TECHNICAL SPECIFICATION

ISO/TS 7240-9

First edition
2006-01-01

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 7240-9:2006(E)

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Published in Switzerland

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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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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*.

ISO/TS 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 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 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 19: Design, installation, commissioning and service of sound systems for emergency purposes*

— *Part 21: Routing equipment*

— *Part 22: Smoke detection equipment for ducts*

The following part is under preparation:

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

Introduction

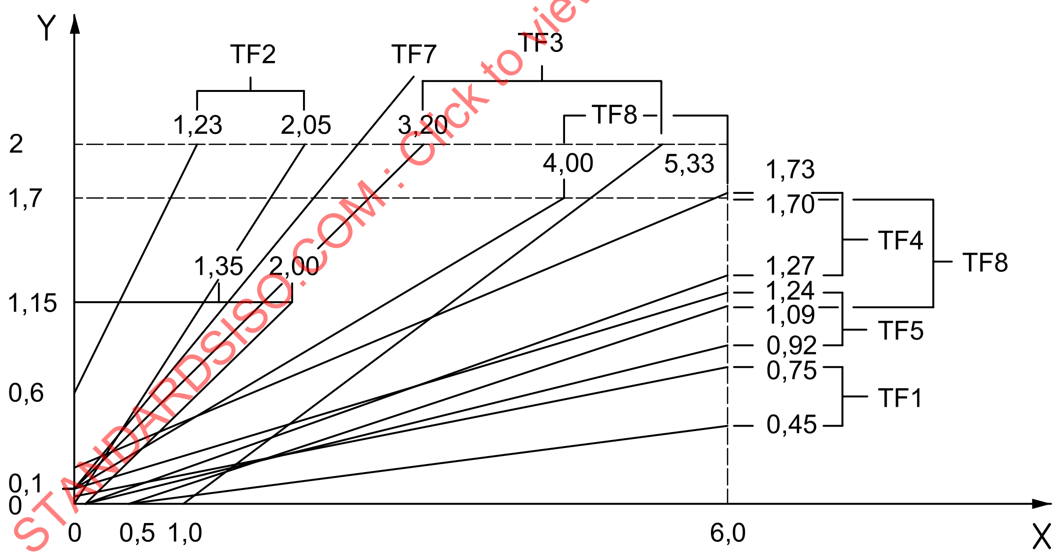
Many countries in different parts of the world have developed standards for the evaluation of fire detectors with the result that there are many variations in a smoke chamber, subjection to different environmental conditions, and variations in test fires.

Except for test fires TF7 and TF9, the working document from which this document evolved was EN 54-9[1], developed by Technical Committee TC 72, which had been adopted as a CEN (European Committee for Standarization) Standard in July 1982. This European Standard was withdrawn in December 2000.

Test fire TF7, *Slow smouldering (pyrolysis) wood test*, is based on development work[2] conducted in the United States. It represents the build up of combustion products in the home from the smouldering of a cigarette on a cotton mattress. This is the same test as presently appears in ANSI-UL217-1994[3], except the test parameters have been translated into the "m" and "y" parameter of this Technical Specification.

Test fire TF9, *Deep seated smouldering cotton fire*, is based on a test developed in the United Kingdom by the BFPSA and LPCB for carbon monoxide fire detectors.

The test fires included in this document are intended to represent a majority of test fires that can occur in the real world. While they are not the actual fires, they are typical of occurrence in practice. The combustibles selected represent the full spectrum of large (m) and small (y) combustion particles for both gray and black smoke. These include burning liquids, plastics and cellulosic (wood) materials, and glowing and smouldering fabrics. See Figure 1 for the acceptable test fire profiles.



Key

Y absorption index, m, dB/m

X MIC, y (dimensionless)

Figure 1 — Composite of ISO test fires TF1 to TF8 profile curves: m versus y

The fires included in this document represent a general test of fire detector performance. The response of the detectors subjected to test fires in this document can be evaluated in relation to three levels during a test fire. Such information is then helpful in permitting the designer of the fire alarm system to select the proper sensitivity for the anticipated application.

The test fires in this document 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 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 and flame are subjected as specified in other International Standards 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 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

4.1 Description

Nine test fires are described in Clause 8 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 8. 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	Development of heat	Up-current	Smoke	Aerosol spectrum	Visible portion	Carbon monoxide
TF1	Open cellulosic fire (wood)	Strong	Strong	Yes	Predominantly invisible	Dark	—
TF2	Rapid smouldering pyrolysis fire (wood)	Can be neglected	Weak	Yes	Predominantly visible	Light, high scattering	Yes
TF3	Glowing smouldering fire (cotton)	Can be neglected	Very weak	Yes	Predominantly invisible	Light, high scattering	Strong
TF4	Open plastics fire (polyurethane)	Strong	Strong	Yes	Partially invisible	Very dark	Weak
TF5	Liquid fire (*n*-heptane)	Strong	Strong	Yes	Predominantly invisible	Very dark	Weak
TF6	Liquid fire (methylated spirits)	Strong	Strong	No	None	None	—
TF7	Slow smouldering (pyrolysis)	Can be neglected	Weak	Yes	Predominantly visible	Light high scattering	—
TF8	Low temperature black smoke	Can be neglected	Weak	Yes	Predominantly visible	Dark	Very weak
TF9	Slow smouldering	Weak	Weak	Yes	Predominantly visible	Light high scattering	Yes

4.2 Measurement parameters

During each test the following parameters are to be recorded:

Parameter	Symbol	Unit
Temperature	T	°C
Temperature change	ΔT	°C
Time	t	seconds (s)
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.

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 are to prevail 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 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.

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).

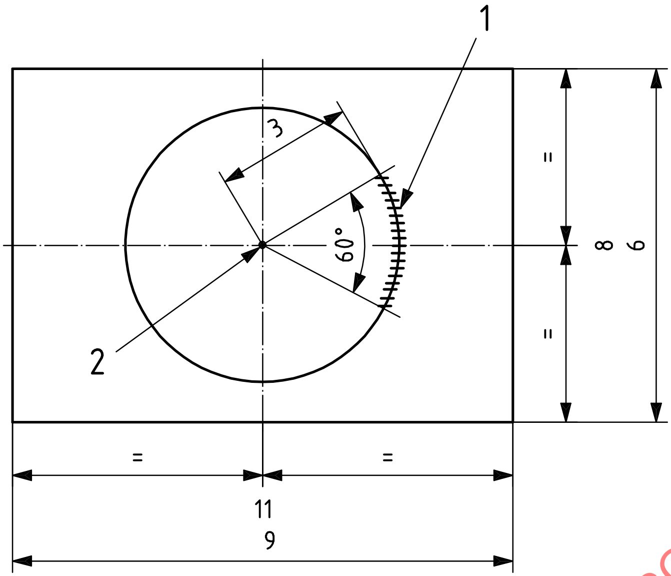
6 Test method

6.1 Arrangement

The location and arrangement of the detectors under test, instrumentation and fire test 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.

Dimensions in metres



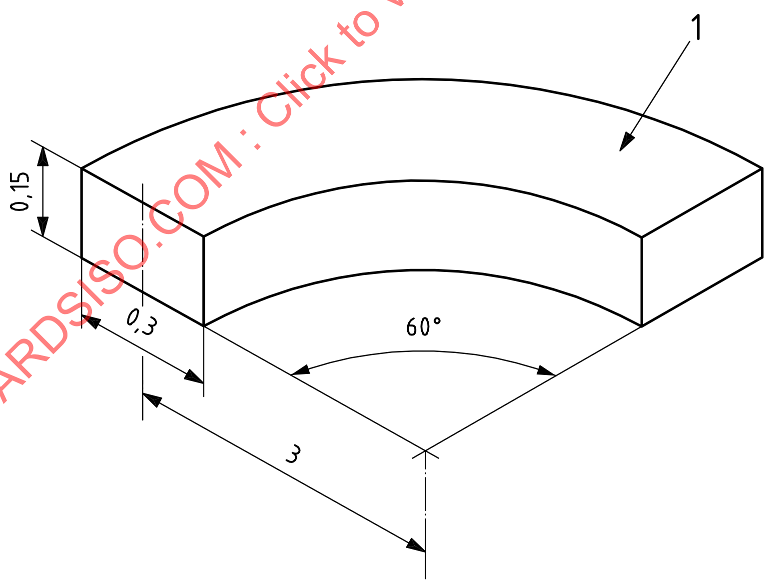
Key

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

2 position of test fire

a) Plan view of fire test room

Dimensions in metres



Key

1 ceiling

b) Mounting positions for instruments and specimens

Figure 2 — Location of detectors, fire and measuring instruments

6.2 Samples

The following samples and conditions shall be employed during each test fire, except as otherwise required in the product standard.

a) Four detectors of the same model, calibrated to the lowest sensitivity setting to be produced by the manufacturer shall be supplied.

b) Detectors shall be mounted in accordance with the manufacturer's instructions and be oriented so that the least favourable position (most difficult to detect) for smoke entry, response to heat or to flame, faces the fire source.

c) Detectors shall be energized from the maximum rated source of supply voltage and frequency. If a voltage range is specified, then the detectors are to be energized from the voltage least likely to obtain an alarm response.

d) Prior to each fire test, the detectors shall be energized in the quiescent (normal standby) condition for a least 15 min or as recommended by the manufacturer.

6.3 Profile curves

6.3.1 MIC versus beam

The MIC (y) versus infrared beam (m) curve build-up during the course of test fires TF1, TF2, TF3, TF4, TF5, TF7 and TF8 shall be within the limits of Figures 5, 8, 12, 15, 18, 23 and 25, respectively.

6.3.2 Beam versus time

The optical density (m) versus time (t) build-up during the course of test fires TF1, TF2, TF3, TF4, TF5, TF7 and TF8 shall be within the limits of Figures 6, 9, 13, 16, 19, 24 and 26, respectively.

6.3.3 Temperature versus time

The temperature (T) curve build-up during the course of test fire TF6 shall be within the limits of Figure 21.

6.3.4 Carbon monoxide versus beam

The carbon monoxide (S) curve build-up during the course of test fire TF9 shall be within the limits of Figure 29.

6.3.5 Carbon monoxide versus time

The carbon monoxide (S) curve build-up during the course of test fires TF2, TF3, TF4, TF5, TF8 and TF9 shall be within the limits of Figures 10, 14, 17, 20, 27 and 30, respectively.

6.4 Recording of data

During the test, the fire parameters T, m, y, t and S shall be measured and recorded. The alarm signal given at the control and indicating equipment shall be taken as the indication that a detector has responded. At the moment of the alarm signal from a detector, the response values, T_A, m_A, y_A, t_A, S_A shall be recorded. If the requirements set out in the relevant test are not fulfilled the fire test shall be repeated.

During the test, at least one of the parameter values at ΔT_3, m_3, y_3, or S_3 shall be exceeded (see Clause 7).

6.5 Fire tests response

To make it easier to assess and classify the detectors according to their response behaviour, the relevant response values T_A, m_A, y_A, t_A, S_A are inserted in the appropriate location of Table 2.

Table 2 — Fire sensitivity table

Test fire	**Detector number**	T_A °C	m_A dB/m	y_A	t_A s	S_A µl/l	**Remarks**
TF1	1 2 3 4						
TF2	1 2 3 4						
TF3	1 2 3 4						
TF4	1 2 3 4						
TF5	1 2 3 4						
TF6	1 2 3 4						
TF7	1 2 3 4						
TF8	1 2 3 4						
TF9	1 2 3 4						

6.6 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 included in Clause 8 are used as the control of the validity and reproducibility of the test fires. The test shall be considered finished when the maximum value 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 and this shall be recorded under "Remarks" in Table 2. The specific limits for each test are included in Clause 8.

7 Fire sensitivity classification

The purpose of the fire sensitivity classification is to give the user an indication of the suitability of a detector type in a particular potential fire situation by providing a suitability table (see example in Table 3). This classification applies only to applications for which the test conditions can be regarded as representative.

The ranges of the fire parameters are divided into three sections, thus defining a total of nine limiting values.

ΔT_1	ΔT_2	ΔT_3
y_1	y_2	y_3
m_1	m_2	m_3

In a three-dimensional system of coordinates with the axes ΔT, m and y, these values define three rectangular boxes (see Figure 3). The response values T_A, m_A, y_A, also termed alarm coordinates, constitute points in this system.

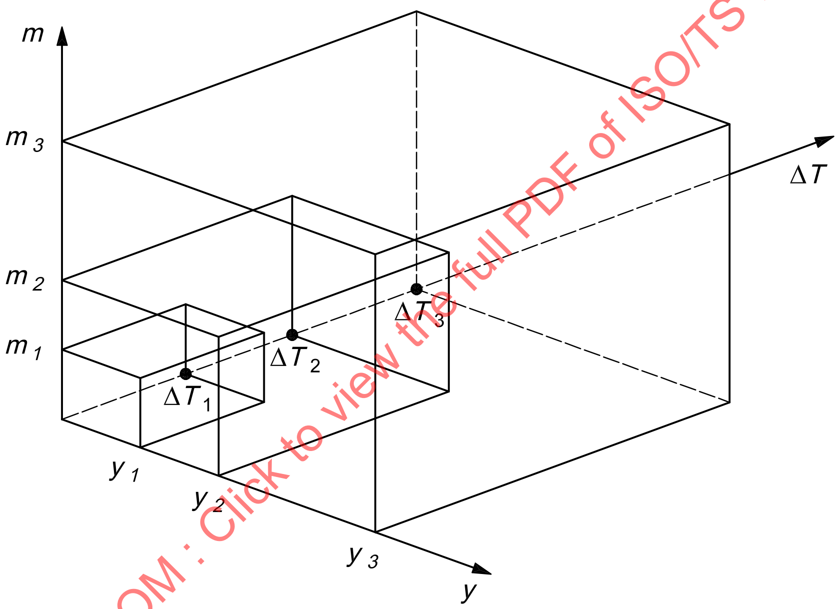


Figure 3 — Coordinates of the rectangular boxes that define Classes A, B and C of the suitability table (see example in Table 3)

If the alarm points of all four detectors are within the smallest rectangular box, the detector for this type of fire shall be classified under Class A of the suitability table (see the example in Table 3), i.e., the following necessary conditions shall be fulfilled:

— $\Delta t_A \leqslant \Delta T_1$ and

— $m_A \leqslant m_1$ and

— $y_A \leqslant y_2$.

If the alarm points of all four detectors are inside the middle rectangular box, but not all inside the smallest one, the detector shall be classified under Class B of the suitability table (see example in Table 3) for this type of fire, i.e., the following necessary conditions shall be fulfilled:

— $\Delta T_A \leqslant T_2$ and

— $m_A \leqslant m_2$ and

— $y_A \leqslant y_2$.

If the alarm points of all four detectors are inside the biggest rectangular box, but not all inside the middle one, the detector shall be classified under Class C of the suitability table (see example in Table 3) for this type of fire, i.e., the following necessary conditions shall be fulfilled:

— $\Delta T_A \leqslant T_3$ and

— $m_A \leqslant m_3$ and

— $y_A \leqslant y_3$.

If the alarm point of one or more of the four detectors is outside the biggest rectangular box, for this type of fire, this type of detector shall not be classified. This shall be recorded under Column N of the suitability test (see the example in Table 3).

The following limiting values shall apply:

— ΔT_1 = 15 °C;

— ΔT_2 = 30 °C;

— ΔT_3 = 60 °C;

— m_1 = 0,5 dB/m;

— m_2 = 1,0 dB/m;

— m_3 = 2,0 dB/m;

— y_1 = 1,5;

— y_2 = 3,0;

— y_3 = 6,0.

Table 3 — Example of a suitability table for a type of detector

Test fire	Class A	Class B	Class C	Not classified
TF1	x [a]	—	—	—
TF2 [b]	—	—	x	
TF3	—	—	x	
TF4	x	—	—	—
TF5	—	x	—	—
TF6	—	—	—	x
TF7	x	—	—	—
TF8	—	—	—	—
TF9	—	—	—	—

[a] For detectors intended for installation in residential occupancies, such as smoke alarms, Test TF7 is employed in lieu of Test TF2.

[b] An “x” indicates that the detector type is classified under Class A, B, or C, or is not classified (did not respond within prescribed limits).

8 Test fires

8.1 General

This section contains a description of the nine test fires, including type and amount of combustible material, illustration of three 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 best 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).

8.2 Test fire TF1 — Open cellulosic (wood) fire

8.2.1 Fuel

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

8.2.2 Conditioning

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

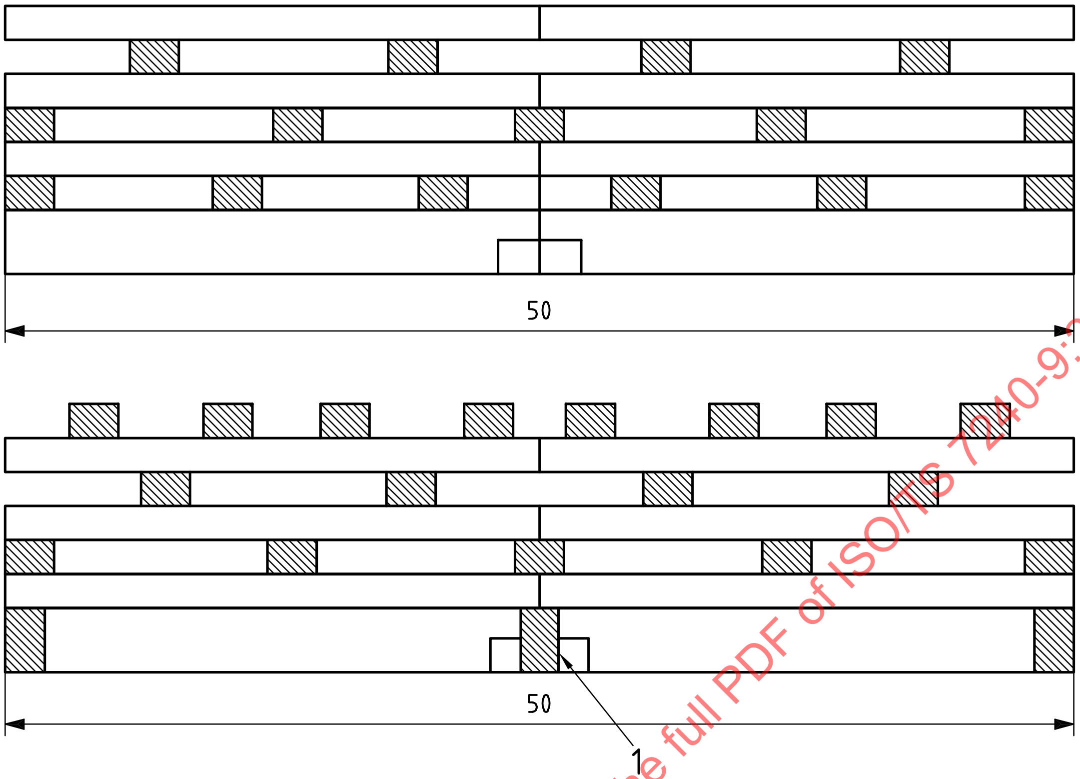
8.2.3 Preparation

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.

8.2.4 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

8.2.5 Ignition

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

8.2.6 Method of ignition

Ignite by flame or spark in the methylated spirits.

8.2.7 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.

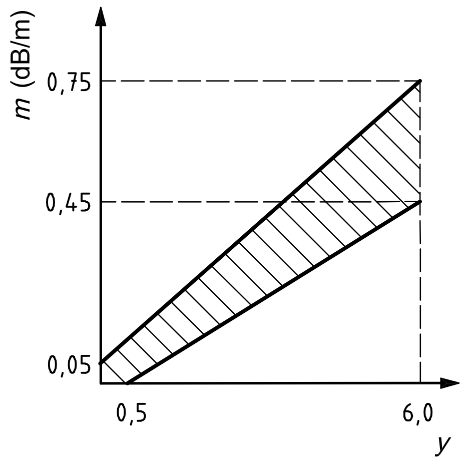


Figure 5 — Limits for m against y, Fire TF1

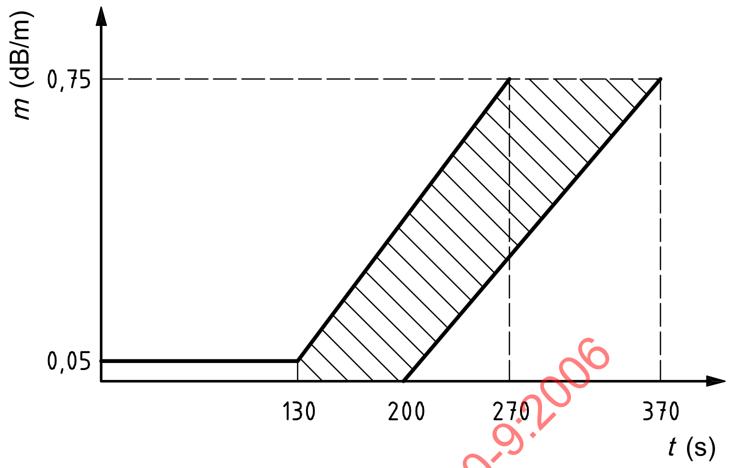


Figure 6 — Limits for m against time, t, Fire TF1

8.2.8 Variables

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

8.2.9 End-of-test condition

The end of test condition shall be when either

— $y_E = 6$;

— $t_E > 370$ s; or

— all the specimens have generated an alarm signal.

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

8.3.1 Fuel

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

8.3.2 Conditioning

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

8.3.3 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.

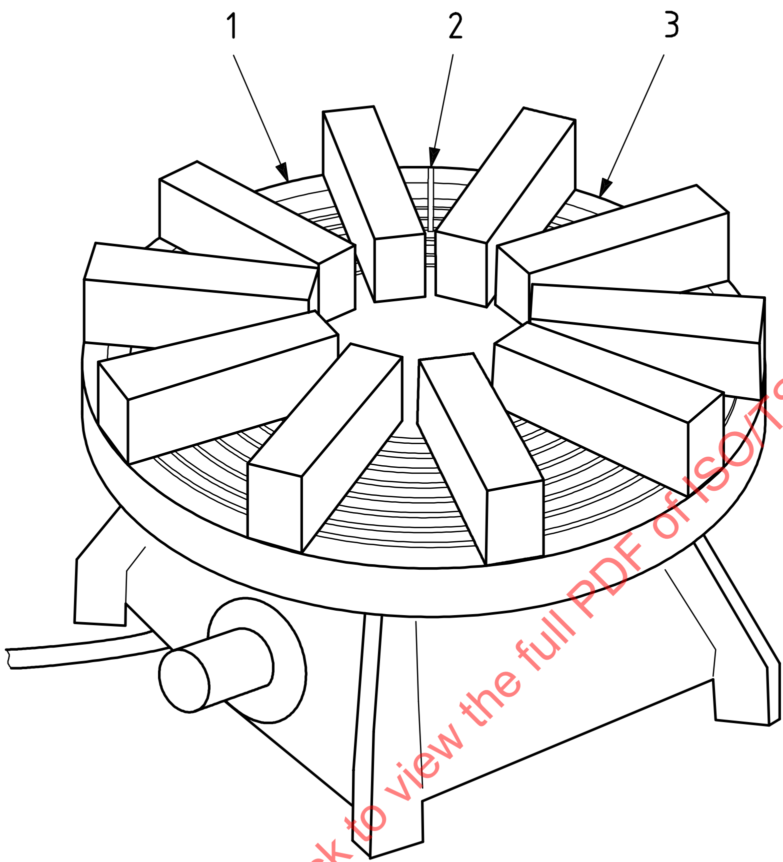
8.3.4 Hotplate

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.

8.3.5 Arrangement

Arrange the sticks radially on the grooved hotplate surface, with the 20-mm side in contact with the surface such that the temperature probe 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

8.3.6 Heating rate

Power the hotplate such that its temperature rises from ambient to 600 °C in approximately 11 min.

8.3.7 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 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.

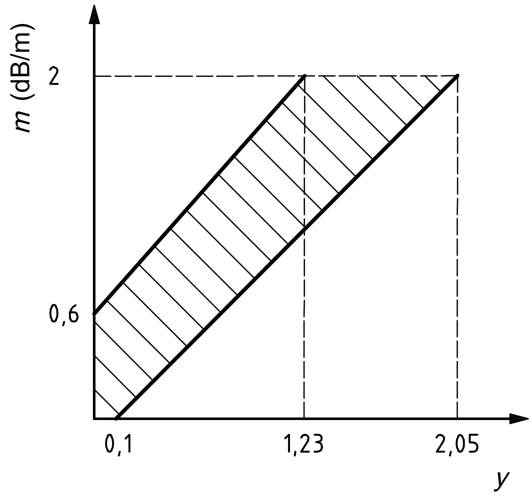


Figure 8 — Limits for m against y, Fire TF2

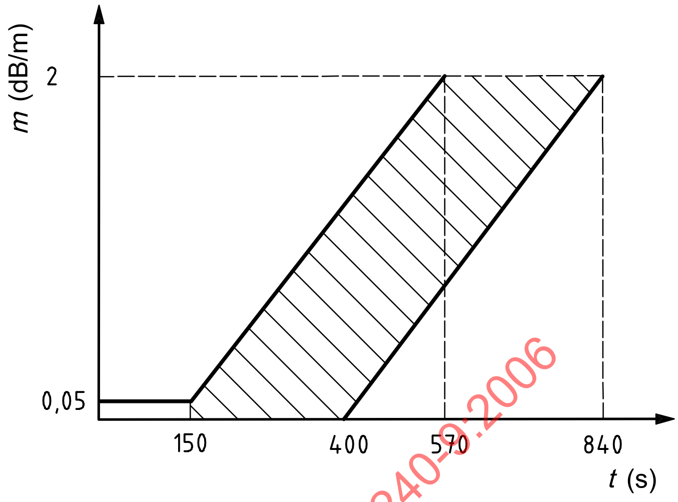


Figure 9 — Limits for m against time, t, Fire TF2

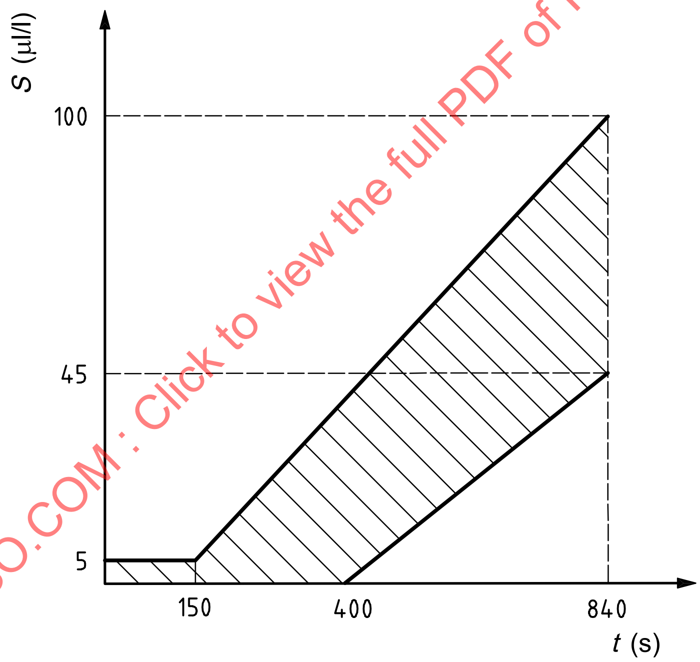


Figure 10 — Limits for S against time, t, Fire TF2

8.3.8 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.

8.3.9 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.

8.4 Test fire TF3 — Glowing (smouldering) cotton fire

8.4.1 Fuel

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

8.4.2 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.

8.4.3 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 11.

Dimension in metres

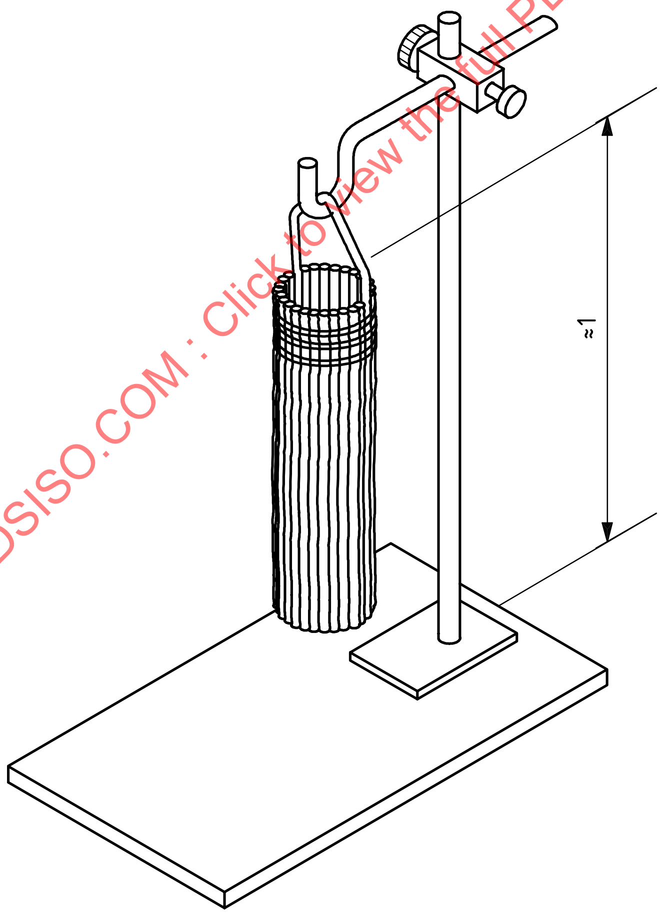


Figure 11 — Arrangement of cotton wicks

8.4.4 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.

8.4.5 Method of ignition

Ignite by match or torch.

8.4.6 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 12, 13 and 14 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.

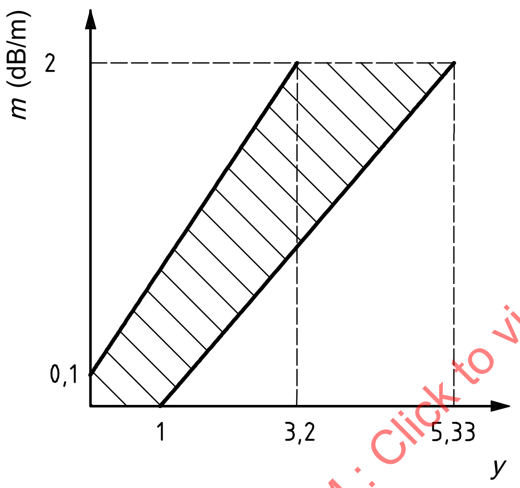


Figure 12 — Limits for m against y, Fire TF3

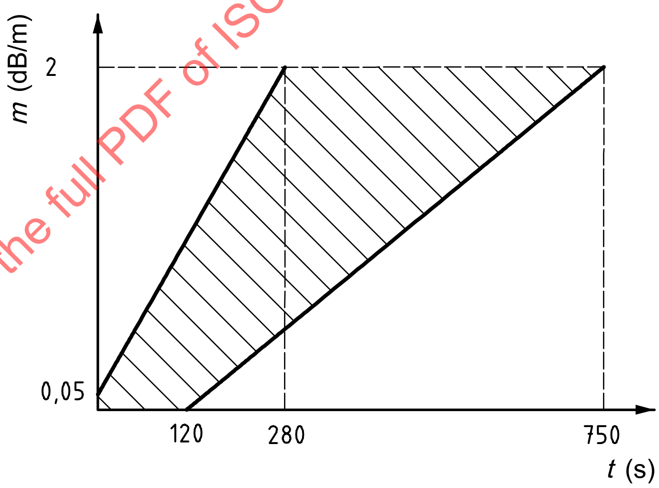


Figure 13 — Limits for m against time, t, Fire TF3

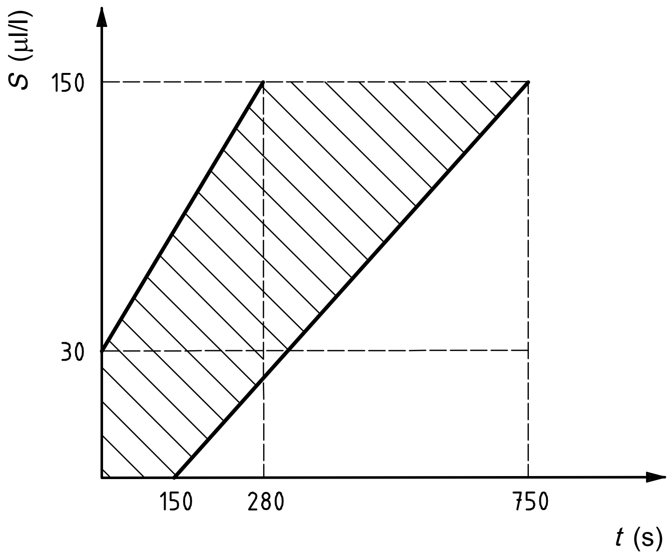


Figure 14 — Limits for S against time, t, Fire TF3

8.4.7 Variables

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

8.4.8 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.

8.5 Test fire TF4 — Open plastics (polyurethane) fire

8.5.1 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.

8.5.2 Conditioning

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

8.5.3 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.

8.5.4 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. 5 cm^3 of methylated spirit) may be used to assist the ignition.

8.5.5 Method of ignition

Ignite by match or spark.

8.5.6 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 15, 16 and 17, respectively. That is, $1{,}27 < m < 1{,}73$ and $140 \text{ s} < t < 180$ s at the end-of-test conditions $y_E = 6$ or $S = 20$ 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 $S > 20$ µl/l.

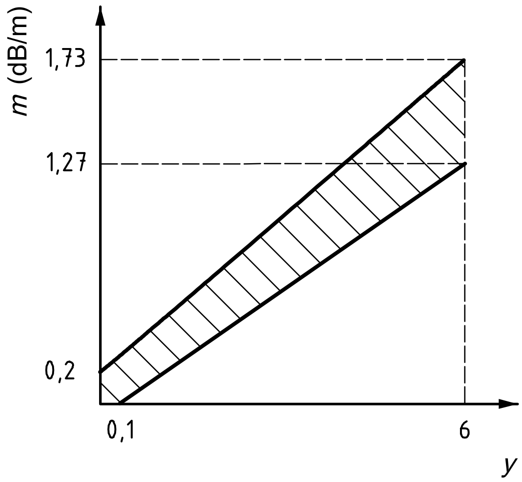


Figure 15 — Limits for m against y, Fire TF4

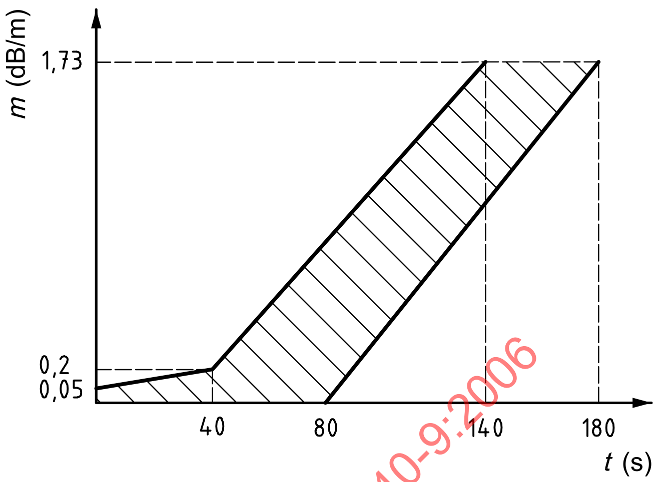


Figure 16 — Limits for m against time, t, Fire TF4

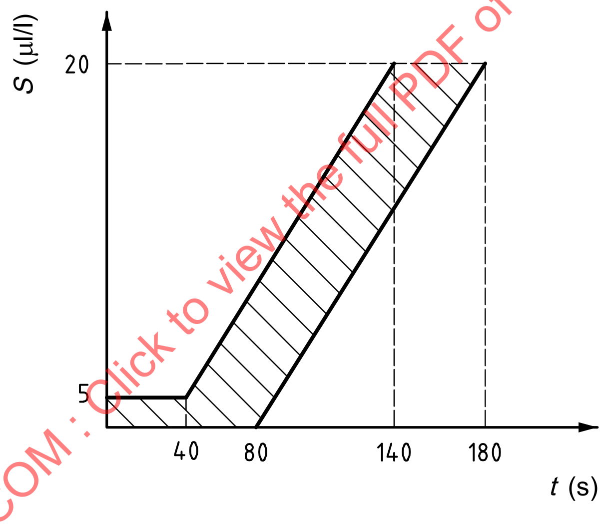


Figure 17 — Limits for S against time, t, Fire TF4

8.5.7 End-of-test condition

The end-of-test condition is 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.

8.6 Test fire TF5 — Liquid (heptane) fire

8.6.1 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.

8.6.2 Arrangement

Burn the heptane/toluene mixture in a square steel tray with dimensions of approximately 33 cm × 33 cm × 5 cm.

8.6.3 Ignition

Ignite by flame or spark.

8.6.4 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 18, 19 and 20, 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.

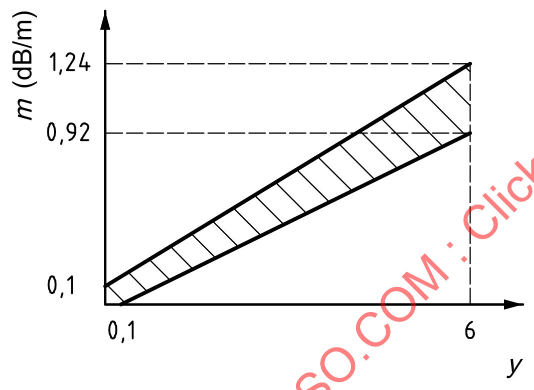


Figure 18 — Limits for m against y, Fire TF5

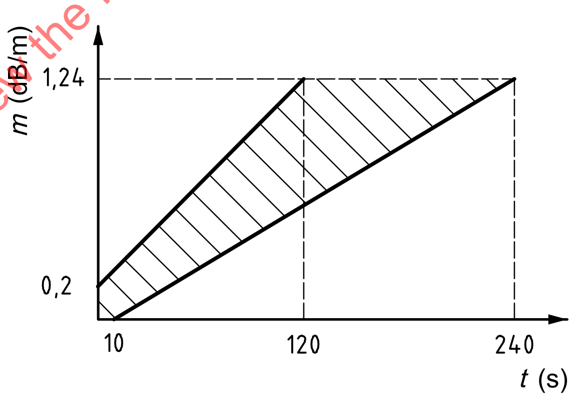


Figure 19 — Limits for m against time, t, Fire TF5

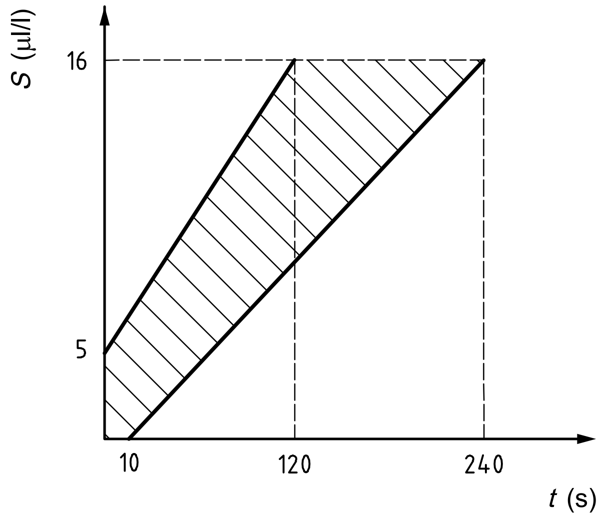


Figure 20 — Limits for S against time, t, Fire TF5

8.6.5 End-of-test condition

The end-of-test condition shall be when

— $y_E = 6$;

— $t_E > 240$ s; or

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

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

8.7 Test fire TF6 — Liquid (methylated spirit) fire

8.7.1 Fuel

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

8.7.2 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.

8.7.3 Volume

Use approximately 2,5 l of methylated spirit.

8.7.4 Ignition

Ignite by flame or spark.

8.7.5 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 Figures 21. That is, at the end-of-test condition 80 °C < ΔT < 100 °C and t < 450 s.

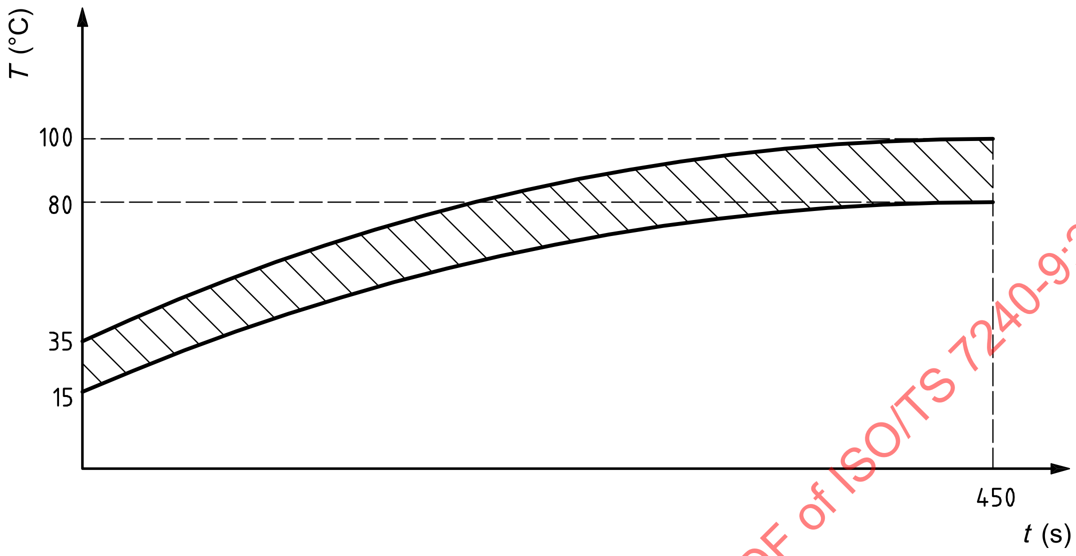


Figure 21 — Limits for T against t, Fire TF6

8.7.6 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.

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

8.8.1 Fuel

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

8.8.2 Conditioning

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

8.8.3 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.

8.8.4 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.

8.8.5 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.

8.8.6 Heating rate

Power the hotplate such that its temperature rises in accordance with Figure 22.

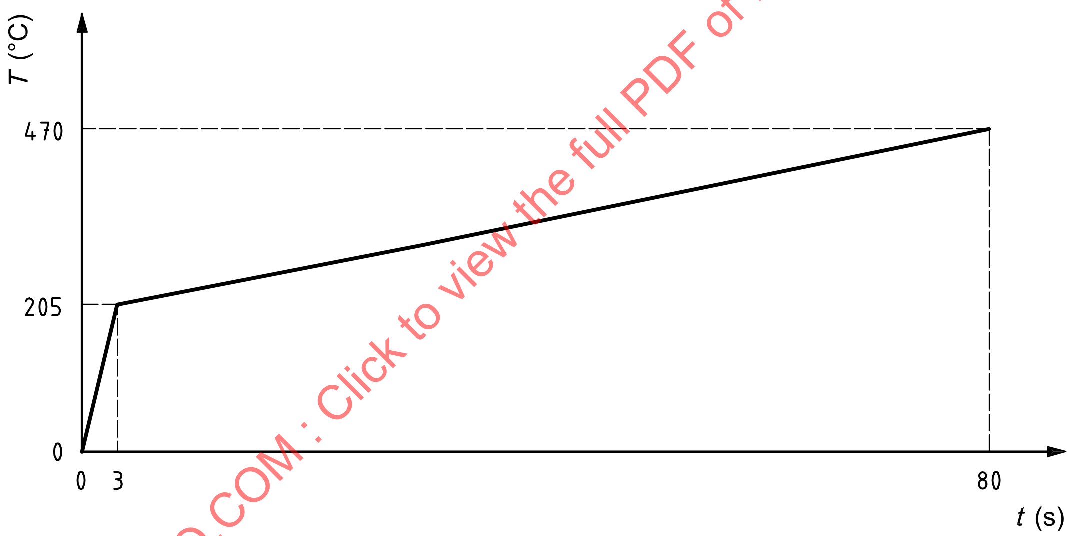


Figure 22 — Slow smouldering (pyrolysis) wood fire hotplate temperature vs. time

8.8.7 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 23 and 24, 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.

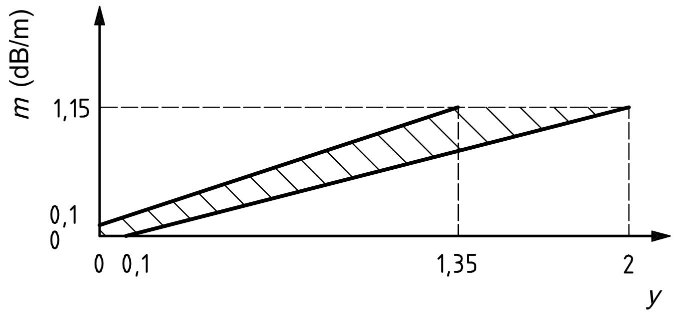


Figure 23 — Limits for m against y, Fire TF7

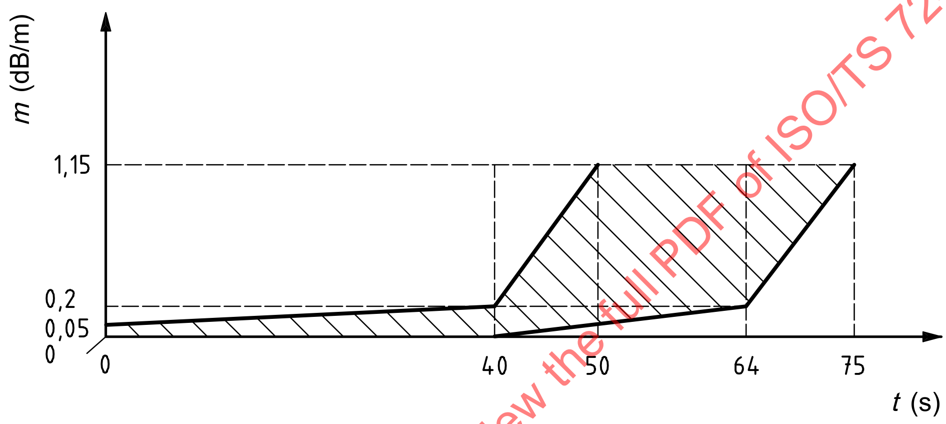


Figure 24 — Limits for m against time, t, Fire TF7

8.8.8 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.

8.8.9 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.

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

8.9.1 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).

8.9.2 Arrangement

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

8.9.3 Volume

Use approximately 170 ml of decalin.

8.9.4 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.

8.9.5 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 25, 26 and 27 respectively. That is, $5{,}0 < y < 9{,}0$ 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 rise in temperature, ΔT, shall not exceed 6 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 6 K.

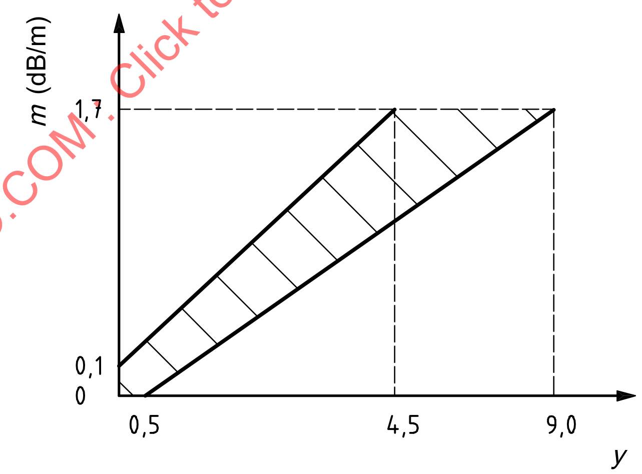


Figure 25 — Limits for m against y, Fire TF8

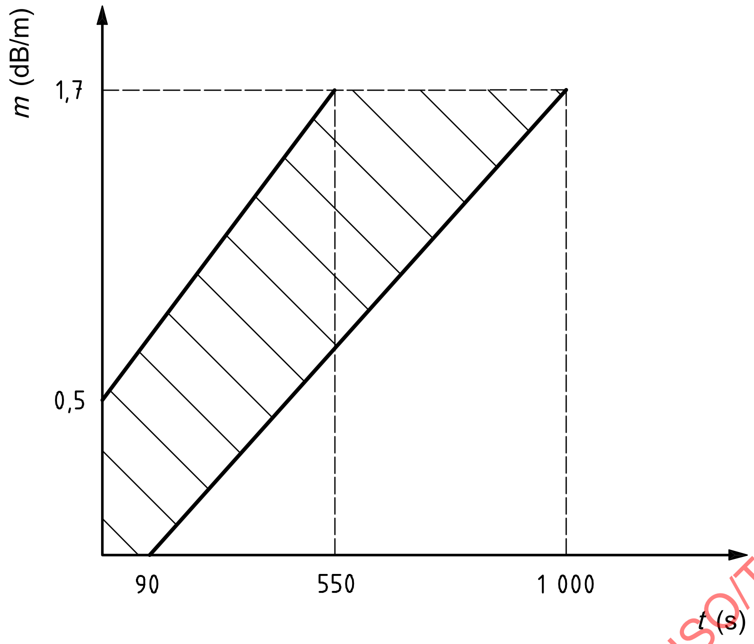


Figure 26 — Limits for m against time, t, Fire TF8

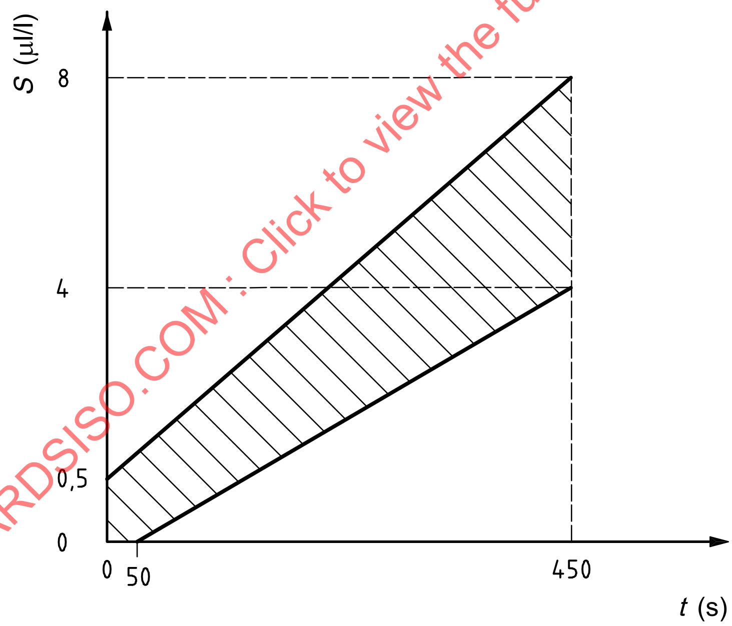


Figure 27 — Limits for S against time, t Fire TF8

8.9.6 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.

8.10 Test fire TF9 — Deep seated smouldering cotton fire

8.10.1 Fuel

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

8.10.2 Conditioning

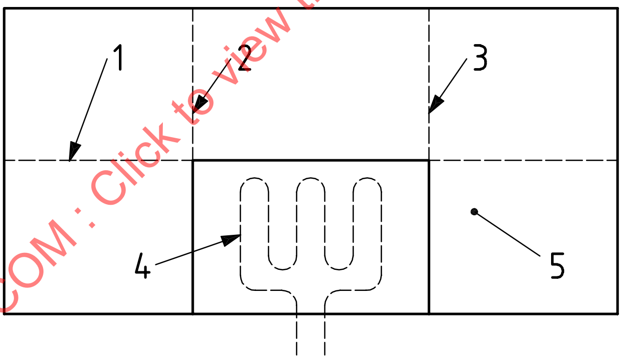
Dry the towel in an oven at 40 °C for a period of at least 12 h.

8.10.3 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 1,5 m of resistance wire, having a specific resistance of approximately 4 Ω/m, as shown in Figure 28.

The whole 1,5 m length of resistance wire should be buried in the towel 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 28 — Arrangement of the cotton towel and ignition source

8.10.4 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.

8.10.5 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 29 and 30, respectively. That is, $0,15 < m < 0,3$ and 20 min $< t <$ 30 min at the end-of-test condition S_E = 100 µl/l.

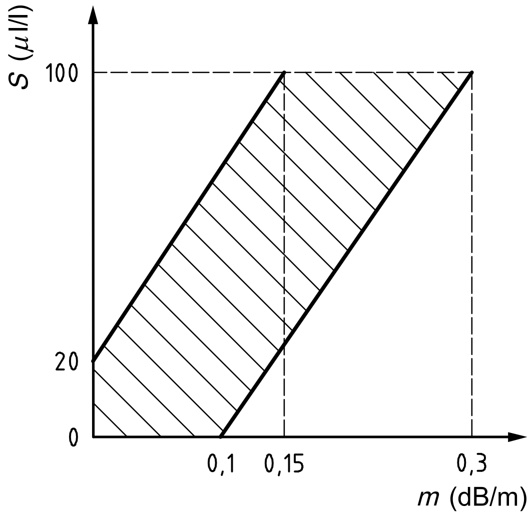


Figure 29 — Limits for S against m, Fire TF9

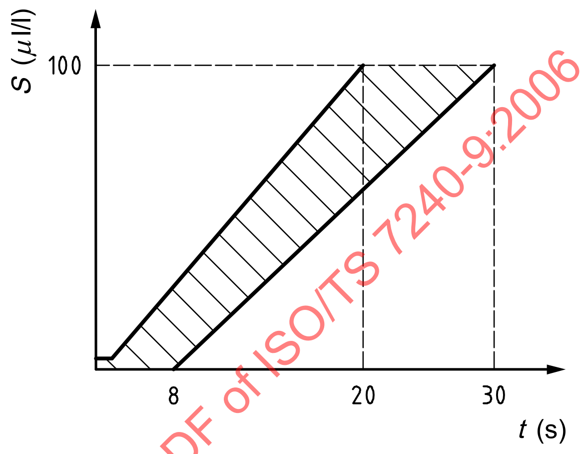


Figure 30 — Limits for S against time, t, Fire TF9

8.10.6 End-of-test condition

The end-of-test condition shall be when

— S_E = 100 µl/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 Equation (A.1):

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

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

Table A.1 (*continued*)

m values dB/m	Beam length d = 0,38 m		Beam length d = 0,5 m	
	Transmission rate %	**Obscuration rate** %	**Transmission rate** %	**Obscuration rate** %
1,30	89,2	10,8	86,1	13,9
1,40	88,5	11,5	85,1	14,9
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

Table A.2 (*continued*)

m values dB/m	Beam length d = 1,0 m		Beam length d = 2,0 m	
	Transmission rate %	Obscuration rate %	Transmission rate %	Obscuration rate %
3,00	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
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 Equation (B.1):

$$y = \frac{I_o}{I} - \frac{I}{I_o} \quad \text{(B.1)}$$

where

I_o 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 $(I_o–I)/I_o$	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

y value	x value $(I_o–I)/I_o$	Ionization current pA
1,8	0,555	44,5
1,9	0,571	42,9
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

y value	*x* value $(I_o - I)/I_o$	Ionization current pA
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
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

y value	*x* value $(I_o - I)/I_o$	Ionization current pA
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
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