$ µl/l.

For detectors incorporating carbon monoxide sensors, if the end of test condition, $m_E = 2$ dB/m is reached before all the specimens have responded, then the test is only considered valid if $S > 150$ µl/l.

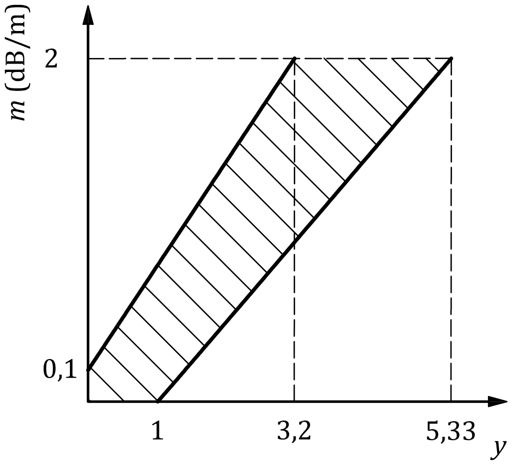


Figure 16 — Limits for *m* against *y*, Fire TF3

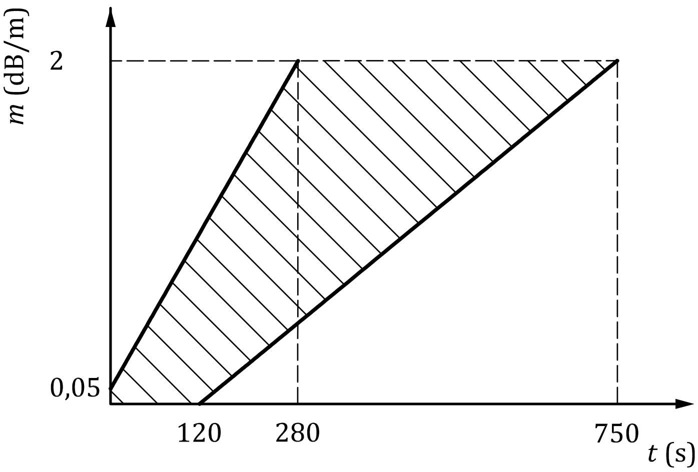


Figure 17 — Limits for *m* against time, *t*, Fire TF3

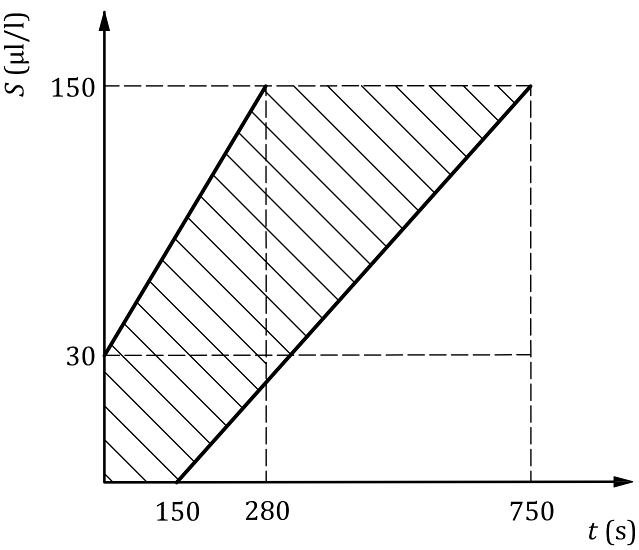


Figure 18 — Limits for *S* against time, *t*, Fire TF3

7.6.7 Variables

The number and weight of each piece may be varied in order for the build-up to stay within the profile curve limits.

7.6.8 End-of-test condition

The end-of-test condition shall be when

— m_E = 2 dB/m;

— t_E > 750 s;

— for detectors incorporating carbon monoxide sensors, S > 150 µl/l; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.7 Test fire TF3a — Glowing (slow smouldering) cotton fire

7.7.1 Fuel

Approximately 30 pieces of braided cotton wick, each of length approximately 80 cm and weighing approximately 3 g.

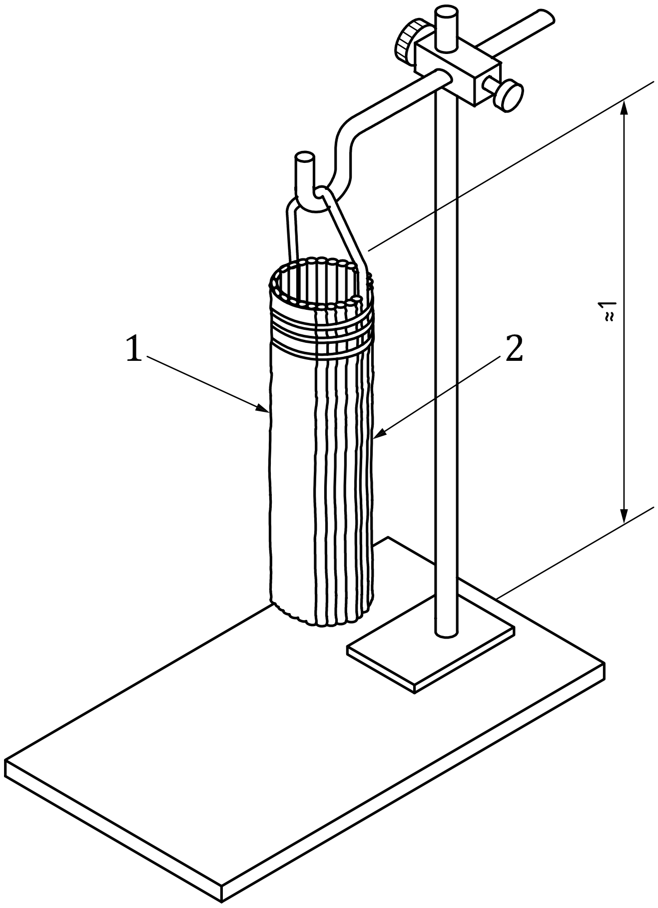
7.7.2 Conditioning

Wash and dry the wicks if they have a protected coating. Store the wicks in an environment of no more than 50 % humidity prior to being ignited.

7.7.3 Arrangement

Fasten the wicks to a ring approximately 10 cm in diameter and suspended approximately 1 m above a non-combustible plate. Position the wicks adjacent to one another and complete the open part of the arc using a curved sheet of non-combustible material to achieve a complete "chimney" as shown in Figure 19.

Dimension in metres



Key

1 curved sheet of non-combustible material

2 cotton wicks

Figure 19 — Arrangement of cotton wicks

7.7.4 Ignition

Ignite the lower end of each wick so that the wicks continue to glow. Immediately blow out any flaming. Start the test time when all wicks are glowing.

7.7.5 Method of ignition

Ignite by match or torch.

7.7.6 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* time, *t*, fall within the limits shown in Figure 20. That is, 660 s < t < 1200 s at the end-of-test condition m_E = 0,05 dB/m.

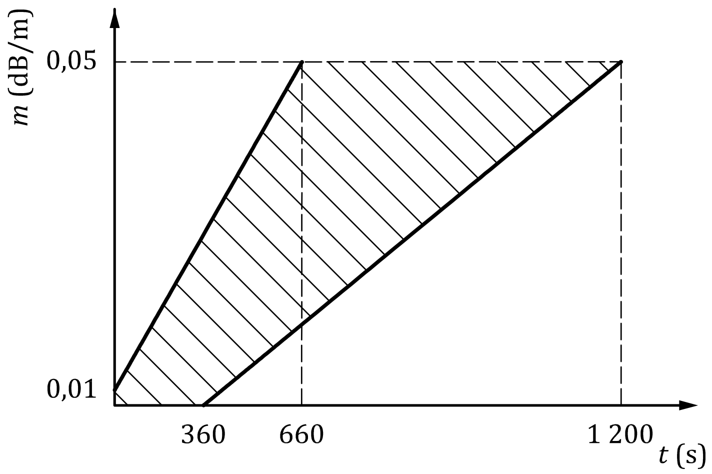


Figure 20 — Limits for *m* against time, *t*, Fire TF3a

7.7.7 Variables

The number and weight of each piece may be varied in order for the build-up to stay within the profile curve limits.

7.7.8 End-of-test condition

The end-of-test condition shall be when

— m_E = 0,05 dB/m;

— t_E > 660 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.8 Test fire TF3b — Glowing (smouldering) cotton fire

7.8.1 Fuel

Approximately 40 pieces of braided cotton wick, each of length approximately 80 cm and weighing approximately 3 g.

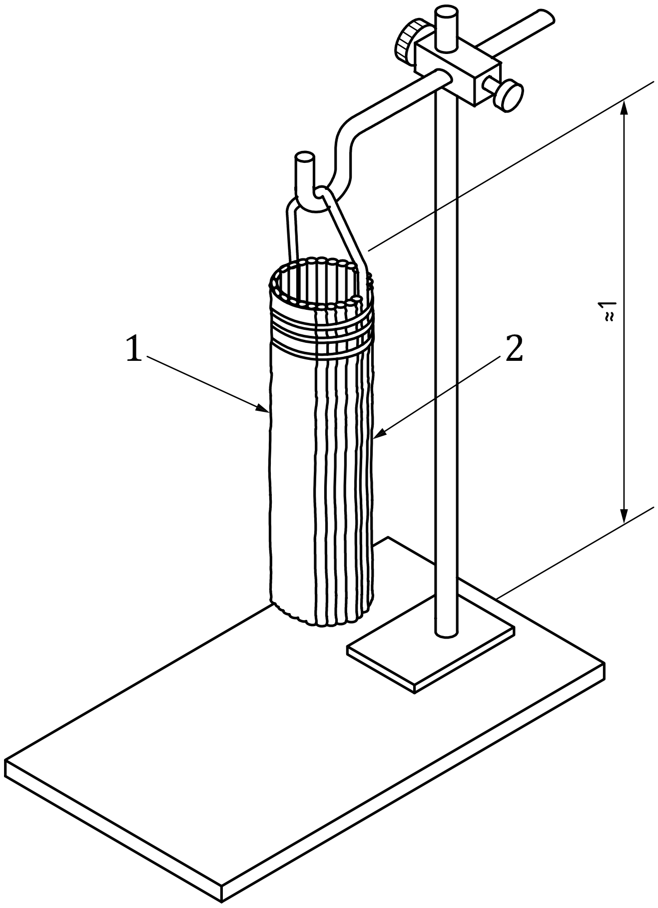
7.8.2 Conditioning

Wash and dry the wicks if they have a protected coating. Store the wicks in an environment of no more than 50 % humidity prior to being ignited.

7.8.3 Arrangement

Fasten the wicks to a ring approximately 10 cm in diameter and suspended approximately 1 m above a non-combustible plate as shown in Figure 21.

Dimension in metres



Key

1 curved sheet of non-combustible material

2 cotton wicks

Figure 21 — Arrangement of cotton wicks

7.8.4 Ignition

Ignite the lower end of each wick so that the wicks continue to glow. Immediately blow out any flaming. Start the test time when all wicks are glowing.

7.8.5 Method of ignition

Ignite by match or torch.

7.8.6 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* time, *t*, fall within the limits shown in Figure 22. That is, 660 s < *t* < 1200 s at the end-of-test condition m_E = 0,15 dB/m.

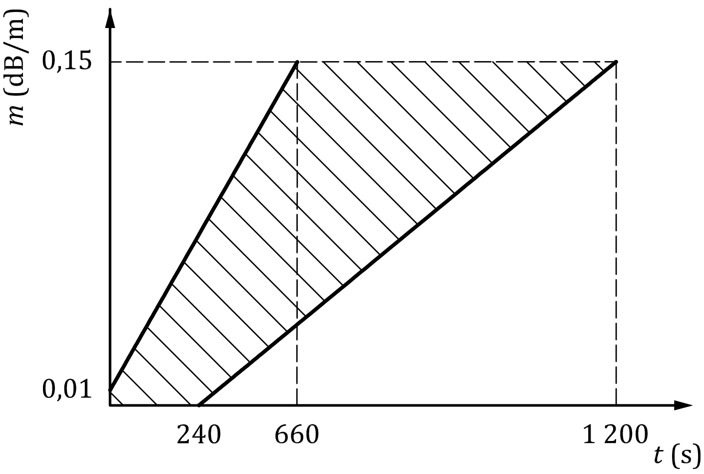


Figure 22 — Limits for *m* against time, *t*, Fire TF3b

7.8.7 Variables

The number and weight of each piece may be varied in order for the build up to stay within the profile curve limits.

7.8.8 End-of-test condition

The end-of-test condition shall be when

— m_E = 0,15 dB/m;

— t_E > 660 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.9 Test fire TF4 — Open plastics (polyurethane) fire

7.9.1 Fuel

Three mats, approximately 50 cm × 50 cm × 2 cm, of soft polyurethane foam, without flame-retardant additives and having a density of approximately 20 kg/m^3, are usually found sufficient. However, the exact quantity of fuel may be adjusted to obtain valid tests.

7.9.2 Conditioning

Maintain the mats in a humidity not exceeding 50 % at least 48 h prior to test.

7.9.3 Arrangement

Place the mats one on top of another on a base formed from aluminium foil with the edges folded up to provide a tray.

7.9.4 Ignition

Ignite the mats at a corner of the lower mat. The exact position of ignition may be adjusted to obtain a valid test. A small quantity of a clean burning material (e.g. Five cm^3 of methylated spirit) may be used to assist the ignition.

7.9.5 Method of ignition

Ignite by match or spark.

7.9.6 Test validity criteria

The development of the fire shall be such that the curves of *m* against *y*, *m* against time, *t*, and, for detectors incorporating carbon monoxide sensors, *S* against time, *t*, fall within the limits shown in Figures 23, 24 and 25, respectively. That is, 1,27 < *m* < 1,73 and 140 s < *t* < 180 s at the end-of-test conditions y_E = 6 or *S* = 20 µl/l.

For detectors using scattered or transmitted light, if the end of test condition, y_E = 6,0 is reached before all the specimens of have responded, then the test is only considered valid if *m* ≥ 1,5 dB/m.

For detectors incorporating carbon monoxide sensors, if the end of test condition, y_E = 6 is reached before all the specimens have responded, then the test is only considered valid if *S* > 20 µl/l.

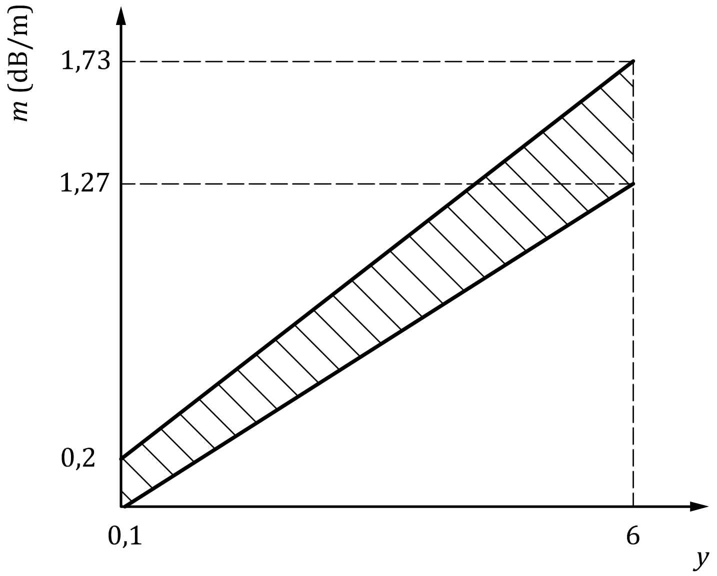


Figure 23 — Limits for *m* against *y*, Fire TF4

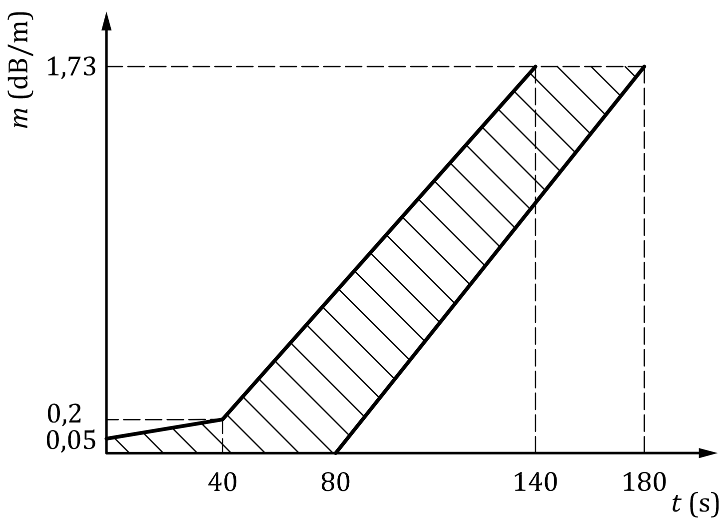


Figure 24 — Limits for *m* against time, *t*, Fire TF4

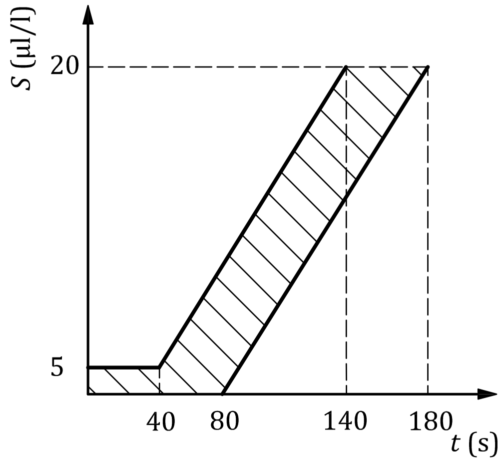


Figure 25 — Limits for *S* against time, *t*, Fire TF4

7.9.7 End-of-test condition

The end-of-test condition shall be when

— $y_E = 6$;

— $t_E > 180$ s;

— for detectors incorporating carbon monoxide sensors, $S > 20$ µl/l; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.9.8 Extended end-of-test condition

Test fire TF4 may be left to burn, with the development of the fire such that the curves of *m* against *y*, and *m* against time, *t*, fall within the limits shown in Figures 26 and 27, respectively. That is, $1{,}38 < m < 1{,}86$ and $150 \text{ s} < t < 193 \text{ s}$ at the end-of-test condition $y_E = 6{,}5$.

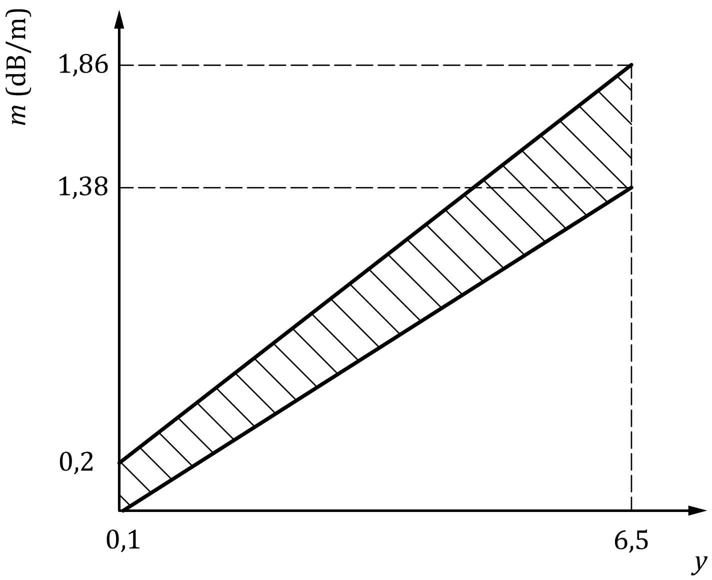


Figure 26 — Limits for *m* against *y*, Fire TF4 (extended)

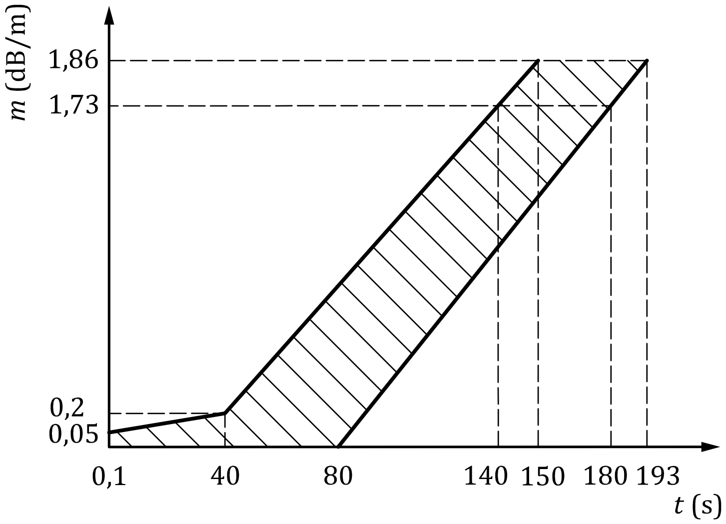


Figure 27 — Limits for *m* against time, *t*, Fire TF4 (extended)

The extended end-of-test condition shall be when

— $y_E = 6{,}5$;

— $t_E > 193$ s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.10 Test fire TF5 — Liquid (heptane) fire

7.10.1 Fuel

Approximately 650 g of a mixture of *n*-heptane (purity ≥ 99 %) with approximately 3 % of toluene (purity ≥ 99 %), by volume. The precise quantities may be varied to obtain valid tests.

7.10.2 Arrangement

Burn the heptane/toluene mixture in a square 2 mm thick steel tray with dimensions of approximately (330 × 330 × 50) mm.

7.10.3 Ignition

Ignite by flame or spark.

7.10.4 Test validity criteria

The development of the fire shall be such that the curves of *m* against *y*, *m* against time, *t*, and, for detectors incorporating carbon monoxide sensors, *S* against time, *t*, fall within the limits shown in Figures 28, 29 and 30, respectively. That is, $0{,}92 < m < 1{,}24$ and $120 \text{ s} < t < 240 \text{ s}$ at the end-of-test conditions $y_E = 6$ or $S = 16$ µl/l.

For detectors incorporating carbon monoxide sensors, if the end of test condition, $y_E = 6$ is reached before all the specimens have responded, then the test is only considered valid if $S > 16$ µl/l.

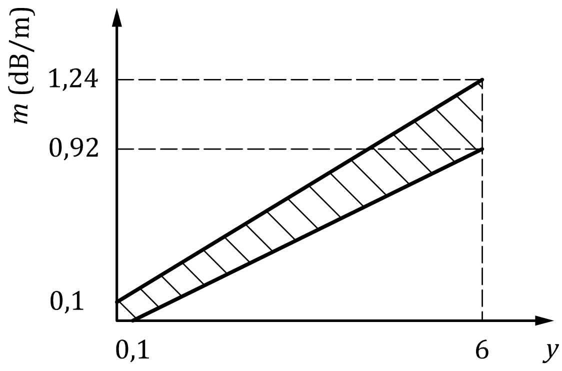


Figure 28 — Limits for *m* against *y*, Fire TF5

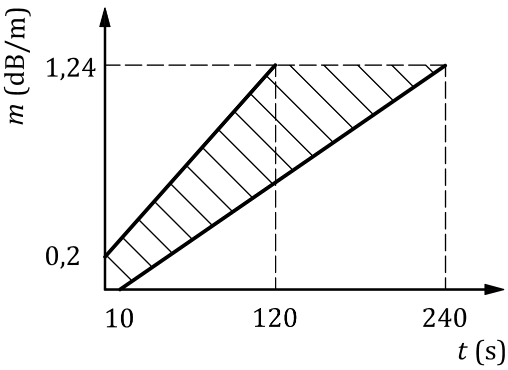


Figure 29 — Limits for *m* against time, *t*, Fire TF5

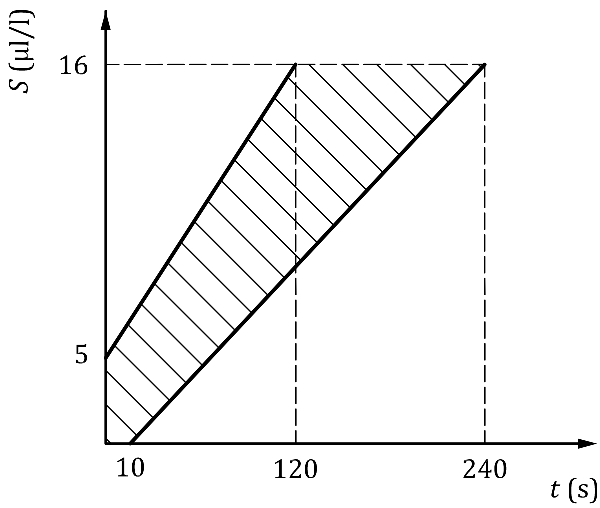


Figure 30 — Limits for *S* against time, *t*, Fire TF5

7.10.5 End-of-test condition

The end-of-test condition shall be when

— $y_E = 6$;

— $t_E > 240$ s;

— for detectors incorporating carbon monoxide sensors, $S > 16$ µl/l; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.10.6 Extended end-of-test condition

Test fire TF5 may be left to burn, with the development of the fire such that the curves of *m* against *y*, and *m* against time, *t*, fall within the limits shown in Figures 31 and 32, respectively. That is, 1,15 < *m* < 1,55 and 150 s < *t* < 300 s at the end-of-test condition y_E = 7,5.

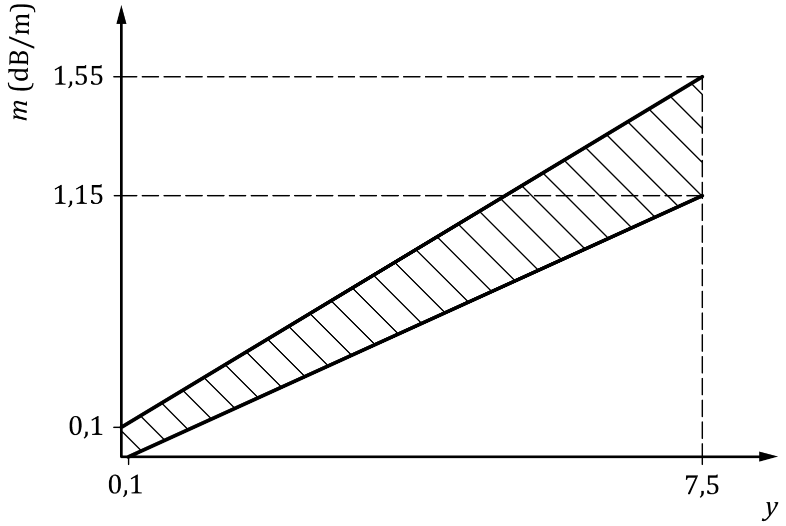


Figure 31 — Limits for *m* against *y*, Fire TF5 (extended)

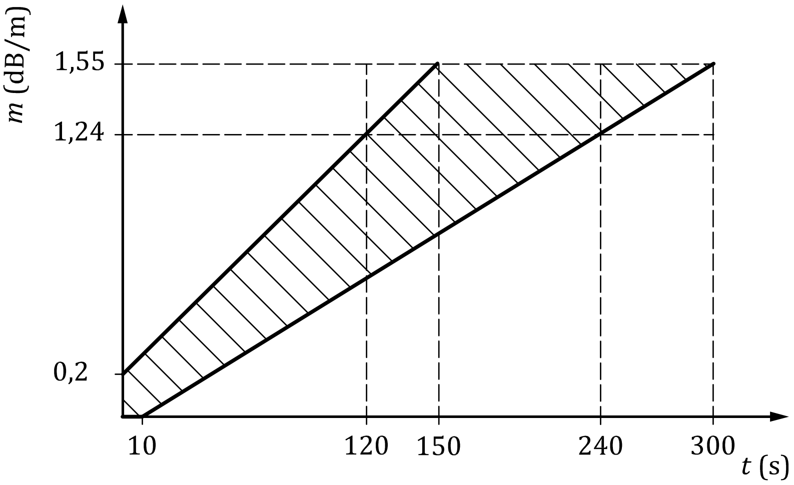


Figure 32 — Limits for *m* against time, *t*, Fire TF5 (extended)

The extended end-of-test condition shall be when

— y_E = 7,5;

— t_E > 300 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.11 Test fire TF5a — Liquid (heptane) small fire

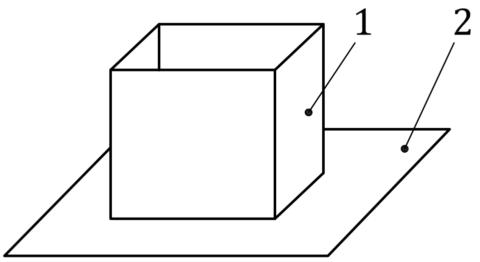
7.11.1 Fuel

Approximately 130 g of a mixture of *n*-heptane (purity ≥ 99 %) with approximately 3 % of toluene (purity ≥ 99 %), by volume. The precise quantities may be varied to obtain valid tests.

7.11.2 Arrangement

Burn the heptane/toluene mixture in a square 2 mm thick steel tray with dimensions of approximately (100 × 100 × 100) mm. Place the tray on a 2 mm thick sheet metal base plate with dimensions of approximately 330 mm × 330 mm, as shown in Figure 33.

NOTE The base plate may be the tray used in TF5 and is needed to act as a heat sink to avoid boiling of the small quantities of fuel used in the reduced test fires.



Key

1 tray

2 base plate

Figure 33 — Arrangement of tray and base plate

7.11.3 Ignition

Ignite by flame or spark.

7.11.4 Test validity criteria

The development of the fire shall be such that the curve m against time, t, falls within the limits shown in Figure 34. That is, the end-of-test condition m = 0,1 dB/m occurs between 540 s and 960 s after m > 0,01 dB/m.

NOTE The time taken for m to exceed 0,01 dB/m is indeterminate for this size fire, although could be approximately 240 s.

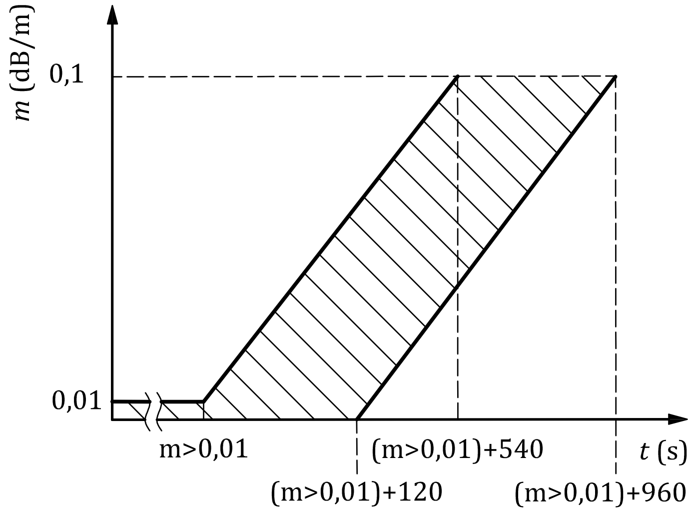


Figure 34 — Limits for *m* against time, *t*, Fire TF5a

7.11.5 End-of-test condition

The end-of-test condition shall be when

— *m* = 0,1 dB/m;

— t_E > 1200 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.12 Test fire TF5b — Liquid (heptane) medium fire

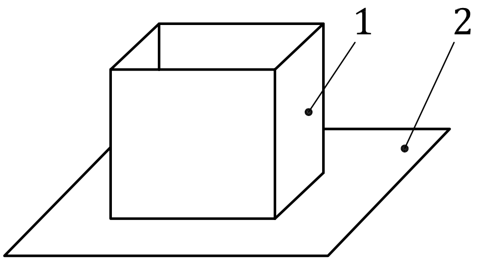
7.12.1 Fuel

Approximately 200 g of a mixture of *n*-heptane (purity ≥ 99 %) with approximately 3 % of toluene (purity ≥ 99 %), by volume. The precise quantities may be varied to obtain valid tests.

7.12.2 Arrangement

Burn the heptane/toluene mixture in a square 2 mm thick steel tray with dimensions of approximately (175 × 175 × 100) mm. Place the tray on a 2 mm thick sheet metal base plate with dimensions of approximately 330 mm × 330 mm, as shown in Figure 35.

NOTE The base plate may be the tray used in TF5 and is needed to act as a heat sink to avoid boiling of the small quantities of fuel used in the reduced test fires.



Key

1 tray

2 base plate

Figure 35 — Arrangement of tray and base plate

7.12.3 Ignition

Ignite by flame or spark.

7.12.4 Test validity criteria

The development of the fire shall be such that the curve *m* against time, *t*, falls within the limits shown in Figure 36. That is, the end-of-test condition *m* = 0,1 dB/m occurs between 540 s and 960 s after *m* > 0,01 dB/m.

NOTE The time taken for *m* to exceed 0,01 dB/m is indeterminate for this size fire, although could be approximately 240 s.

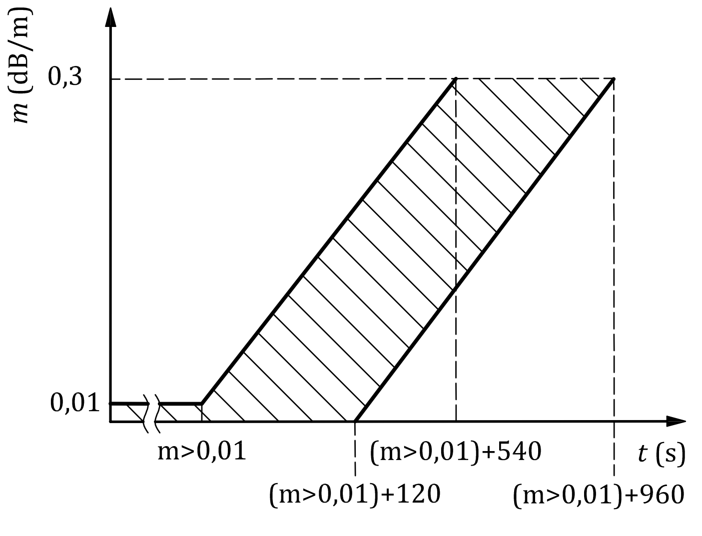


Figure 36 — Limits for *m* against time, *t*, Fire TF5b

7.12.5 End-of-test condition

The end-of-test condition shall be when

— *m* = 0,3 dB/m;

— t_E > 1200 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.13 Test fire TF6 — Liquid (methylated spirit) fire

7.13.1 Fuel

Methylated spirits at least 90 % ethanol C_2H_5OH to which has been added 10 % denaturant impurity (methanol).

7.13.2 Arrangement

Burn the methylated spirit in a container made from 2 mm thick sheet steel, base surface, 1 900 cm^2 area, dimensions approximately 43,5 cm × 43,5 cm × 5 cm high.

7.13.3 Volume

Use approximately 1,5 l of methylated spirit.

7.13.4 Ignition

Ignite by flame or spark.

7.13.5 Test validity criteria

The development of the fire shall be such that the curve of temperature, *T*, against time, *t*, falls within the hatched areas shown in Figure 37. That is, at the end-of-test condition 80 °C < ΔT < 100 °C and *t* < 450 s.

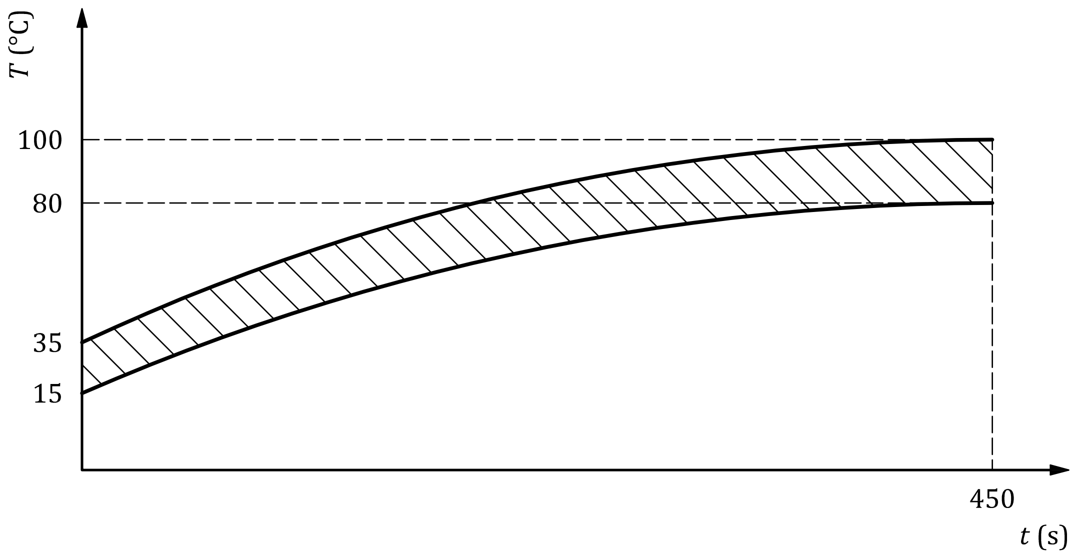


Figure 37 — Limits for *T* against *t*, Fire TF6

7.13.6 End-of-test condition

The end-of-test condition shall be when

— ΔT = 60 °C;

— t_E > 450 s; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.14 Test fire TF7 — Slow smouldering (pyrolysis) wood fire

7.14.1 Fuel

Approximately ten dried beechwood sticks, each stick having dimensions of 75 mm × 25 mm × 20 mm.

7.14.2 Conditioning

Dry the sticks in a heating oven so the moisture content is less than 3 %.

7.14.3 Preparation

If necessary, transport the sticks from the oven in a closed plastic bag and open the bag just prior to laying out the sticks in the test arrangement.

7.14.4 Hotplate

The hotplate shall have a 220 mm diameter grooved surface with eight concentric grooves with a distance of 3 mm between grooves. Each groove shall be 2 mm deep and 5 mm wide, with the outer groove 4 mm from the edge. The hotplate shall have a rating of approximately 2 kW.

Measure the temperature of the hotplate by attaching a sensor to the fifth groove, counted from the edge of the hotplate, and securing the sensor to provide a good thermal contact.

7.14.5 Arrangement

Arrange the sticks radially on the grooved hotplate surface, with the 20 mm side in contact with the surface such that the temperature probe lies between the sticks and is not covered, as shown in Figure 7.

The ceiling height of the test laboratory shall be 3 m.

7.14.6 Heating rate

Power the hotplate such that its temperature rises in accordance with Figure 38.

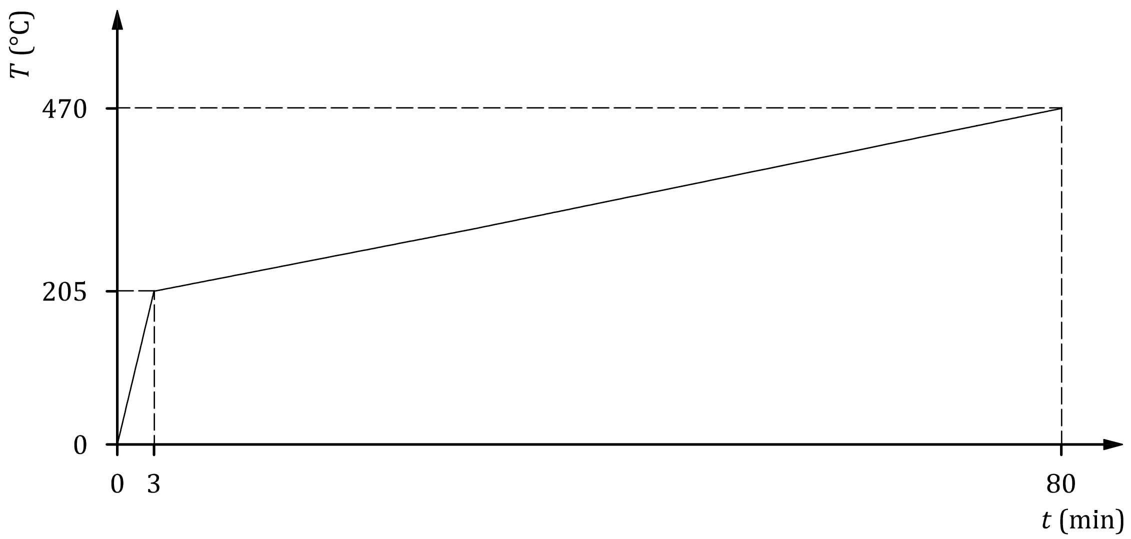


Figure 38 — Slow smouldering (pyrolysis) wood fire hotplate temperature vs. time

7.14.7 Test validity criteria

No flaming shall occur before the end-of-test condition has been reached. The development of the fire shall be such that the curves of *m* against *y*, and *m* against time, *t*, fall within the hatched areas shown in Figures 39 and 40, respectively. That is, $1{,}35 < y < 2{,}00$ and $50 \text{ min} < t < 75 \text{ min}$ at the end-of-test condition m_E = 1,15 dB/m.

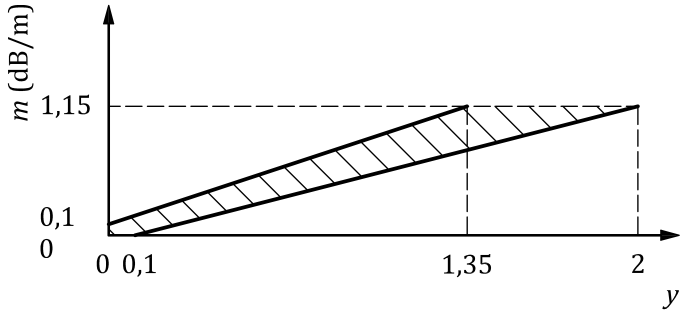


Figure 39 — Limits for *m* against *y*, Fire TF7

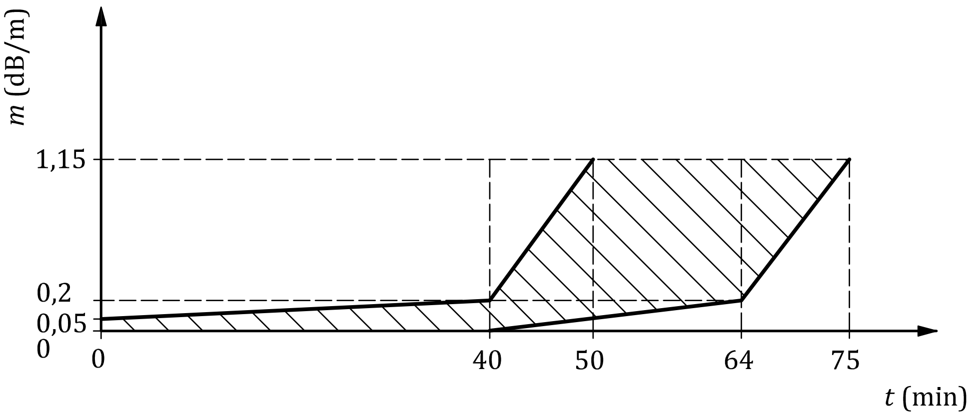


Figure 40 — Limits for *m* against time, *t*, Fire TF7

7.14.8 Variables

The number of sticks, the rate of temperature increase of the hotplate and the degree of conditioning of the wood may be varied in order for the test fire to remain within the profile curve limits.

7.14.9 End-of-test condition

The end-of-test condition shall be when

— m_E = 1,15 dB/m;

— t_E > 75 min; or

— all the specimens have generated an alarm signal.

7.15 Test fire TF8 — Low temperature black smoke (decalin) liquid fire

7.15.1 Fuel

Decalin (decahydronaphtaline for synthesis; a mixture of *cis* and *trans* isomers; $C_{10}H_{18}$; *M* = 138,25 g/mol; 1 l = 0,88 kg).

7.15.2 Arrangement

Burn the decalin in a square steel tray with dimensions approximately 12 cm × 12 cm and 2 cm depth.

7.15.3 Volume

Use approximately 170 ml of decalin.

7.15.4 Ignition

Ignite by flame or spark. A small quantity of a clean burning material (5 g of ethanol C_2H_5OH) may be used to assist ignition.

7.15.5 Test validity criteria

The development of the fire shall be such that the curves of *m* against *y*, *m* against time, *t* and, for detectors incorporating carbon monoxide sensors, *S* against time, *t*, fall within the limits shown in Figures 41, 42 and 43 respectively. That is, $4,5 < y < 9,0$ and $550 \text{ s} < t < 1\,000 \text{ s}$ at the end-of-test condition $m_E = 1,7$ dB/m and 4 µl/l < *S* < 8 µl/l at end-of-test condition *t* = 450 s.

For detectors incorporating carbon monoxide sensors, if the end of test condition, $m_E = 1,7$ dB/m is reached before all the specimens have responded, then the test is only considered valid if *S* > 4 µl/l.

During the test, the maximum in temperature rise until the end-of-test, ΔT, shall not exceed 10 K.

The test condition can be changed to get the specified profile of test fire if it was not produced. For example, the height of room or the position of fire may be altered to ensure the smoke reaches the ceiling and the tray may be kept cool (e.g. by using heavier grade steel or by placing the tray in an outer bath of cooling water) to ensure ΔT does not rise above 10 K.

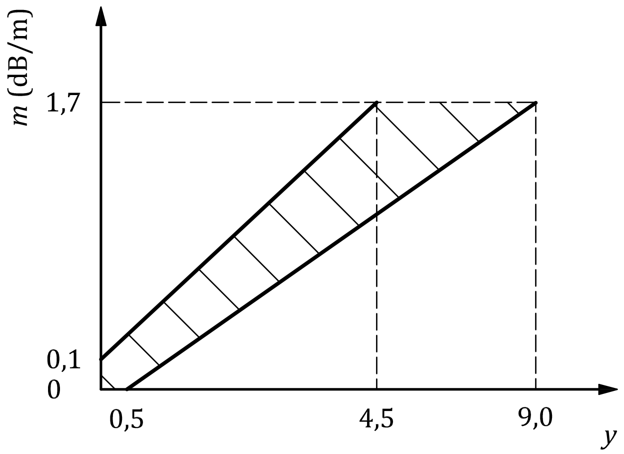


Figure 41 — Limits for *m* against *y*, Fire TF8

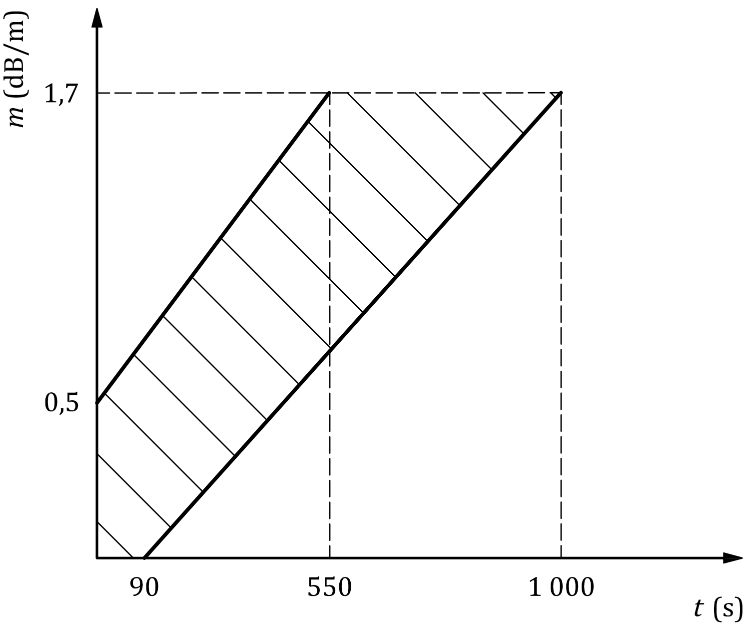


Figure 42 — Limits for *m* against time, *t*, Fire TF8

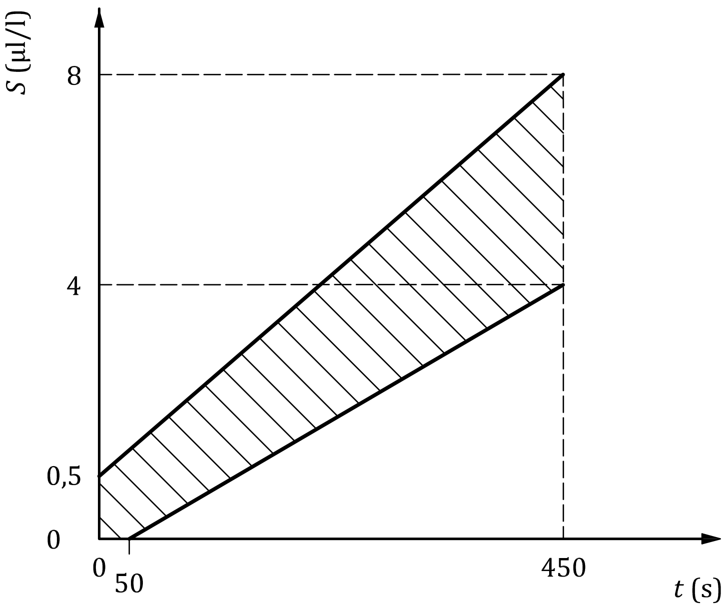


Figure 43 — Limits for *S* against time, *t* Fire TF8

7.15.6 End-of-test condition

The end-of-test condition shall be when

— m_E = 1,7 dB/m;

— t_E > 1 000 s;

— for detectors incorporating carbon monoxide sensors, *S* > 8 µl/l; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

7.16 Test fire TF9 — Deep seated smouldering cotton fire

7.16.1 Fuel

An unused white towel, made from 100 % cotton, having dimensions 50 cm × 100 cm, and a density of 540 g/m^2.

7.16.2 Conditioning

Dry the towel in an oven at 40 °C for a period of at least 12 h.

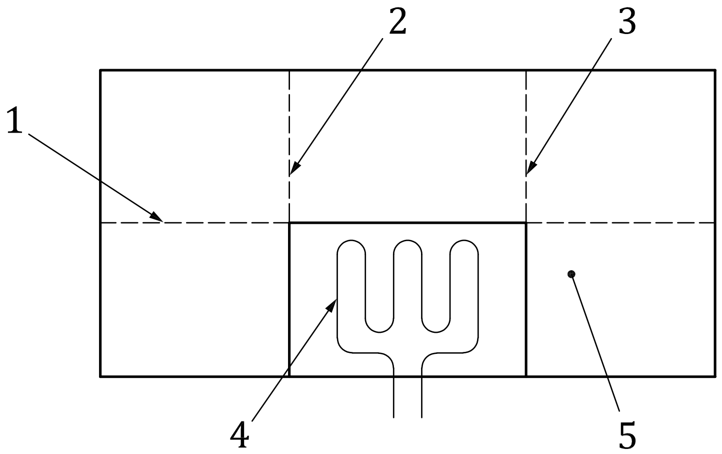
7.16.3 Arrangement

Fold the towel three times to give a rectangle 30 cm × 25 cm, the first fold being on the long dimension. Place the towel on a base formed from aluminium foil with the edges folded up to form a tray.

Form approximately 2 m of resistance wire, having a specific resistance of approximately 4 Ω/m, as shown in Figure 40.

NOTE Nichrome wire is a suitable resistance wire for this test.

Place the whole 2 m length of resistance on the towel and fold the towel as shown in Figure 44 to achieve the deep seated fire condition intended.



Key

1 first fold
2 second fold
3 third fold
4 resistance wire
5 towel, 1 000 mm × 500 mm

Figure 44 — Arrangement of the cotton towel and ignition source

7.16.4 Ignition

Connect the resistance wire to a 20 V / 5 A power supply. The start of the test corresponds with the instant of switching on the supply.

Supply power to the ignition source throughout the test.

NOTE The input voltage can be adjusted to change the heating rate to achieve the required profile curves shown in Figures 41 and 42.

7.16.5 Test validity criteria

The development of the fire shall be such that the curves of *S* against *m*, and *S* against time, *t*, fall within the hatched areas shown in Figures 45 and 46, respectively. That is, $0{,}15 < m < 0{,}3$ and $20\ \text{min} < t < 30\ \text{min}$ at the end-of-test condition $S_E = 100\ \mu l/l$.

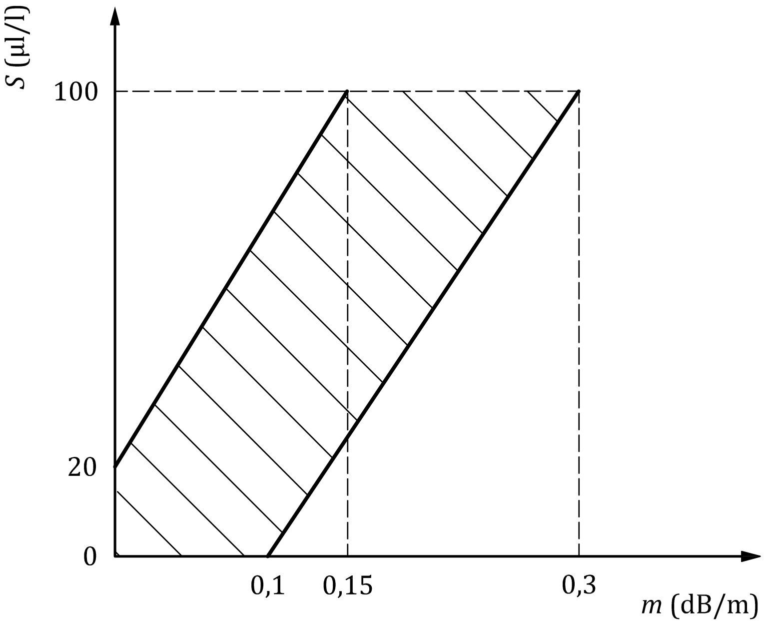


Figure 45 — Limits for *S* against *m*, Fire TF9

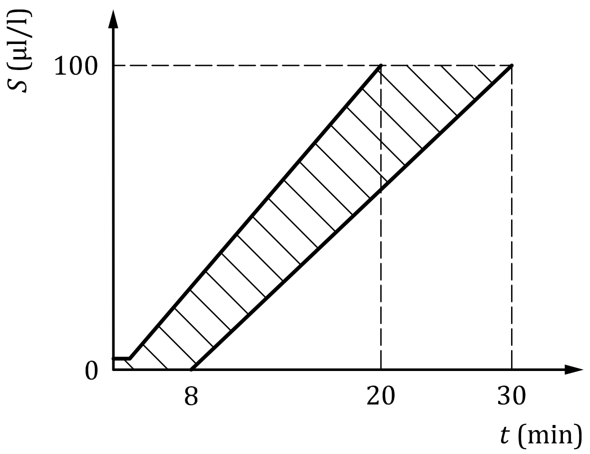


Figure 46 — Limits for *S* against time, *t*, Fire TF9

7.16.6 End-of-test condition

The end-of-test condition shall be when

— $S_E = 100\ \mu l/l$;

— $t_E > 30$ min; or

— all of the specimens have generated an alarm signal, whichever is the earlier.

Annex A
(normative)

m value for different light beam lengths

The absorbance index is designated m and expressed in decibels per metre (dB/m). The absorbance index m is given by Formula (A.1):

$$m = \frac{10}{d} \log\left(\frac{P_0}{P}\right) \quad (A.1)$$

where

d is the distance, expressed in metres, travelled by the light in the test aerosol or smoke, from the light source to the light receiver;

P_0 is the radiated power received without test aerosol or smoke;

P is the radiated power received with test aerosol or smoke.

Table A.1

m values dB/m	Beam length d = 0,38 m		Beam length d = 0,5 m	
	Transmission rate %	**Obscuration rate %**	**Transmission rate %**	**Obscuration rate %**
0,00	100,00	0,0	100,00	0,0
0,05	99,6	0,4	99,4	0,6
0,10	99,1	0,9	98,9	1,1
0,15	98,7	1,3	98,3	1,7
0,20	98,3	1,7	97,7	2,3
0,25	97,8	2,2	97,2	2,8
0,30	97,4	2,6	96,6	3,4
0,35	97,0	3,0	96,1	3,9
0,40	96,6	3,4	95,5	4,5
0,45	96,1	3,9	95,0	5,0
0,50	95,7	4,3	94,4	5,6
0,60	94,9	5,1	93,3	6,7
0,70	94,1	5,9	92,3	7,7
0,80	93,2	6,8	91,2	8,8
0,90	92,4	7,6	90,2	9,8
1,00	91,6	8,4	89,1	10,9
1,10	90,8	9,2	88,1	11,9
1,15	90,4	9,6	87,6	12,4
1,20	90,0	10,0	87,1	12,9
1,30	89,2	10,8	86,1	13,9
1,40	88,5	11,5	85,1	14,9

Table A.1

m values dB/m	Beam length *d* = 0,38 m		Beam length *d* = 0,5 m	
	Transmission rate %	**Obscuration rate %**	**Transmission rate %**	**Obscuration rate %**
1,50	87,7	12,3	84,1	15,9
1,60	86,9	13,1	83,2	16,8
1,70	86,2	13,8	82,2	17,8
1,80	85,4	14,6	81,3	18,7
1,90	84,7	15,3	80,4	19,6
2,00	83,9	16,1	79,4	20,6
2,10	83,2	16,8	78,5	21,5
2,20	82,5	17,5	77,6	22,4
2,30	81,8	18,9	76,7	23,3
2,40	81,1	18,9	75,9	24,1
2,50	80,4	19,6	75,0	25,0
2,60	79,7	20,3	74,1	25,9
2,70	79,0	21,0	73,3	26,7
2,80	78,3	21,7	72,4	27,6
2,90	77,6	22,4	71,6	28,4
3,00	76,9	23,1	70,8	29,2
3,10	76,2	23,8	70,0	30,0
3,20	75,6	24,4	69,2	30,8
3,30	74,9	25,1	68,4	31,6
3,40	74,3	25,7	67,6	32,4
3,50	73,6	26,4	66,8	33,2
3,60	73,0	27,0	66,1	33,9
3,70	72,3	27,7	65,3	34,7
3,80	71,7	28,3	64,6	35,4
3,90	71,1	28,9	63,8	36,2
4,00	70,5	29,5	63,1	36,9
4,10	69,9	30,1	62,4	37,6
4,20	69,2	30,8	61,7	38,3
4,30	68,6	31,4	61,0	39,0
4,40	68,0	32,0	60,3	39,7
4,50	67,5	32,5	59,6	40,4
4,60	66,9	33,1	58,9	41,1
4,70	66,3	33,7	58,2	41,8
4,80	65,7	34,3	57,5	42,5
4,90	65,1	34,9	56,9	43,1
5,00	65,6	35,4	56,2	43,8

Table A.2

m values dB/m	Beam length *d* = 1,0 m		Beam length *d* = 2,0 m	
	Transmission rate %	Obscuration rate %	Transmission rate %	Obscuration rate %
0,00	100,0	0,0	100,0	0,0
0,05	98,9	1,1	97,7	2,3
0,10	97,7	2,3	95,5	4,5
0,15	96,6	3,4	93,3	6,7
0,20	95,5	4,5	91,2	8,8
0,25	94,4	5,6	89,1	10,9
0,30	93,3	6,7	87,1	12,9
0,35	92,3	7,7	85,1	14,9
0,40	91,2	8,8	83,2	16,8
0,45	90,2	9,8	81,3	18,7
0,50	89,1	10,9	79,4	20,6
0,60	87,1	12,9	75,9	24,1
0,70	85,1	14,9	72,4	27,6
0,80	83,2	16,8	69,2	30,8
0,90	81,3	18,7	66,1	33,9
1,00	79,4	20,6	63,1	36,9
1,10	77,6	22,4	60,3	39,7
1,15	76,7	23,3	58,9	41,1
1,20	75,9	24,1	57,5	42,5
1,30	74,1	25,9	55,0	45,0
1,40	72,4	27,6	52,5	47,5
1,50	70,8	29,2	50,1	49,9
1,60	69,2	30,8	47,9	52,1
1,70	67,6	32,4	45,7	54,3
1,80	66,1	33,9	43,7	56,3
1,90	64,6	35,4	41,7	58,3
2,00	63,1	36,9	39,8	60,2
2,10	61,7	38,3	38,0	62,0
2,20	60,3	39,7	36,3	63,7
2,30	58,9	41,1	34,7	65,3
2,40	57,5	42,5	33,1	66,9
2,50	56,2	43,8	31,6	68,4
2,60	55,0	45,0	30,2	69,8
2,70	53,7	46,3	28,8	71,2
2,80	52,5	47,5	27,5	72,5
2,90	51,3	48,7	26,3	73,7
3,00	50,1	49,9	25,1	74,9
3,10	49,0	51,0	24,0	76,0
3,20	47,9	52,1	22,9	77,1

Table A.2

m values dB/m	**Beam length** *d* = 1,0 m		**Beam length** *d* = 2,0 m	
	Transmission rate **%**	**Obscuration rate** **%**	**Transmission rate** **%**	**Obscuration rate** **%**
3,30	46,8	53,2	21,9	78,1
3,40	45,7	54,3	20,9	79,1
3,50	44,7	55,3	20,0	80,0
3,60	43,7	56,3	19,1	80,9
3,70	42,7	57,3	18,2	81,8
3,80	41,7	58,3	17,4	82,6
3,90	40,7	59,3	16,6	83,4
4,00	39,8	60,2	15,8	84,2
4,10	38,9	61,1	15,1	84,9
4,20	38,0	62,0	14,5	85,5
4,30	37,2	62,8	13,8	86,2
4,40	36,3	63,7	13,2	86,8
4,50	35,5	64,5	12,6	87,4
4,60	34,7	65,3	12,0	88,0
4,70	33,9	66,1	11,5	88,5
4,80	33,1	66,9	11,0	89,0
4,90	32,4	67,6	10,5	89,5
5,00	31,6	68,4	10,0	90,0

Annex B
(normative)

y value

The dimensionless *y* values are calculated as given in Formula (B.1):

$$y = \frac{I_0}{I} - \frac{I}{I_0} \tag{B.1}$$

where

I_0 is the ionization (MIC) current in aerosol-free air;

I is the ionization (MIC) current with test aerosol or smoke.

Table B.1

y value	*x* value $(I_0-I)/I_0$	Ionization current pA
0,00	0,000	100,0
0,05	0,025	97,5
0,10	0,049	95,1
0,15	0,072	92,8
0,20	0,095	90,5
0,25	0,117	88,3
0,30	0,139	86,1
0,35	0,160	84,0
0,40	0,180	82,0
0,45	0,200	80,0
0,5	0,219	78,1
0,6	0,256	74,4
0,7	0,291	70,9
0,8	0,323	67,7
0,9	0,353	64,7
1,0	0,382	61,8
1,1	0,409	59,1
1,2	0,434	56,6
1,3	0,457	54,3
1,4	0,479	52,1
1,5	0,500	50,0
1,6	0,519	48,1
1,7	0,538	46,2
1,8	0,555	44,5
1,9	0,571	42,9

Table B.1

y value	*x* value $(I_0-I)/I_0$	Ionization current pA
2,0	0,586	41,4
2,1	0,600	40,0
2,2	0,613	38,7
2,3	0,626	37,4
2,4	0,638	36,2
2,5	0,649	35,1
2,6	0,660	34,0
2,7	0,670	33,0
2,8	0,680	32,0
2,9	0,689	31,1
3,0	0,697	30,3
3,1	0,705	29,5
3,2	0,713	28,7
3,3	0,721	27,9
3,4	0,728	27,2
3,5	0,734	26,6
3,6	0,741	25,9
3,7	0,747	25,3
3,8	0,753	24,7
3,9	0,759	24,1
4,0	0,764	23,6
4,1	0,769	23,1
4,2	0,774	22,6
4,3	0,779	22,1
4,4	0,783	21,7
4,5	0,788	21,2
4,6	0,792	20,8
4,7	0,796	20,4
4,8	0,800	20,0
4,9	0,804	19,6
5,0	0,807	19,3
5,1	0,811	18,9
5,2	0,814	18,6
5,3	0,818	18,2
5,4	0,821	17,9
5,5	0,824	17,6
5,6	0,827	17,3
5,7	0,830	17,0
5,8	0,832	16,8
5,9	0,835	16,5

Table B.1

y value	*x* value $(I_0-I)/I_0$	Ionization current pA
6,0	0,838	16,2
6,1	0,840	16,0
6,2	0,843	15,7
6,3	0,845	15,5
6,4	0,847	15,3
6,5	0,850	15,0
6,6	0,852	14,8
6,7	0,854	14,6
6,8	0,856	14,4
6,9	0,858	14,2
7,0	0,860	14,0
7,1	0,862	13,8
7,2	0,864	13,6
7,3	0,865	13,5
7,4	0,867	13,3
7,5	0,869	13,1
7,6	0,871	12,9
7,7	0,872	12,8
7,8	0,874	12,6
7,9	0,875	12,5
8,0	0,877	12,3
8,1	0,878	12,2
8,2	0,880	12,0
8,3	0,881	11,9
8,4	0,883	11,7
8,5	0,884	11,6
8,6	0,885	11,5
8,7	0,887	11,3
8,8	0,888	11,2
8,9	0,889	11,1
9,0	0,890	11,0
9,1	0,891	10,9
9,2	0,893	10,7
9,3	0,894	10,6
9,4	0,895	10,5
9,5	0,896	10,4
9,6	0,897	10,3
9,7	0,898	10,2
9,8	0,899	10,1
9,9	0,900	10,0

Table B.1

y **value**	x **value** $(I_0-I)/I_0$	**Ionization current** pA
10,0	0,901	9,9
11,0	0,910	9,0
12,0	0,917	8,3
13,0	0,924	7,6
14,0	0,929	7,1
15,0	0,934	6,6

Annex C
(normative)

Optical measuring instrument

The response threshold of alarms using scattered light or transmitted light is characterized by the absorbance index (extinction module) of the test aerosol, measured in the proximity of the alarm, at the moment that it generates an alarm signal.

The absorbance index is designated *m* and expressed in decibels per metre (dB/m). The absorbance index *m* is given by Formula (C.1):

$$m = \frac{10}{d} \log \left(\frac{P_0}{P} \right) \text{dB/m} \quad \text{(C.1)}$$

where

d is the distance, expressed in metres, travelled by the light in the test aerosol or smoke, from the light source to the light receiver;

P_0 is the radiated power received without test aerosol or smoke;

P is the radiated power received with test aerosol or smoke.

The measuring instrument shall have the following properties:

a) The length of the measuring zone in which the aerosol is measured shall be not more than 1,1 m. Greater effective optical measuring lengths can be obtained by reflection of the measuring beam inside the measuring zone;

b) The effective radiated power of the light beam shall be

— at least 50 % within a wavelength range from 800 nm to 950 nm;

— not more than 1 % in the wavelength range below 800 nm;

— not more than 10 % in the wavelength range above 1 050 nm.

NOTE The effective radiated power in each wavelength range is the product of the power emitted by the light source, the transmission level of the optical measuring path in clean air and the sensitivity of the receiver within this wavelength range.

c) For all aerosol or smoke concentrations corresponding to an attenuation of up to 2 dB/m, the measuring error of the obscuration meter shall not exceed 0,02 dB/m + 5 % of the measured attenuation of the aerosol or smoke concentration.

The optical system shall be arranged so that any light scattered more than 3° by the test aerosol or smoke is disregarded by the light detector.

Annex D
(normative)

Measuring ionization chamber (MIC)

D.1 Application

The measuring device is used for continuously measuring aerosol concentrations in the range of the response threshold values of smoke detectors using the ionization principle.

D.2 Theory of operation

The air within the measuring volume is ionized by alpha radiation from an americium radioactive source, such that there is a bipolar flow of ions when an electrical voltage is applied between the electrodes. This flow of ions is affected in a known manner by the aerosol or smoke particles. The ratio of the current in the aerosol-free chamber to that in the presence of an aerosol is a known function of the aerosol or smoke concentration. Thus it can be shown that the non-dimensional quantity *y*, is approximately proportional to the particle concentration for a particular type of aerosol or smoke and may be used as a measure of the response threshold value for smoke detectors using the ionization chamber principle.

The measuring chamber is so dimensioned and operated that Formulae (D.1) and (D.2) apply:

$$Z \times \bar{d} = \eta \times y \tag{D.1}$$

$$y = \left(\frac{I_0}{I}\right) - \left(\frac{I}{I_0}\right) \tag{D.2}$$

where

I_0 is the chamber current in air without test aerosol or smoke;

I is the chamber current in air with test aerosol or smoke;

η is the chamber constant;

Z is the particle concentration in particles per cubic metre;

$\bar{d}$ is the average particle diameter.

The measuring chamber connected to the electronic amplifier by means of a cable, and if necessary, an impedance transformer may be incorporated in the measuring chamber.

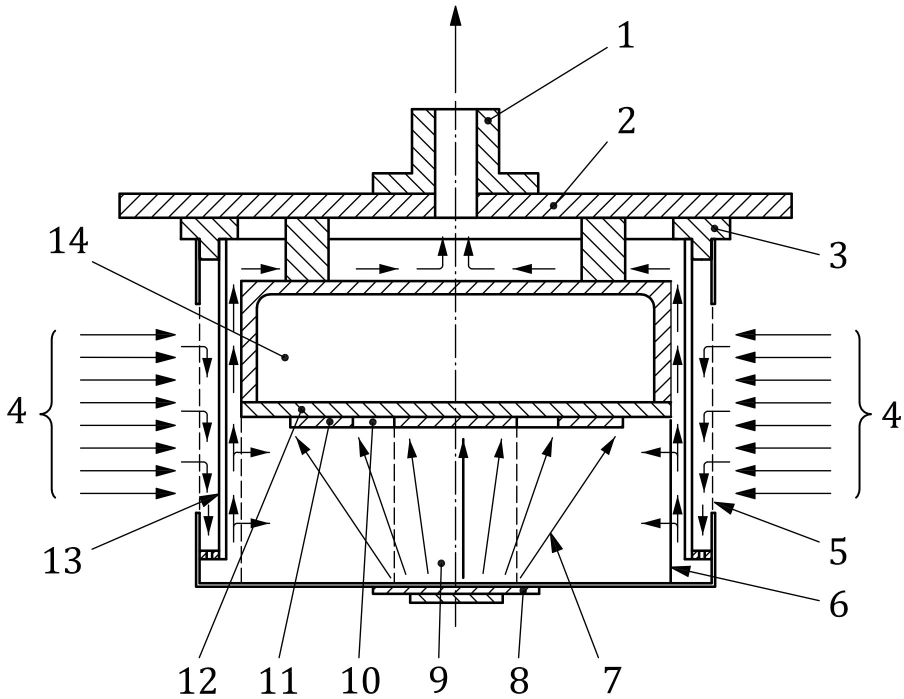
The air is sucked in by means of a fan connected to the measuring chamber by a hose. The quantity of air which flows through the measuring chamber is regulated so that the test conditions are not affected by the suction process.

D.3 Method of operation

The measuring device operates on the suction principle, i.e. the aerosol content of the air to be examined is measured by continuous sampling.

The measuring device consists of a measuring chamber, an electronic amplifier and a method of continuously sucking in a sample of the aerosol or smoke to be measured.

The principle of operation of the measuring chamber is shown in Figure D.1. The measuring chamber contains a measuring volume and a suitable means by which the sampled air is sucked in and passes the measuring volume in such a way that the aerosol/smoke particles diffuse into this volume. This diffusion is such that the flow of ions within the measuring volume is not disturbed by air movement.



Key

1	suction nozzle	8	α source
2	assembly plate	9	measuring volume
3	insulating ring	10	measuring electrode
4	air/smoke entry	11	guard ring
5	outer grid	12	insulating material
6	inner grid	13	windshield
7	α rays	14	electronics

Figure D.1 — Ionization-measuring chamber method of operation

D.4 Radiation source

Details on the radioactive source employed in the MIC are described below:

Isotope: americium ^{241}Am

Activity: (130 ± 6,5) kBq

Average energy: (4,5 ± 0,225) MeV

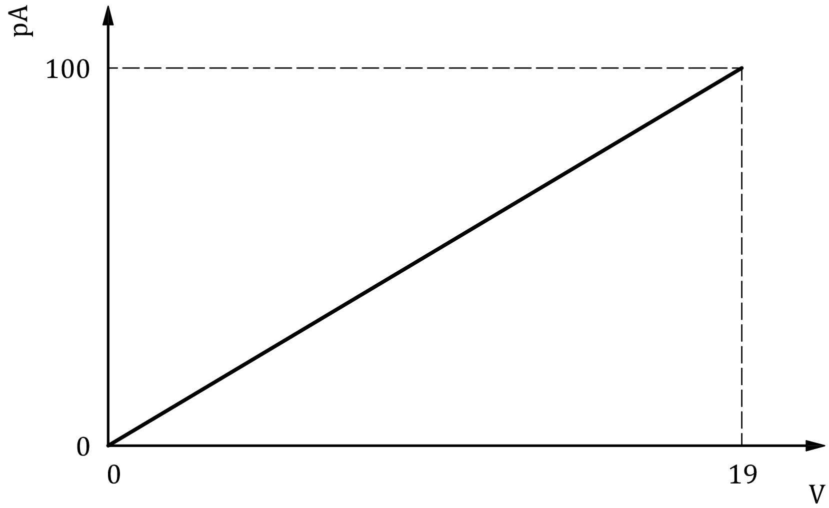
Mechanical construction: Americium oxide embedded in gold between two layers of gold, covered with a hard gold alloy. The source is in the form of a circular disc with a diameter of 27 mm, which is mounted in a holder such that no cut edges are accessible.

D.5 Ionization chamber

The chamber current should be as shown in Figure D.2. The chamber impedance (i.e. the reciprocal of the slope of the current versus voltage characteristic of the chamber in its linear region where the chamber current < 100 pA) shall be (1,9 ± 0,095) × 10^{11} Ω, when measured in aerosol- and smoke-free air at the following conditions:

Pressure:	(101,3 ± 1) kPa
Temperature:	(25 ± 2) °C
Relative humidity:	(55 ± 20) %

The potential of the guard ring shall be within ± 0,1 V of the voltage of the measuring electrode.



Key

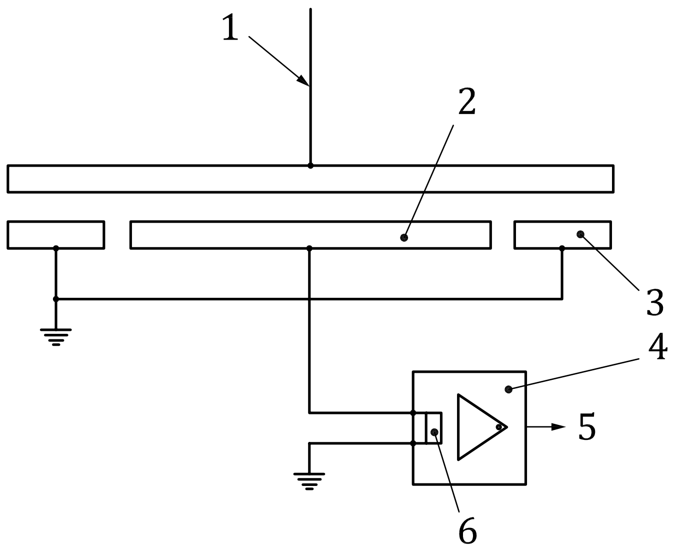
1 chamber current, pA

2 chamber volts, V

Figure D.2 — Ionization measuring chamber

D.6 Current measuring amplifier

The chamber is operated in the circuit shown in Figure D.3, with the supply voltage such that the chamber current between the measuring electrodes is 100 pA in aerosol- or smoke-free air. The input impedance of the current measuring device shall be < 10^9 Ω.



Key

1 supply voltage

2 measuring electrode

3 guard ring

4 current measuring amplifier

5 output voltage proportional to chamber current

6 input impedance, $Z_{in} < 10^9\ \Omega$

Figure D.3 — Measuring ionization chamber — Operating circuit

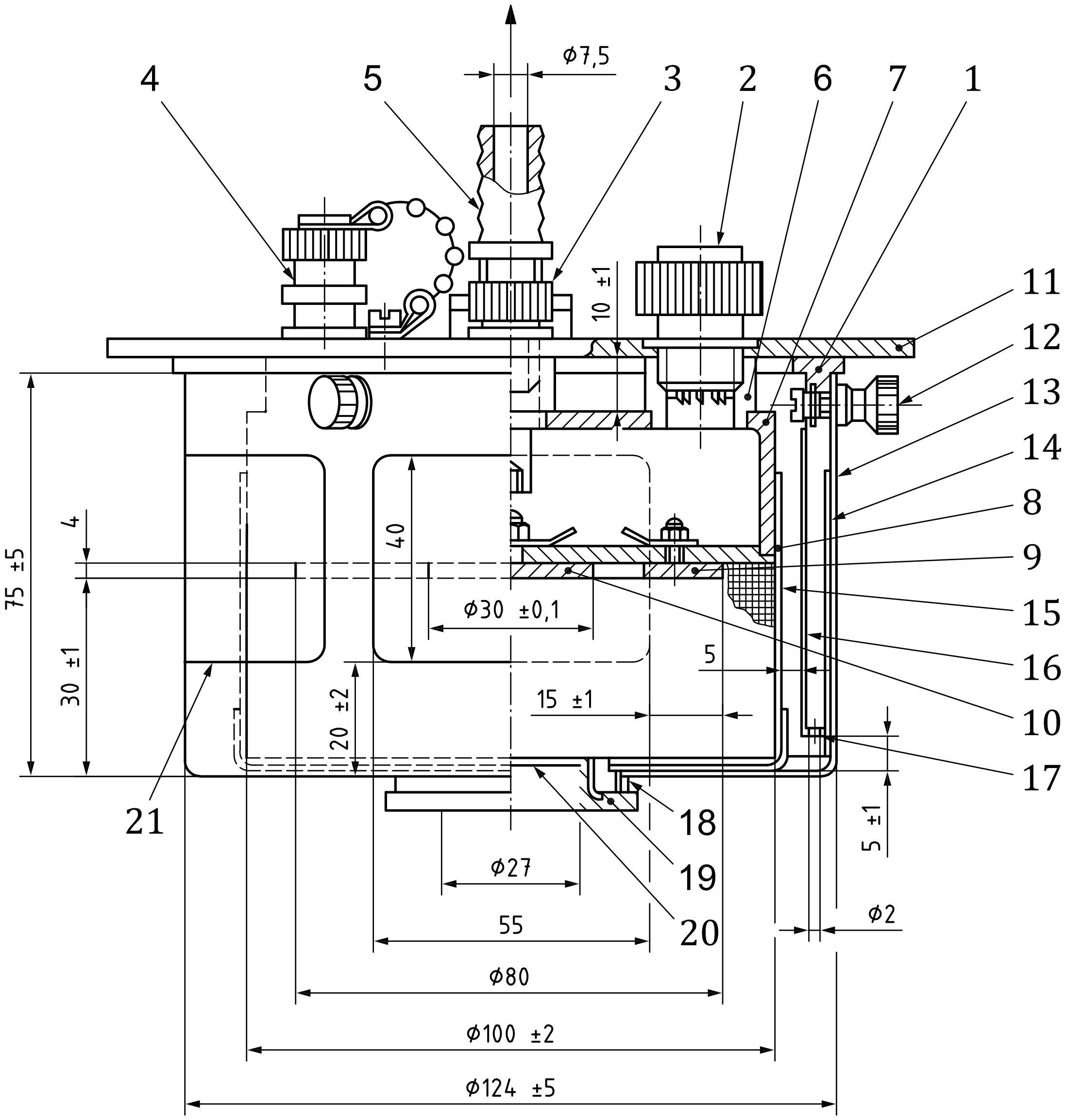
D.7 Suction system

The suction system shall draw air through the device at a continuous steady flow of (30 ± 3) l/min at atmospheric pressure.

D.8 Mechanical construction

The mechanical construction of the measuring chamber is shown in Figure D.4. The functionally important dimensions are marked with their tolerances. All other dimensions are recommended but not compulsory. They can be seen from the drawing. Details of parts are given in Table D.1.

Dimensions in millimetres



NOTE 1 See Table D.1 for the list of parts.

NOTE 2 Dimensions without a tolerance marked are recommended dimensions.

Figure D.4 — Ionization measuring chamber-construction

Table D.1 — List of parts

Reference No.	Item	Number provided	Dimensions, special features	Material
1	Insulating ring	1		Polyamide
2	Multipole socket	1	10-pole	
3	Measuring electrode terminal	1	To chamber supply	
4	Measuring electrode terminal	1	To amplifier or current measuring device	
5	Suction nozzle	1		
6	Guide socket	4		Polyamide
7	Housing	1		Aluminium
8	Insulating plate	1		Polycarbonate
9	Guard ring	1		Stainless steel
10	Measuring electrode	1		Stainless steel
11	Assembly plate	1		Aluminium
12	Fixing screw with milled nut	3	M3	Nickel plated brass
13	Cover	1	Six openings	Stainless steel
14	Outer grid	1	Wire, 0,2 mm in diameter; internal mesh width, 0,8 mm	Stainless steel
15	Inner grid	1	Wire, 0,4 mm in diameter; internal mesh width, 1,6 mm	Stainless steel
16	Windshield	1		Stainless steel
17	Intermediate ring	1	With 72 equispaced holes each 2 mm in diameter	
18	Threaded ring	1		Nickel plated brass
19	Source holder	1		Nickel plated brass
20	^{241}Am source	1	27 mm-diameter	See D.4
21	Openings on the periphery	6		

Annex E
(normative)

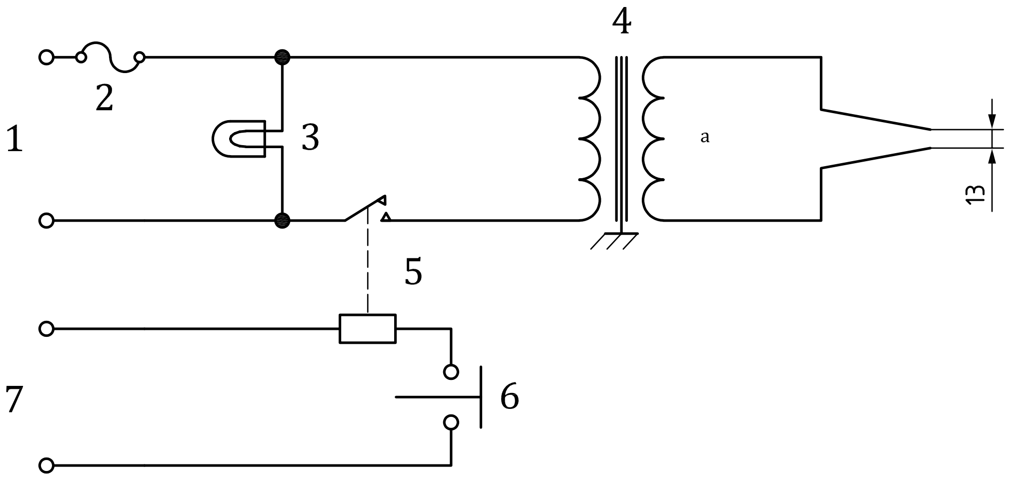
Spark-generating equipment

The spark-generating equipment is to consist of the following or equivalent components. (See Figure E.1 for an example of one type of equipment presently employed.)

a) Igniter probes: The metal probes, approximately 6 mm diameter and tapered at the ends to form a point and maintained approximately 13 mm apart, are connected to the output leads of a high-voltage transformer. Adjustment and support for the probes is provided by metal clamps affixed to a vertical steel bar integral with assembly.

b) Igniter source: Consists of a mains voltage primary, 10 000 V, 23 mA secondary oil burner ignition or equivalent transformer, the output of which is to be connected to the igniter probes. The arc used for ignition is to be obtained by the closure of a remote, low-voltage, momentary contact switch, which energizes a relay, whose contacts control the transformer primary.

Dimensions in millimetres



Key

1 mains supply
2 fuse
3 power-on indicator
4 step-up transformer
5 relay (normally open contacts)
6 momentary switch (normally open contacts)
7 extra low voltage source
a 10 kV to 15 kV.

Figure E.1 — Spark generator schematic

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Price based on 54 pages