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Plastics — Smoke generation —

Part 2: Determination of optical density by a single-chamber test

Plastiques — Production de fumée —

Partie 2: Détermination de la densité optique par un essai en enceinte unique

Reference number
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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

This fourth edition cancels and replaces the third edition (ISO 5659-2:2012), which has been technically revised. It details several technical points for sampling (essentially Annex F) and harmonizes sample preparation with other standards like ISO 5660-1.

A list of all parts in the ISO 5659 series can be found on the ISO website.

Introduction

Fire is a complex phenomenon; its development and effects depend upon a number of interrelated factors. The behaviour of materials and products depends upon the characteristics of the fire, the method of use of the materials and the environment in which they are exposed to (see also ISO/TS 3814 and ISO 13943).

A test such as is specified in this document deals only with a simple representation of a particular aspect of the potential fire situation, typified by a radiant heat source, and it cannot alone provide any direct guidance on behaviour or safety in fire. A test of this type may, however, be used for comparative purposes or to ensure the existence of a certain quality of performance (in this case, smoke production) considered to have a bearing on fire behaviour generally. It would be wrong to attach any other meaning to results from this test.

The term "smoke" is defined in ISO 13943 as a visible suspension of solid and/or liquid particles in gases resulting from incomplete combustion. It is one of the first response characteristics to be manifested and should almost always be taken into account in any assessment of fire hazard as it represents one of the greatest threats to occupants of a building or other enclosure, such as a ship or train, on fire.

The responsibility for the preparation of ISO 5659 was transferred during 1987 from ISO/TC 92 to ISO/TC 61 on the understanding that the scope and applicability of the standard for the testing of materials should not be restricted to plastics but should also be relevant to other materials where possible, including building materials.

Plastics — Smoke generation —

Part 2:
Determination of optical density by a single-chamber test

1 Scope

This document specifies a method of measuring smoke production from the exposed surface of specimens of materials or composites. It is applicable to specimens that have an essentially flat surface and do not exceed 25 mm in thickness when placed in a horizontal orientation and subjected to specified levels of thermal irradiance in a closed cabinet with or without the application of a pilot flame. This method of test is applicable to all plastics.

It is intended that the values of optical density determined by this test be taken as specific to the specimen or assembly material in the form and thickness tested and are not to be considered inherent, fundamental properties.

The test is intended primarily for use in research and development and fire safety engineering in buildings, trains, ships, etc. and not as a basis for ratings for building codes or other purposes. No basis is provided for predicting the density of smoke that can be generated by the materials upon exposure to heat and flame under other (actual) exposure conditions. This test procedure excludes the effect of irritants on the eye.

NOTE This test procedure addresses the loss of visibility due to smoke density, which generally is not related to irritancy potency (see Annex E).

It is emphasized that smoke production from a material varies according to the irradiance level to which the specimen is exposed. The results yielded from the method specified in this document are based on exposure to the specific irradiance levels of 25 kW/m^2 and 50 kW/m^2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 13943, *Fire safety — Vocabulary*

ISO 14934-3, *Fire tests — Calibration and use of heat flux meters — Part 3: Secondary calibration method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
assembly
fabrication of *materials* (3.6) and/or *composites* (3.2)

Note 1 to entry: Sandwich panels are an example of an assembly.

Note 2 to entry: The assembly may include an air gap.

3.2
composite
combination of *materials* (3.6) which are generally recognized in building construction as discrete entities

Note 1 to entry: Coated or laminated materials are examples of composites.

3.3
essentially flat surface
surface which does not deviate from a plane by more than 1 mm

3.4
exposed surface
surface of the *product* (3.9) subjected to the heating conditions of the test

3.5
irradiance
radiant flux incident on an infinitesimal element of the surface containing the point divided by the area of that element

3.6
material
basic single substance or uniformly dispersed mixture

Note 1 to entry: Metal, stone, timber, concrete, mineral fibre and polymers are examples.

3.7
mass optical density
MOD
measure of the degree of opacity of smoke in terms of the mass loss of the *material* (3.6)

3.8
optical density of smoke
D
measure of the degree of opacity of smoke, taken as the negative common logarithm of the relative transmission of light

3.9
product
material (3.6), *composite* (3.2) or *assembly* (3.1) about which information is required

3.10
specific optical density
D_S
optical density multiplied by a factor which is calculated by dividing the volume of the test chamber by the *product* (3.9) of the exposed area of the *specimen* (3.11) and the path length of the light beam

Note 1 to entry: See 11.1.1.

3.11
specimen
representative piece of the product to be tested together with any substrate or surface coating

Note 1 to entry: The specimen may include an air gap.

3.12
intumescent material
dimensionally unstable *material* (3.6), developing a carbonaceous expanded structure

Note 1 to entry: Generally, a material developing an expanded structure of thickness >10 mm during the test, with the cone heater 25 mm from the specimen, is considered as intumescent material.

4 Principles of the test

Specimens of the product are mounted horizontally within a chamber and exposed to thermal radiation on their upper surfaces at selected levels of constant irradiance up to 50 kW/m^2.

The smoke evolved is collected in the chamber, which also contains photometric equipment. The attenuation of a light beam passing through the smoke is measured. The results are reported in terms of specific optical density.

5 Suitability of a material or product for testing

5.1 Material or product geometry

5.1.1 The method is applicable to essentially flat materials, products, composites or assemblies not exceeding 25 mm in thickness.

5.1.2 The method is sensitive to small variations in geometry, surface orientation, thickness (either overall or of the individual layers), mass and composition of the material, and so the results obtained by this method only apply to the thickness of the material or product as tested.

5.1.3 It is not possible to calculate the specific optical density of one thickness of a material or product from the specific optical density of another thickness of the material or product.

5.2 Surface characteristics

A material or product having one of the following properties is suitable for testing:

a) an essentially flat exposed surface;

b) a surface irregularity which is evenly distributed over the exposed surface provided that

   1) at least 50 % of the surface of a representative 100 mm^2 area lies within a depth of 10 mm from a plane taken across the highest points on the exposed surface or

   2) for surfaces containing cracks, fissures, or holes not exceeding 8 mm in width or 10 mm in depth, the total area of such cracks, fissures, or holes at the surface does not exceed 30 % of a representative 100 mm^2 area of the exposed surface.

When an exposed surface does not meet the requirements of either 5.2 a) or 5.2 b), the material or product shall be tested in a modified form complying as close as possible with the requirements given in 5.2. The test report shall state that the material or product has been tested in a modified form and clearly describe the modification.

5.3 Asymmetrical products

It is possible that a product submitted to this test will have faces which differ or contain laminations of different materials arranged in a different order in relation to the two faces. If either of the faces can be exposed in use within a room, cavity, or void, both faces shall be tested.

6 Specimen construction and preparation

6.1 Number of specimens

6.1.1 The test sample shall comprise a minimum of 12 specimens if all four modes are to be tested: six specimens shall be tested at 25 kW/m^2 (three specimens with a pilot flame and three specimens without a pilot flame) and six specimens shall be tested at 50 kW/m^2 (three specimens with a pilot flame and three specimens without a pilot flame).

If fewer than four modes are to be tested, a minimum of three specimens per mode shall be tested.

6.1.2 An additional number of specimens as specified in 6.1.1 shall be used for each face, in accordance with the requirements of 5.2.

6.1.3 An additional 12 specimens (i.e. three specimens per test mode) shall be held in reserve if required by the modes specified in 10.9.

6.1.4 In case of intumescent materials, it is necessary to make a preliminary test with the cone heater at 50 mm from the specimen, so at least two additional specimens are required.

6.2 Size of specimens

6.2.1 The specimens shall be square, with sides measuring 75 mm ± 1 mm.

6.2.2 Materials of 25 mm nominal thickness or less shall be evaluated at their full thickness. For comparative testing, materials shall be evaluated at a thickness of 1,0 mm ± 0,1 mm. All materials consume oxygen when they burn in the chamber, and the smoke generation of some materials (especially rapid-burning or thick specimens) is influenced by the reduced oxygen concentration in the chamber. As far as possible, materials shall be tested in their end-use thickness.

6.2.3 Materials with a thickness greater than 25 mm shall be cut to give a specimen thickness of 25 mm ± 0,1 mm, in such a way that the original (uncut) face can be evaluated.

6.2.4 Specimens of multi-layer materials with a thickness greater than 25 mm, consisting of core material(s) with facings of different materials, shall be prepared as specified in 6.2.3 (see also 6.3.2).

6.3 Specimen preparation

6.3.1 The specimen shall be representative of the material and shall be prepared in accordance with the procedures described in 6.3.2 and 6.3.3. The specimens shall be cut, sawn, moulded or stamped from identical sample areas of the material, and records shall be kept of their thicknesses and, if required, their masses.

6.3.2 If flat sections of the same thickness and composition are tested in place of curved, moulded or speciality parts, this shall be stated in the test report. Any substrate or core materials for the specimens shall be the same as those used in practice.

6.3.3 When coating materials, including paints and adhesives, are tested with the substrate or core as used in practice, specimens shall be prepared following normal practice, and in such cases the method of application of the coating, the number of coats and the type of substrate shall be included in the test report.

6.3.4 This test method has been found suitable for applications outside the field of plastics, or to transformed products in their end-use shape. Such specific sampling conditions are proposed in Annex F.

6.4 Conditioning

6.4.1 Before the test, specimens shall be conditioned to constant mass at a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) % in accordance with ISO 291.

Constant mass is considered to be reached when two successive weighing operations, carried out at an interval of 24 h, do not differ by more than 0,1 % of the mass of the test piece or 0,1 g, whichever is the greater. Materials, such as polyamides, which require more than one week of conditioning to reach equilibrium, may be tested after conditioning for a period specified by the sponsor. This period shall not be less than one week and shall be described in the test report.

6.4.2 While in the conditioning chamber, specimens shall be supported in racks so that air has access to all surfaces.

Forced-air movement in the conditioning chamber may be used to assist in accelerating the conditioning process.

The results obtained from this method are sensitive to small differences in specimen conditioning. It is important therefore to ensure that the requirements of 6.5 are followed carefully.

6.5 Wrapping of specimens

6.5.1 All specimens shall be covered across the back, along the edges and over the front surface periphery, leaving a central exposed specimen area of 65 mm × 65 mm, using a single sheet of aluminium foil (approximately 0,04 mm thick) with the dull side in contact with the specimen. Care shall be taken not to puncture the foil or to introduce unnecessary wrinkles during the wrapping operation. The foil shall be folded in such a way as to minimize losses of any melted specimen material at the bottom of the specimen holder. After mounting the specimen in its holder, any excess foil along the front edges shall be trimmed off.

6.5.2 Wrapped specimens of thickness up to 12,5 mm shall be backed with a sheet of non-combustible insulating board of oven-dry density 850 kg/m^3 ± 100 kg/m^3 and nominal thickness 12,5 mm and a layer of low-density (nominal 65 kg/m^3) refractory fibre blanket under the non-combustible board.

Wrapped specimens of thickness greater than 12,5 mm but less than 25 mm shall be backed with a layer of low-density (nominal 65 kg/m^3) refractory fibre blanket.

Wrapped specimens of a thickness of 25 mm shall be tested without any backing board or refractory fibre blanket.

6.5.3 For resilient materials, each specimen in its aluminium foil wrapper shall be installed in the holder in such a way that the exposed surface lies flush with the inside face of the opening of the specimen holder. Materials with uneven exposed surfaces shall not protrude beyond the plane of the opening in the specimen holder.

6.5.4 When thin impermeable specimens, such as thermoplastic films, become inflated during the test owing to gases trapped between the film and backing, they shall be maintained essentially flat by making two or three cuts (20 mm to 40 mm long) in the film to act as vents.

7 Apparatus and ancillary equipment

7.1 General

The apparatus (see Figure 1) shall consist of an air-tight test chamber with provision for containing a specimen holder, radiation cone, pilot burner, light transmission and measuring system and other, ancillary facilities for controlling the conditions of operation during a test.

7.2 Test chamber

7.2.1 Construction

7.2.1.1 The test chamber (see Figure 1 and Figure 2) shall be fabricated from laminated panels, the inner surfaces of which shall consist of either a porcelain enamelled metal not more than 1 mm thick or an equivalent coated metal which is resistant to chemical attack and corrosion and capable of easy cleaning. The internal dimensions of the chamber shall be 914 mm ± 3 mm long, 914 mm ± 3 mm high and 610 mm ± 3 mm deep. It shall be provided with a hinged front-mounted door with an observation window and a removable opaque door cover to the window to prevent light entering the chamber. The door of the chamber shall occupy a complete side of the smoke chamber. A safety blow-out panel, consisting of a sheet of aluminium foil of thickness not greater than 0,04 mm and having a minimum area of 80 600 mm^2, shall be provided in the chamber, fastened in such a way as to provide an airtight seal.

The blow-out panel may be protected by a stainless-steel wire mesh. It is important that any such mesh is spaced at least 50 mm from the blow-out panel to prevent any obstruction in the event of an explosion.

7.2.1.2 Two optical windows, each with a diameter of 75 mm, shall be mounted one each in the top and bottom of the cabinet, at the position shown in Figure 2, with their interior faces flush with the outside of the chamber lining. The underside of the window in the floor shall be provided with an electric heater of approximately 9 W capacity in the form of a ring, which shall be capable of maintaining the upper surface of the window at a temperature just sufficient to minimize smoke condensation on that face (a temperature of 50 °C to 55 °C has been found suitable) and which shall be mounted around its edge so as not to interrupt the light path. Optical platforms 8 mm thick shall be mounted around the windows on the outside of the chamber and shall be held rigidly in position relative to each other by three metal rods, with a diameter of at least 12,5 mm, extending through the chamber and fastened securely to the platforms.

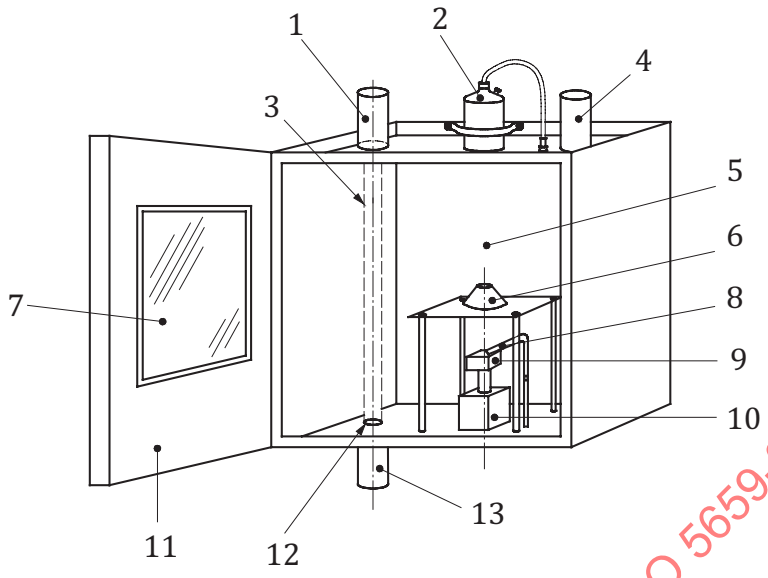
7.2.1.3 Other openings in the chamber shall be provided for services as specified and where appropriate. They shall be capable of being closed so that a positive pressure up to 1,5 kPa (150 mm water gauge) above atmospheric pressure can be developed inside the chamber (see 7.2.2) and maintained when checked in accordance with 7.6 and 9.6. All components of the chamber shall be capable of withstanding a greater positive internal pressure than the safety blow-out panel.

7.2.1.4 An inlet vent with shutter shall be provided in the front (towards the top of the chamber) or on the roof of the chamber and away from the radiator cone, and an exhaust vent with shutter shall be provided in the bottom of the chamber connected to an extraction fan capable of creating a negative pressure of at least 0,5 kPa (50 mm water gauge). The outlet of the fan should be connected to the laboratory exhaust system, typically using flexible tubing with a diameter between 50 mm and 100 mm.

7.2.2 Chamber pressure control facilities

Provision shall be made for controlling the pressure inside the test chamber. A manometer, with a range of up to 1,5 kPa (150 mm water gauge) shall be provided for connection to a pressure regulator and to a tube in the top of the chamber. The manometer can be either electronic or a suitable fluid in a tube (water or an appropriate indicating fluid).

A suitable pressure regulator (see Figure 3) consists of a vented water-filled bottle and a length of flexible tubing of diameter 25 mm, inserted 100 mm below the water surface: the other end of the tubing is connected to the manometer and the chamber. The regulator shall be vented to the exhaust system.



a) Schematic drawing of typical test apparatus

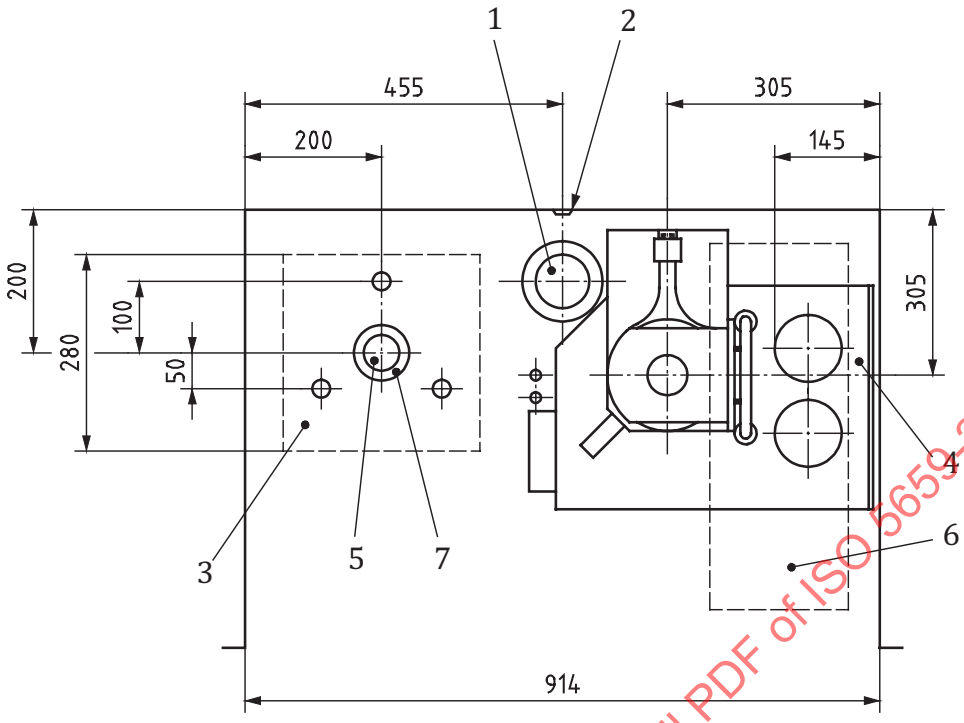
b) Typical example of test apparatus

Key

1	optical measurement system	8	pilot burner
2	pressure controller	9	specimen in specimen holder
3	optical path	10	weighing device
4	upper vent (on top) and lower vent connected to exhaust fan (on bottom)	11	full front open door
5	chamber	12	optical system floor window
6	conical heater	13	light source
7	window		

Figure 1 — Test apparatus

Dimensions in millimetres (not to scale)

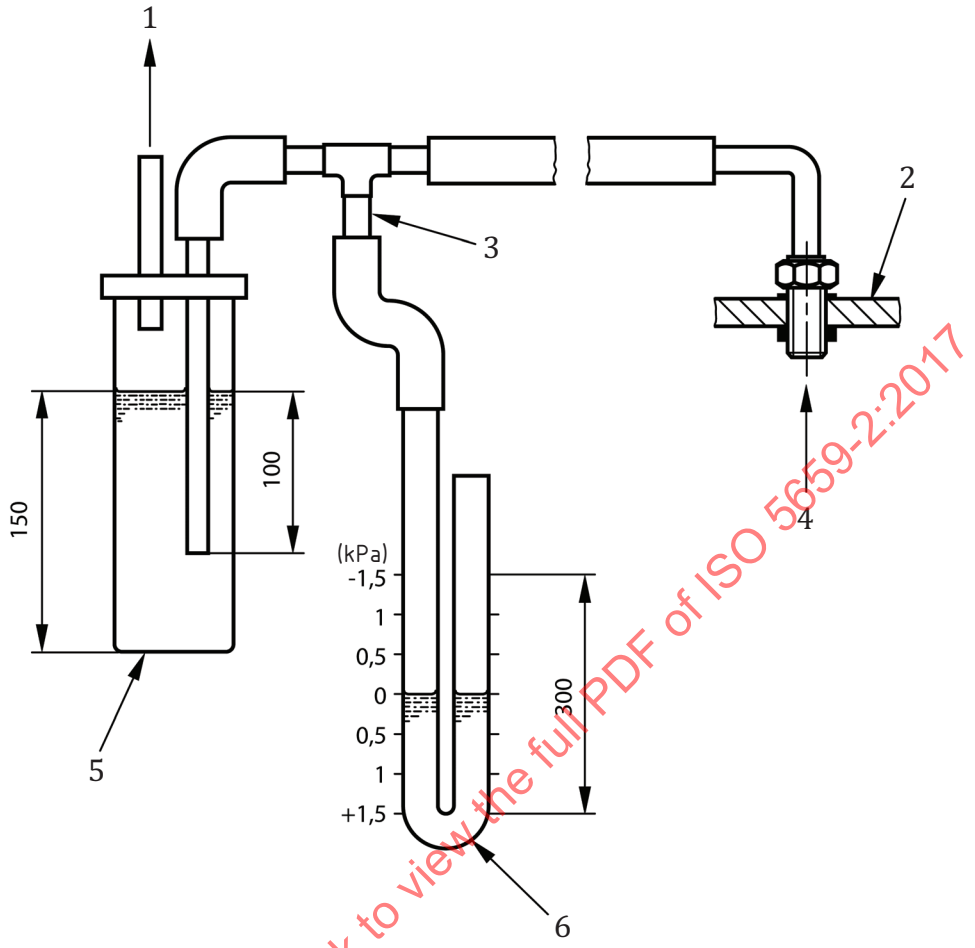


Key

1 exhaust vent
2 wall thermocouple
3 optical platform
4 radiator cone assembly
5 optical window
6 blow-out panel
7 window heater

Figure 2 — Plan view of typical chamber

Dimensions in millimetres



Key

1 to exhaust system
2 chamber wall
3 restriction to prevent chamber blow-out
4 effluent from chamber
5 water bottle
6 glass manometer opt U-tube (filled to zero mark with water-dye solution)

Figure 3 — Typical chamber pressure relief manometer

7.2.3 Chamber wall temperature

A thermocouple measuring junction, made from wires of diameter not greater than 1 mm, shall be mounted on the inside of the back wall of the chamber, at the geometric centre, by covering it with an insulating disc (such as polystyrene foam) having a thickness of approximately 6,5 mm and a diameter of not more than 20 mm, attached to the wall of the chamber with a suitable cement. The thermocouple junction shall be connected to a recorder or meter and the system shall be suitable for measuring temperatures in the range 35 °C to 80 °C (see 10.2.2).

7.3 Specimen support and heating arrangements

7.3.1 Radiator cone

7.3.1.1 The radiator cone shall consist of a heating element, of nominal rating 2600 W, contained within a stainless-steel tube, approximately 2 210 mm in length and 6,5 mm in diameter, coiled into the shape of a truncated cone and fitted into a shade. The shade shall have an overall height of 45 ± 0,4 mm, an internal diameter of 55 mm ± 1 mm and an internal base diameter of 110 mm ± 3 mm. It shall consist of two layers of 1 mm thick stainless steel with a 10 mm thickness of ceramic-fibre insulation of nominal density 100 kg/m^3 sandwiched between them. The heating element shall be clamped at the top and bottom of the shade.

7.3.1.2 The radiator cone shall be capable of providing irradiance in the range 10 kW/m^2 to 50 kW/m^2 at the centre of the surface of the specimen.

When the irradiance is determined at two other positions 25 mm each side of the specimen centre, the irradiance at these two positions shall be not less than 85 % of the irradiance at the centre of the specimen.

The temperature controller for the radiator cone shall be a proportional, integral differential-type 3-term controller with solid-state relay, thyristor stack fast-cycle or phase angle control of not less than 10 A maximum rating. Capacity for adjustment of integral time up to 50 s and differential time up to 30 s shall be provided to permit reasonable matching with the response characteristics of the heater. The temperature at which the heater is to be controlled shall be set on a scale capable of being held steady to ±2 °C. An input range of temperature of 0 °C to 1 000 °C is suitable; an irradiance of 50 kW/m^2 is typically given by a heater temperature in the range 770 °C to 840 °C for the specimen position 25 mm below the edge of the heater. Automatic cold-junction compensation of the thermocouple shall be provided.

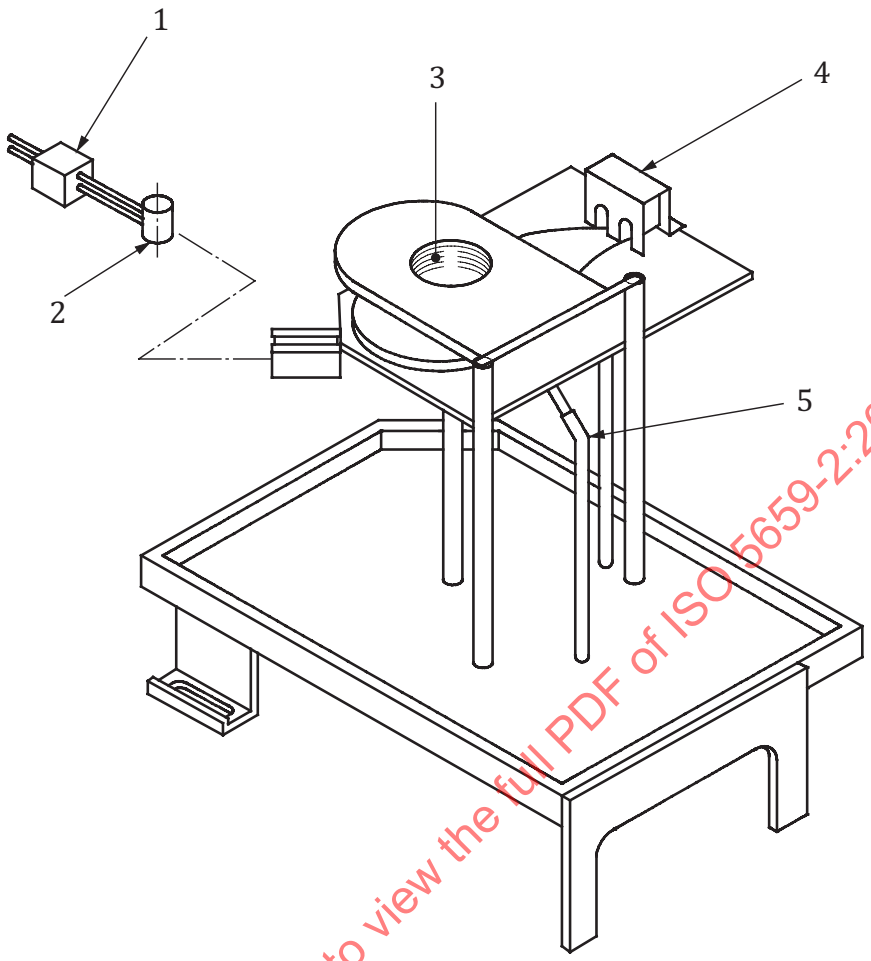
NOTE The heater temperature range for testing with 50 mm distance between the edge of the radiator cone and specimen is given in Table D.3.

The irradiance of the radiator cone shall be controlled by reference to the reading of two type K sheathed thermocouples mounted diametrically opposite and in contact with, but not welded to, the element. The thermocouples shall be of equal length and wired in parallel to the temperature controller and be positioned one-third of the distance from the top surface of the cone.

While phase angle control is allowed for in the temperature controller of the radiator cone, it should be noted that this will usually require electrical filtering to avoid risk of low-level signal lines.

7.3.2 Framework for support of the radiator cone, specimen holder and heat flux meter

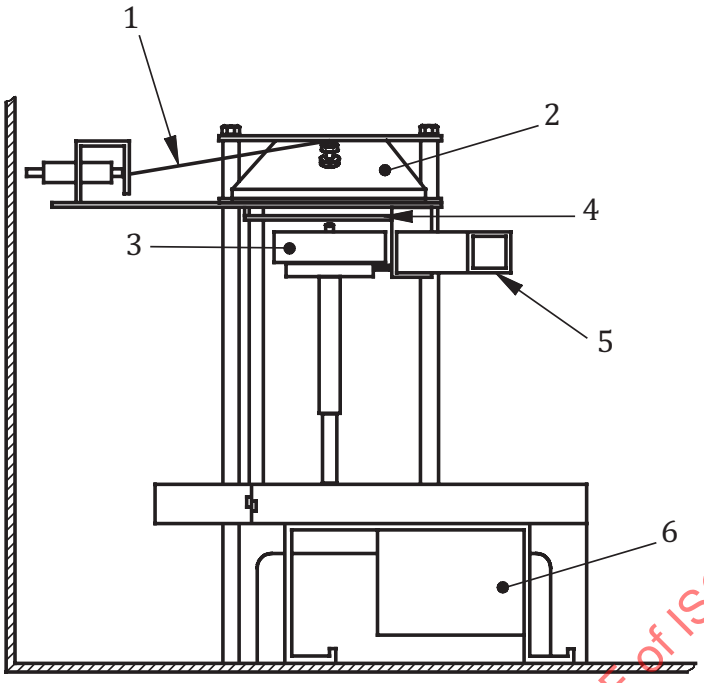
The radiator cone shall be located and secured from the vertical rods of the support framework so that for non-intumescent materials the lower rim of the radiator cone shade junction is 25 mm ± 1 mm above the upper surface of the specimen when oriented in the horizontal position. For intumescent materials, this distance shall be 50 mm. Details of the radiator cone and supports are shown in Figure 4 and Figure 5.



Key

1 heat flux meter mount
2 heat flux meter
3 heating element
4 thermocouple mount and shield
5 pilot burner

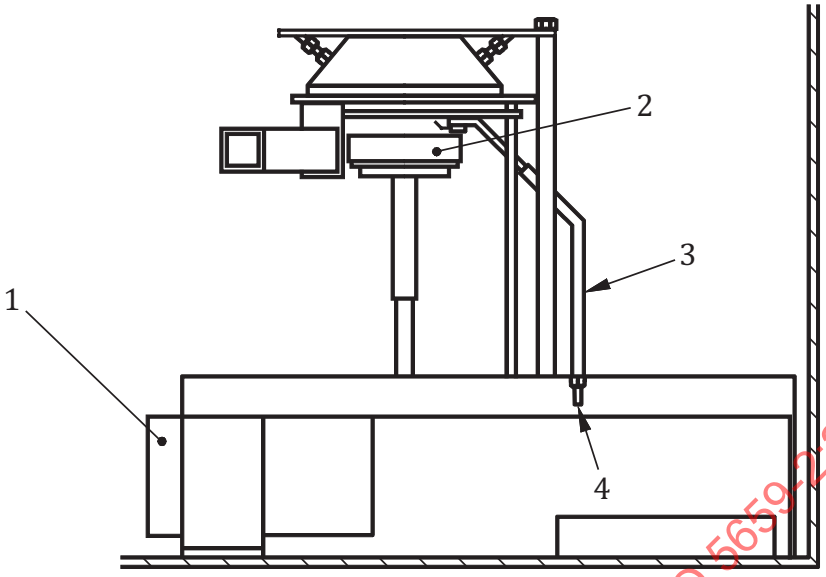
Figure 4 — Typical framework for support of radiator cone, specimen holder and flux meter



Key

1 thermocouple
2 radiator cone
3 specimen holder
4 radiator shield
5 heat flux meter support
6 spark ignition housing

Figure 5 — Typical arrangement of radiator cone, specimen holder and radiator shield (side view)



Key

1 spark ignition housing
2 specimen holder
3 pilot burner and ignition electrode
4 propane and air

Figure 6 — Typical arrangement of radiator cone, specimen holder and radiator shield (front view)

7.3.3 Radiator shield

A remotely controllable metallic and/or inorganic shield (see Figure 5 and Figure 6) of minimum diameter 130 mm and upper surface situated (when in place) between the base of the radiator cone and the specimen surface (and above the pilot burner) shall be provided to stop irradiance of the specimen before and after the required exposure period.

NOTE This facility is necessary in order to enable repeat tests to be carried out without switching off the radiator cone.

7.3.4 Heat flux meter

7.3.4.1 The heat flux meter shall be of a thermopile (Schmidt–Boelter) type with a design range of at least 50 kW/m^2. The body shall have an external diameter of approximately 12,7 mm. The target receiving the radiation (see Figure 4) shall have a flat, circular face of approximately 10,0 mm diameter, coated with a durable matt-black finish. The target shall be water-cooled.

7.3.4.2 The heat flux meter shall be connected, directly to a suitable recorder or meter in accordance with 7.8.6, so that it is capable, when calibrated, of recording heat fluxes of 25 kW/m^2 and 50 kW/m^2 to an accuracy of ± 1 kW/m^2.

If a recorder which only displays a mV output is used, the mV value shall be converted to kW/m^2 using the calibration factor (or formula if appropriate) specific to the heat flux meter.

7.3.4.3 The heat flux meter system shall be calibrated by comparing its response with that of a primary reference standard when exposed to heat fluxes of 25 kW/m^2 ± 1 kW/m^2 and 50 kW/m^2 ± 1 kW/m^2 averaged over the 10 mm diameter area of the heat flux meter in accordance with Annex A.

7.3.5 Specimen holder

Details of the specimen holder are shown in Figure 7. The base shall be lined with low-density (nominal density 65 kg/m^3) refractory fibre blanket with a minimum thickness of 10 mm (unless the specimen is 25 mm thick; see 6.5.2). A retainer frame shall always be used to reduce unrepresentative edge-burning of composite specimens. Lifting of the retainer frame and touching the pilot flame shall be avoided. If there is a risk of this happening, drill holes in the holder/frame and use two screws to hold retainer frame in place.

A wire grid can be used for retaining specimens prone to delamination or to distortion. Any such wire grid shall be 75 mm square with 20 mm-square holes constructed from 2 mm stainless-steel rod welded at all intersections. When testing intumescing specimens, the wire grid shall not be used.

Dimensions in millimetres

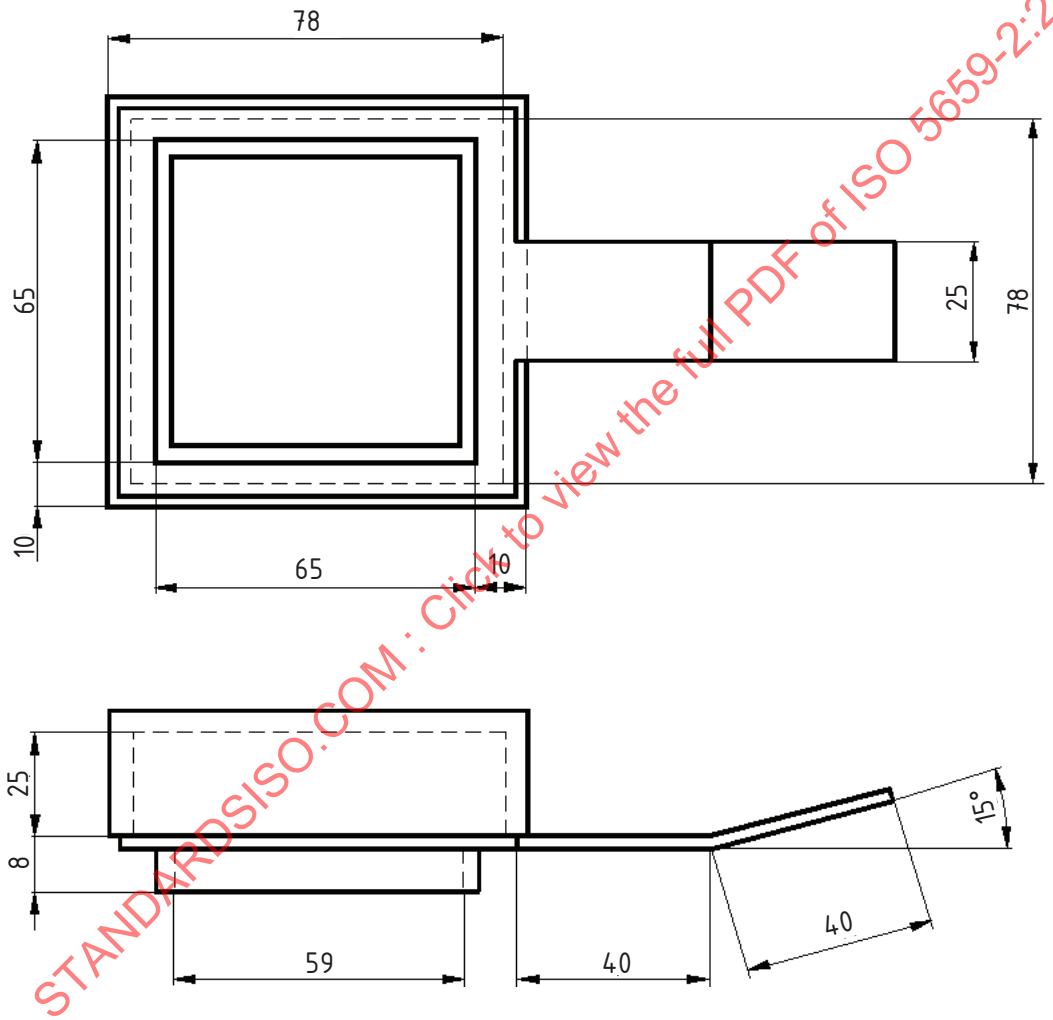


Figure 7 — Typical specimen holder

7.3.6 Pilot burner

The single-flame burner, shown in Figure 6, shall have a horizontal flame length of 30 mm ± 5 mm and for non-intumescent materials shall be positioned horizontally 10 mm above the top face of the specimen. For intumescent materials, the burner shall be positioned 15 mm down from the cone heater bottom edge. The colour of the flame shall be blue with a yellow tip. A small spark ignition device shall be sited next to the outlet tube of the burner so that the flame may be ignited by the operator without opening the door of the chamber.

The nozzle of the pilot-burner shall be positioned vertically above the centre of one of the edges of the opening in the top of the edge frame, with the flame extending horizontally towards a position above the centre of the specimen.

7.4 Gas supply

A mixture of propane of at least 95 % purity and at a minimum pressure of 3,5 kPa ± 1 kPa (350 mm ± 100 mm water gauge) and air under a pressure of 170 kPa ± 30 kPa (17 m ± 3 m water gauge) shall be supplied to the burner. Each gas shall be fed via needle valves and flow meters to a point at which they are mixed and supplied to the burner. The flow meter for the propane supply shall be capable of measuring 100 cm^3/min and that for the air a flow of 500 cm^3/min.

7.5 Photometric system

7.5.1 General

The photometric system shall consist of a light source in accordance with 7.5.2, a lens in a light-tight housing mounted below the optical window in the floor of the cabinet, and a photo detector with lens, filters and shutter, in accordance with 7.5.3, in a light-tight housing above the optical window in the top of the chamber.

A schematic drawing of a typical system is shown in Figure 8. Equipment shall be provided to control the output the light source, and to measure the amount of light falling on the photo detector.

7.5.2 Light source

The light source shall be a 6,5 V incandescent lamp. Power for the lamp shall be provided so that the voltage across the lamp, as determined by a voltmeter, is maintained at 4 V ± 0,2 V. The lamp shall be mounted in the lower light-tight box, and a lens to provide a collimated light beam of 51 mm diameter, passing towards and through the optical window in the floor of the chamber, shall be mounted, with provision for adjustment, to control the collimated beam in direction and diameter. The housing shall be provided with a cover to allow access for adjustments to be made to the position of the lens.

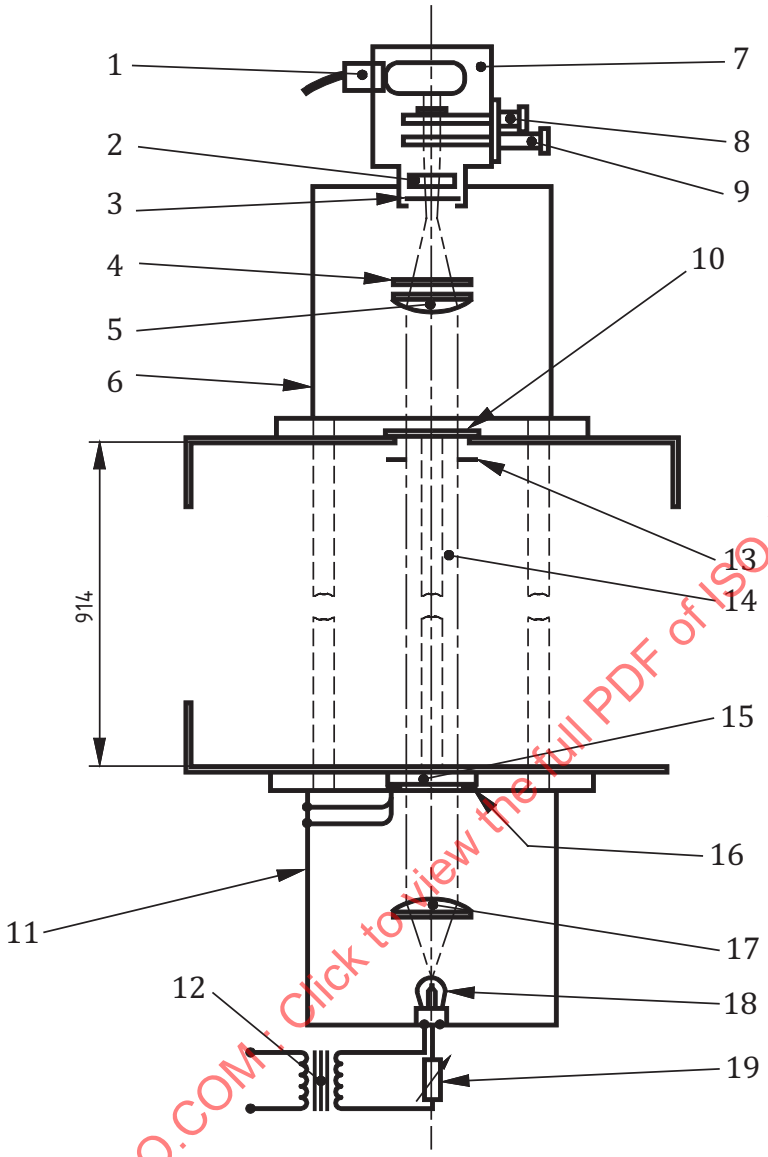
7.5.3 Photo detector

7.5.3.1 The light-measuring system shall consist of a photo multiplier tube connected to a multi-range amplifier coupled to a recording device in accordance with 7.8.6, capable of continuously measuring relative light intensity against time as percentage transmission over at least five orders of magnitude with an S-4 spectral sensitivity response similar to that of human vision and a dark current less than 10^{-9} A. The system shall have a linear response with respect to transmittance and an accuracy of better than ±3 % of the maximum reading on any range.

For selection of photo multiplier tubes, as applicable, the minimum sensitivity shall allow a 100 % reading to be obtained with a 0,5 neutral-density filter and a ND-2 range-extension filter (see 7.5.3.2) in the light path. Provision shall be made for adjusting the reading of the instrument under given conditions over the full range of any scale.

NOTE The required accuracy of the photo detector using a photo multiplier tube can be obtained more easily if the measuring systems incorporate scale ranges of 30, 3, 0,3, etc., as well as ranges of 100, 10, 1, etc.

Dimensions in millimetres



Key

1 photomultiplier tube and socket
2 opal diffuser filter (optional)
3 aperture disc
4 natural density compensating
5 lens
6 optical system housing
7 optical system upper housing
8 range-extension filter (ND-2)
9 shutter
10 optical window
11 optical system lower housing
12 transformer
13 opaque disc template
14 parallel light beam
15 optical window
16 optical window heater
17 lens
18 light source
19 adjustable resistor

Figure 8 — Example of photometric system using a photomultiplier tube

7.5.3.2 The photo multiplier tube shall be mounted in the upper section of the detector housing. Below it, there shall be an assembly, which provides for the positioning of a filter and of a shutter, in or out of the path of the collimated light beam. The filter, referred to as the range-extension filter (ND-2), shall be

a glass neutral-density filter of nominal optical density 2. When in the closed position, the shutter shall prevent all light in the test chamber from reaching the photo multiplier tube. An optional opal diffuser may be permanently mounted below the shutter.

7.5.3.3 The lower part of the upper housing shall support a lens with a diameter greater than 51 mm capable of being adjusted so that the collimated beam is focused to form a small intense spot of light at the disc aperture between the upper and lower parts of the housing. Above the lens, there shall be a mount for supporting one or more compensating filters from a set of nine neutral-density filters with optical density varying from 0,1 to 0,9 in steps of 0,1. The housing shall be provided with a cover to allow access for adjustments to be made to the position of the lens and for inserting or removing filters.

7.5.3.4 A neutral-density filter, with a nominal optical density of 3,0, large enough to cover the lower optical window shall be available for calibrating the photometric system.

7.5.3.5 Handle all filters by their edges only, because fingerprints can greatly affect their rating. Make no attempt to clean the surface of a filter; once the surface has been damaged or spoilt, the filter shall be replaced.

The smoke measurement system has a spectral band quite similar to that corresponding to human vision. This is defined by the operating condition of the lamp source and the spectral sensitivity of the photodetector. Since no precise control is maintained over the size of this spectral band, it would be necessary, if accurate calibration were to be attempted, to make use of filters with constant transmission over a spectral band of at least 350 to 750 nm. Such filters are not readily available. Because of this and the inherent linearity of a properly constructed photometer and measuring circuit, it is not recommended that the test method user attempt precise calibration of the instrument over its operating range.

7.5.4 Additional equipment

7.5.4.1 A template for checking the collimated light beam shall be provided, consisting of an opaque disc marked with a concentric ring of 51 mm diameter, and capable of fitting snugly between the support pillars. It shall be capable of being attached to, and centred on, the underside of the upper optical window in the chamber.

7.5.4.2 A piece of white cloth, tissue or a set of neutral-density filters of sufficient size to completely cover the lower optical window of the chamber, and capable of transmitting an amount of light to give a mid-scale reading of the photometric system when switched to the scale with a range of 1 % transmission, shall be available for calibrating the range-extension filter.

7.5.4.3 A piece of opaque material, sufficiently large to cover the lower optical window, shall be available for blocking the light from the light source to prevent it from entering the chamber.

7.6 Chamber leakage

With the specified items of equipment properly assembled ready for test but the cone heater switched off, the chamber shall be sufficiently airtight to comply with the requirements of the leakage rate test given in 9.6.

NOTE The most likely sources of leakage have been found to be the door seal, the inlet and outlet vents and the safety blow-out panel.

7.7 Cleaning materials

Appropriate materials shall be available for cleaning the inside of the chamber.

NOTE An ammoniated spray detergent and soft scouring pads have been found effective for cleaning the chamber walls and ethyl alcohol and soft tissue for the optical windows. Use of a tray of 0,880 N ammonia overnight inside the chamber also helps to reduce acidity inside the chamber and the sampling lines.

7.8 Ancillary equipment

7.8.1 Balance

This shall have a capacity exceeding the mass of the specimen and shall be readable and accurate to 0,5 % of the specimen mass.

7.8.2 Timing device

A timing device capable of recording elapsed time to the nearest second over a period of at least 1 h with accuracy within 1 s in 1 h shall be used for timing operations and observations.

7.8.3 Linear measuring devices

Rules, callipers, gauges or other devices of suitable accuracy shall be used for checking the dimensions, etc., specified with given tolerances.

7.8.4 Auxiliary heater

An auxiliary heater of 500 W capacity capable of raising the air temperature uniformly without local heating of the walls may be used if required to help the chamber to reach the stabilized temperature more rapidly under adverse conditions. Alternatively, the walls of the chamber may be heated externally to help the chamber temperature to stabilize.

7.8.5 Protective equipment

Protective clothing, such as gloves, goggles, respirators, etc., and handling equipment such as tongs, shall be available when the type of specimen being tested demands them.

7.8.6 Recorder

The recorder shall be capable of recording continuously the millivolt output of the photo detector (7.5.3) to an accuracy of better than 0,5 % full range deflection. The recorder shall also be capable of recording the heat flux meter output (see 7.3.4.2) to the required accuracy.

7.8.7 Water-circulating device

To cool the heat flux meter, water shall be provided to flow through the device. The temperature of the water must be above the local dew point to avoid condensation forming on the measuring surface of the heat flux meter.

8 Test environment

8.1 The test apparatus shall be protected from direct sunlight, or any strong light source, to avoid the possibility of spurious light readings.

8.2 Adequate provision shall be made for removing potentially hazardous and objectionable smoke and gases from the area of operation, and other suitable precautions shall be taken to prevent exposure

of the operator to them, particularly during the removal of specimens from the chamber or when cleaning the apparatus.

9 Setting-up and calibration procedures

9.1 General

Assemble the apparatus, connect to the services and control devices as specified in Clause 7, and check for proper functioning of the various systems, including the electrical connections to ensure good electrical contact.

Heat up the radiator cone gradually from cold and do not allow it to heat up or remain operating without a blank specimen holder, a specimen in its holder or the heat flux meter being in position under it.

9.2 Alignment of photometric system

9.2.1 General

Carry out the procedure detailed in 9.2.2 and 9.2.3 in the initial setting-up of the apparatus, after the replacement of the light source or after some accidental misalignment has occurred, and then always follow this by the procedure for selecting appropriate compensating filter(s) in accordance with 9.3.

9.2.2 Beam collimation

9.2.2.1 Check the optical platforms for rigidity. Attach the opaque-disc template to the lower face of the upper optical window with the marked ring downwards and centred on the window. Switch on the light source and adjust its projected image on the template so that the light beam completely fills the 51 mm diameter ring with no more light outside the ring than is necessary to satisfy this requirement.

9.2.2.2 Make the adjustments by removing the cover to the light-source enclosure, releasing the lower-lens mount fixings and repositioning the lens mount so that the light pattern on the template is centred and of the correct size. Alternatively, reposition the lens using external adjustments, if provided.

NOTE In cases of severe maladjustment, it might be necessary to reposition the lamp socket.

9.2.2.3 Re-fix the lens mount and replace the cover, ensuring that the test cabinet has been adequately resealed. Remove the template from the upper optical window.

This adjustment may also include the optimizing of the lens mount position so that the reading given by the photo-detector is a maximum; this operation will require removal of the template and shall be followed by a final check on the position of the image as described above.

9.2.3 Beam focusing

Open the cover to the housing on top of the test chamber, remove the compensating filter holder and slacken the lens mount. With the photo-detector system switched off and the light source switched on, adjust the lens mount for focusing and alignment so that the converging beam forms a small intense spot of light on the aperture to the photo-multiplier tube housing. Tighten the lens mount, check the beam-focusing adjustment, replace the compensating-filter holder, and close and seal the enclosure cover.

9.3 Selection of compensating filter(s)

Clean the faces of both optical windows inside the test chamber. Switch on the photometric system with the range-extension filter in the light path, the shutter open, an ND-0,5 compensating filter above the upper lens and the multi-range meter set to the range capable of recording 100 % light transmission. Operate the control for adjusting the reading of the instrument to determine whether a reading of

100 % can actually be obtained. If it can, no change in compensating filter is required; if not, use another compensating filter to satisfy this requirement.

An indication of the appropriate filter, or combination of filters, can be obtained conveniently by removing any compensating filter in the housing above the test chamber, closing the housing cover, placing a compensating filter, or filters, over the lower optical window inside the test chamber and checking the instrument reading. The choice of compensating filter determined this way shall be confirmed by the specified procedure.

Alternatively, the voltage to the photomultiplier tube may, if possible, be adjusted in order to ensure that a reading of 100 % can be reached.

9.4 Linearity check

Switch on the photometric system with the range-extension filter in the light path and the shutter closed. Adjust the zeroing device to give a reading of 0 % transmission with the instrument range switched to a full-scale reading of 0,1 % transmission; switch the instrument to the other ranges to check that the recorded transmission remains 0 %.

Open the shutter and ensure that the range-extension filter is in the light path. Adjust filter span control to give a reading of 100 % transmission with the instrument range switched to a full-scale reading of 100 % transmission.

Measure the transmission of a neutral density filter of nominal optical density of 3,0 which has been previously calibrated in another smoke density chamber system shown to be operating correctly. The difference between two transmission measurements, when expressed as a percentage of the transmission in the other smoke chamber, shall be ≤5 %. Failing such agreement, an investigation is required to determine the reason for the discrepancy.

9.5 Calibration of range-extension filter

Bring the apparatus to its normal operating condition at 25 kW/m^2 in accordance with 10.2 with the chamber wall temperature remaining steady at 40 °C ± 5 °C. Switch on the photometric system with the range-extension filter in the light path and, with the shutter closed. Adjust the zeroing device to give a reading of 0 % transmission with the instrument range switched to a full-scale reading of 0,1 % transmission.

Switch the amplifier to its 100 % transmission range, open the shutter and ensure that the range-extension filter is in the light path. Adjust the spanning device to give a reading of 100 % transmission. Place the white cloth, sheets of tissue or filter(s) with an optical density of about 2,5 (see 7.5.4.2) over the lower optical window, and switch to the 1 % transmission range. Add further filters or sheets of tissue to obtain a reading of approximately 0,5 %; do NOT adjust the controls of the photometric system. Record the transmission as T_{with}.

Without disturbing the cloth, tissue or filter(s), reset to 100 % transmission and withdraw the ND-2 range-extension filter from the light path. Note the transmission reading T_s and use it to determine, from Formulae (1) and (2), the value of the range-extension filter optical density d_f and the appropriate correction factor C_f for readings obtained when the range-extension filter is not in the light path.

$$d_f = \log_{10} \frac{T_s}{T_{with}} \quad (1)$$

$$C_f = 132(d_f - 2) \quad (2)$$

For materials having known performance, this calibration procedure is not needed unless the optical density is greater than 4.

9.6 Chamber leakage rate test

Measure the air-tightness of the test chamber on each occasion of use once every test day and when the safety blow-out panel or new seals are fitted (with the door, vents and spare gas sampling pipes closed) by introducing compressed air into the test chamber through one of the gas sampling pipes (or other compressed-air inlet) until the pressure recorded on the manometer is over 0,76 kPa (76 mm water gauge) and then shutting the supply off. The air-tightness of the test chamber shall be such that the time taken for the recorded pressure to drop from 0,76 kPa to 0,50 kPa (76 mm to 50 mm water gauge), determined using the timing device, shall be not less than 5,0 min.

9.7 Burner calibration

Set the flow rates of propane and air to achieve the flame length specified in 7.3.6.

NOTE Flow rates of approximately 50 cm^3/min of propane and 300 cm^3/min of air have been shown to give the correct flame length.

9.8 Radiator cone calibration

9.8.1 Clean the apparatus of any residues left from previous tests and, when a cone calibration is to follow soon after a test, flush the chamber (with the door shut and the exhaust and inlet vents open) with air for 2 min. Mount the heat flux meter in the specimen position with the distance from the radiator cone as specified in 7.3.2, and connect to the electrical and water services.

For intumescent materials mount, the working heat flux meter in position with a distance of 50 mm between the cone heater bottom edge and the surface of the heat flux meter, and on the centre-line of the cone heater.

9.8.2 Bring the apparatus to its normal operation condition in accordance with 10.2 with the chamber wall temperature remaining steady in accordance with 10.2.2, and move the radiation shield away from the cone.

9.8.3 With the chamber door closed, the inlet vent open and the exhaust vent closed, supply water to the heat flux meter to cool the heat flux meter body. Monitor the heat flux meter output to determine when thermal equilibrium has been reached, and then adjust the cone, as necessary, to give a steady millivolt reading corresponding to the calibrated value equivalent to an irradiance of 25 kW/m^2 or 50 kW/m^2, as required. If the door is opened for any reason during calibration, allow sufficient time after closing the door for thermal equilibrium to be reached before taking the final millivolt reading.

NOTE With some water supply systems, it may be necessary to have the chamber door slightly open to allow access for the tubing.

Allow about 10 min for stabilizing between adjustments.

9.8.4 Move the heat flux meter 25 mm away from the centre. Ensure the chamber is in the same condition as the measurement taken in 9.8.3 and allow the heat flux meter to stabilize, but do not adjust the heater control. Record the heat flux and check that it meets the requirements of 7.3.1.2.

Repeat the measurement with the heat flux meter 25 mm on the other side of the centre position.

9.8.5 Return the radiation shield to the position below the cone and remove the heat flux meter from the test chamber so that tests on specimens can proceed immediately. Continue to circulate water through the heat flux meter until the meter is cool enough for the protective cap to be replaced without melting or distortion.

9.9 Cleaning

Clean the inside walls of the chamber and the supporting framework for the cone and specimen holder using materials as described in 7.7, whenever periodic visual inspection indicates the need. Because the test is sensitive to variations in the composition of specimens, clean the apparatus when changing from tests on one material to another so that the results are not affected by chemical or physical interaction between the specimen and the residues left from previous tests on products.

NOTE Even when testing specimens of the same material, accumulations of residue can reduce the amount of deposition of smoke, resulting in an increase in the measured value of the specific optical density.

9.10 Frequency of checking and calibrating procedure

9.10.1 Undertake regular checking and calibration at periods as given in Table 1.

NOTE Products of combustion of some materials can cause corrosion of the cone heating element which can be compensated for by adjusting the applied voltage for a limited amount of change. If the cone cannot be made to give the required output, a new heating element may be required.

9.10.2 Follow the relevant setting-up procedure after any part of the equipment has been renewed or repaired.

10 Test procedure

10.1 General

The test may be carried out in the absence or in the presence of a pilot flame.

The preferred conditions are as follows:

a) specimens are exposed to an irradiance of 25 kW/m^2 in the presence or absence of a pilot flame;

b) specimens are exposed to an irradiance of 50 kW/m^2 in the presence or absence of a pilot flame.

If required, a full test evaluation will require exposure of test specimens to all 4 modes detailed in 10.9.1.

NOTE 1 Some materials will not ignite when exposed to the conditions given in a) and b), but the smoke generated in a non-flaming mode is measured under these exposure conditions whether ignition of the test specimen has occurred or not.

NOTE 2 Additional measurements presented in Annex C can be measured simultaneously during tests.

10.2 Preparation of test chamber

10.2.1 Prepare the test chamber in accordance with the requirements of Clause 9 with the cone set at 25 kW/m^2 or 50 kW/m^2. For materials that intumesce more than 10 mm, the distance between cone heater and the specimen shall be 50 mm and the pilot burner shall be positioned 15 mm down from the cone heater bottom edge.

10.2.2 If a test has just been completed, flush the test chamber with air until it is completely clear of smoke with the test chamber door closed and exhaust and inlet vents open. Inspect the inside of the cabinet and clean the walls and the supporting framework if necessary (see 9.9). Clean the faces of the optical windows inside the chamber before each test. Allow the apparatus to stabilize until the chamber

wall temperature is within the range 40 °C ± 5 °C for tests with the radiator cone at 25 kW/m^2 or within the range 55 °C ± 5 °C for tests with the radiator cone at 50 kW/m^2. Close the inlet valve.

For testing intumescent materials, the chamber wall temperature shall be within the range 50 °C ± 10 °C for tests with the radiator cone at 25 kW/m^2 or within the range 60 °C ± 10 °C for tests with the radiator cone at 50 kWm^2.

If the temperature is too high, the exhaust fan may be used to draw in cooler air from the laboratory.

10.3 Tests with pilot flame

For tests with the pilot flame, with the burner in its correct position turn on the gas and air supplies and ignite the burner, check the flame length and colour and, if necessary, adjust the flow rates to ensure that the flame is as specified in 7.3.6.

10.4 Preparation of the photometric system

Set the zero and then open the shutter to set the full-scale 100 % transmission reading. Close the shutters again and check and reset the zero if necessary, using the most sensitive (0,1 %) range. Recheck the 100 % setting. Repeat the sequence of operations until accurate zero and 100 % readings are obtained on the amplifier and recorder when the shutters are opened and closed.

10.5 Loading the specimen

Place a wrapped specimen, prepared in accordance with 6.3 and 6.4 in the holder. Place the holder and specimen on the supporting framework below the radiator cone. Remove the radiation shield from below the cone and simultaneously start the data recording system and close the inlet vent. The test chamber door and the inlet vent shall be closed immediately after the start of the test.

If preliminary tests indicate that the pilot flame has become extinguished before the shield is removed, immediately relight the pilot burner and release the shield at the same time.

10.6 Recording of light transmission

Record the percentage light transmission and time continuously from the start of the test (i.e. when the radiation shield was removed). Switch the range of the photo detector amplifier system to the next decade when required, so that readings less than 10 % of full-scale deflection are avoided.

If the transmission levels become very low and below 0,000 1 %, i.e. the smoke density becomes very high, this shall be reported as smoke density D_S above 792, i.e. $D_S > 792$.

If the light transmission falls below 0,01 %, cover the observation window in the chamber door and withdraw the range-extension filter from the light path.

Table 1 — Frequency of checks and calibrations

Item of equipment	Minimum frequency of checks and calibrations	Procedure (subclause reference)
Test chamber interior	Inspect before testing every specimen and before any calibration	9.9
Radiator cone	Once every test day and when radiator cone is renewed or replaced	9.8
Chamber (leakage rate)	Once every test day and when safety blow-out panel or new seals are fitted	9.6
Heat flux meter	Every 12 months and when meter is cleaned or recoated	7.3.4.3 and Annex A
Photometric system:		

Table 1 *(continued)*

Item of equipment	Minimum frequency of checks and calibrations	Procedure (subclause reference)
calibration	Before testing every specimen	
alignment	Every 6 months and when light source is replaced or when damage occurs	9.2
compensating filters	Every 6 months and when transmission through windows deteriorates	9.3
linearity	Every 6 months and when transmission through windows deteriorates	9.4
range-extension filter	Every 6 months	9.5

10.7 Observations

Note any particular burning characteristics of the specimen, such as delamination, intumescence, shrinkage, melting and collapse, and note the time from the start of the test at which the particular behaviour occurs, including the time of ignition and the duration of flaming. Also note the smoke characteristics, such as the colour and nature of the settled particulate matter.

The smoke generation from some materials differs significantly depending on whether combustion occurs in a non-flaming or flaming mode (see Annex E). It is important, therefore, to record as much information as possible about the mode of combustion during each test.

NOTE Coated and faced materials, including sheet laminates, tiles, fabrics and other materials secured to a substrate with an adhesive, and composite materials not attached to a substrate, can be subject to delamination, cracking, peeling or other types of separation affecting their smoke generation.

If the pilot flame is extinguished by gaseous effluent during a test and fails to re-ignite within 10 s, the gas supply to the pilot burner shall be immediately switched off (see 7.3.6).

If inflation of a thin specimen that has not been cut (see 6.5.4) has occurred, the results from that specimen shall be ignored and an extra cut specimen tested.

10.8 Termination of test

10.8.1 Carry out the test for a period of 10 min. If required, it is permissible for this test to be conducted for periods in excess of 10 min if minimum light transmittance values have not been reached during a 10 min exposure. The maximum time for any single test exposure shall be 30 min.

10.8.2 Extinguish the burner if the pilot flame has been used.

NOTE The burner is extinguished in order to obviate the possibility of air mixing with any combustion products present and causing an explosion.

10.8.3 Move the radiation shield below the cone.

10.8.4 Switch on the exhaust fan and, when the manometer indicates a small negative pressure, open the inlet vent and continue exhausting until a maximum value of light transmission is recorded, with the appropriate range selected, and noted as the "clear beam" reading T_c, for use in calculating D_c to evaluate the level of deposits on the optical windows.

10.9 Testing in different modes

10.9.1 Measure the percentage light transmission of four sets of three specimens for each material in accordance with the following schedule:

— Mode 1: Irradiance 25 kW/m^2, no pilot flame;

— Mode 2: Irradiance 25 kW/m^2, pilot flame;

— Mode 3: Irradiance 50 kW/m^2, no pilot flame;

— Mode 4: Irradiance 50 kW/m^2, pilot flame.

10.9.2 For each individual specimen, determine the percentage value of light transmission and from this calculate the appropriate specific optical density as given in 11.1. If the value of $D_s$max for any individual specimen differs from the average value for the set of three specimens of which it is part by more than 50 % of that average for no apparent reason, test an additional set of three specimens from the same sample in the same mode and record the average of all six results obtained.

NOTE Even in the same test condition, a specimen can burn with flaming and the others can burn without flaming. This would be an apparent reason and this can occur due to the different smoke emitting propensities of some materials when they burn without flames compared to when they burn with flames.

11 Expression of results

11.1 Specific optical density, D_S

NOTE The variability in the specific optical density D_s10 at 10 min from the start of the test has been investigated in a preliminary interlaboratory trial (see Annex B).

11.1.1 For each specimen, produce a graph of light transmission against time and determine the minimum transmission T_{min}. T_{min} shall be converted to specific optical density $D_s$max by calculation to two significant figures using Formula (3):

$$D_s\text{max} = 132 \log_{10} \frac{100}{T_{min}} \quad (3)$$

where

132 is a factor derived from the expression V/AL for the test chamber, where

V is the volume of the chamber;

A is the exposed area of the specimen;

L is the length of the light path.

If required, D_s at 10 min (D_s10) can be obtained from light transmission at 10 min (T_{10}) using Formula (3) replacing T_{min} with T_{10}.

The transmission used in this formula is the measured transmission. For the first four decades, this is the value recorded by the system. For the final two decades (where the range-extension filter is removed from the light path), calculate the transmission relative to the actual measuring range of 0,01 % or 0,001 %.

NOTE If the measuring range is set to 1 % with the range-extension filter removed, then the actual measuring range is 0,01 %. If the displayed transmission value is 0,523, then the actual measured transmission is 0,005 23 %.

11.1.2 If required, to each value of $D_s$max and D_s10 determined in 11.1.1, add the correction factor C_f, which depends upon the use of the range-extension filter. The value of C_f is

a) zero

   1) if the filter is in the light path at the time the transmission was recorded ($T \geq 0{,}01$ %), or

   2) if the photometric system is not equipped with a removable filter;

b) as determined by the procedure described in 9.5 if the filter is moved out of the light path at the time it is measured ($T < 0{,}01$ %).

11.2 Clear-beam correction factor, D_c

For each specimen, record the value of the "clear beam" reading T_c (see 10.8.4) to determine the correction factor D_c. Calculate D_c using Formula (3) replacing T_{min} with T_c (see 11.1). Do not record the correction factor D_c if it is less than 5 % of the maximum specific optical density determined from the graph (see 11.1).

12 Precision

The variability in the specific optical density D_s10 at 10 min from the start of the test has been investigated in a preliminary interlaboratory trial; see Annex B.

Results of an interlaboratory test on intumescent materials are summarized in Annex D.

13 Test report

The test report shall include a reference to this document together with the following information:

a) the name and address of the laboratory undertaking the test;

b) where applicable, the name and address of the manufacturer or supplier of the product tested;

c) the date(s) of the test;

d) a full description of the product tested, including such aspects as its name, type, form, essential dimensions, mass or density, colour and coverage rate of any coating;

e) a full description of the specimen construction and preparation (see 6.2.3 and 6.3);

f) the specimen face tested (see 6.1.2);

g) if calculated, the neutral-density correction factor, C_f;

h) the mode of testing (see 10.9.1), if limited testing was carried out;

i) whether the wire grid (see 7.3.5) was used;

j) the number of specimens tested for each type of exposure (see 10.9);

k) the thickness of each specimen tested;

l) for each valid specimen tested, the mode of testing, the graph of light transmission against time and the maximum specific optical density $D_s$max and, if required, the specific optical density, D_s10 at 10 min from the start of the test (see 11.1), together with the duration of the test (see 10.8);

m) for each valid specimen tested, the clear-beam correction factor, D_c (see 11.2);

n) observations of the specimens and the times from the start of the test at which the observations were made (see 5.1 and 10.7), together with details of any invalid tests and the reasons for these;

o) the mean value of $D_s$max and D_s10, if required, for each mode of testing;

p) the statement: “These results relate only to the behaviour of the specimens of the product under the particular conditions of test; they are not intended to be the sole criterion for assessing the potential smoke obscuration hazard of the product in use.”

Annex A
(normative)

Calibration of heat flux meter

Calibration of the heat flux meter shall be conducted in accordance with ISO 14934-3 whenever a check is made on the adjustment of the heater and its temperature controller. This shall be done by comparison with two instruments of the same type as the working heat flux meter and of similar range, held as reference standards and not used for any other purpose. One of the heat flux meter reference standards shall be fully calibrated at an accredited laboratory at yearly intervals. This meter shall be used to adjust the heater temperature controller (see Figure 4 and Figure 5). It shall be positioned at a location equivalent to the centre of the specimen face during this procedure.

NOTE The use of two reference standards rather than one provides a greater safeguard against change in sensitivity of the reference instruments.

Annex B
(informative)

Variability in the specific optical density of smoke measured in the single-chamber test

A preliminary interlaboratory trial has been carried out in which replicate batches of 16 materials were tested in accordance with this document by eight laboratories. The interlaboratory trial showed that the specific optical density D_s10 of some materials was more variable than that of others. The variability increased particularly for materials which did not ignite readily at 25 kW/m^2 and for materials which showed higher D_s10 values in non-flaming combustion than in flaming combustion.

The preliminary interlaboratory trial has shown that this document can enable users to discriminate between materials which generate low and high levels of smoke. Table B.1 and Table B.2 give the repeatabilities and reproducibilities of D_s10 for five plastics and five building materials, derived in accordance with ISO 5725:1986. This interlaboratory trial has been performed on configuration from edition 1 of ISO 5659-2. There is no information whether the repeatability and reproducibility results have been affected by different editions of this document.

Repeatability, r, is the value below which the difference between two D_s10 values obtained with the same method on identical test material, under the same conditions (same laboratory, same apparatus, same operator and a short interval of time), may be expected to lie with a probability of 95 %.

Reproducibility, R, is the value below which the difference between two D_s10 values obtained with the same method on identical test material, under different conditions (different laboratories, different operators, different apparatus), may be expected to lie with a probability of 95 %.

The preliminary interlaboratory trial has indicated that it is not meaningful to quote a single value for the variation of the test. The D_s10 data show that smoke generation depends upon the ignition behaviour of materials. Since ignition times are sensitive to irradiance, it is clear that careful attention has to be paid to the measurement of irradiance.

Table B.1 — Repeatability and reproducibility of specific optical density for plastics

Material	Thickness mm	Irradiance kW/m²	Mean D_s10	Repeatability (within laboratory)		Reproducibility (between laboratories)	
				r	% of mean	R	% of mean
PMMA	1,0	25 25 + pf 50	11 55 54	4 13 11	38 24 20	10 29 17	91 53 32
ABS	1,1	25 25 + pf 50	312 441 435	77 146 102	25 33 23	311 205 192	100 46 44
Rigid polyurethane foam (28 kg/m³)	25,0	25 25 + pf 50	49 48 145	16 24 48	32 51 33	61 26 97	124 54 67
Flexible polyurethane foam (27 kg/m³)	25,0	25 25 + pf 50	178 80 127	49 28 46	27 35 36	114 56 80	64 70 63
Expanded polystyrene (non-fire-retardant; 14 kg/m³)	25,0	25 25 + pf 50	112 102 270	75 75 88	67 74 33	196 130 195	175 128 72
NOTE + pf indicates a test carried out in mode 2 (i.e. with pilot flame).							

Table B.2 — Repeatability and reproducibility of specific optical density for building materials

Material	Thickness mm	Irradiance kW/m²	Mean D_s10	Repeatability (within laboratory)		Reproducibility (between laboratories)	
				r	% of mean	R	% of mean
Pine	12,1	25 25 + pf 50	403 26 196	97 15 191	24 55 98	300 56 191	74 211 98
Chipboard	12,2	25 25 + pf 50	411 58 481	47 59 96	12 102 20	187 88 464	45 153 97
Plywood	4,2	25 25 + pf 50	251 33 113	31 15 58	12 47 51	132 58 82	52 175 72
Medium-density fibreboard	11,9	25 25 + pf 50	420 68 688	127 42 114	30 62 17	281 72 413	67 106 60
Paper-faced plasterboard	12,7	25 25 + pf 50	20 8 17	8 8 11	42 104 64	21 25 23	107 314 132
NOTE + pf indicates a test carried out in mode 2 (i.e. with pilot flame).							

Annex C
(informative)

Determination of mass optical density

C.1 General

This annex gives, for information only, a method which may be used to determine the mass optical density of a material (see 3.7). Values of mass optical density determined by this method are specific to the specimen or assembly material in the form and thickness tested and are not to be considered inherent, fundamental properties.

C.2 Principles of the test

The conditions of thermal exposure and of smoke collection are the same as for specific optical density. Additional mass measurements are carried out on the specimen during the test so that a mass loss/time curve is determined and mass optical density is also calculated.

C.3 Test specimens

C.3.1 The same specifications for suitability of materials shall apply (see Clause 5). Similarly, the same number of specimens and the same preparation and conditioning procedures shall be used (see Clause 6).

C.3.2 Each test specimen shall be weighed wrapped in its aluminium foil and held in its specimen holder, to give the initial mass (m_i).

C.4 Ancillary equipment

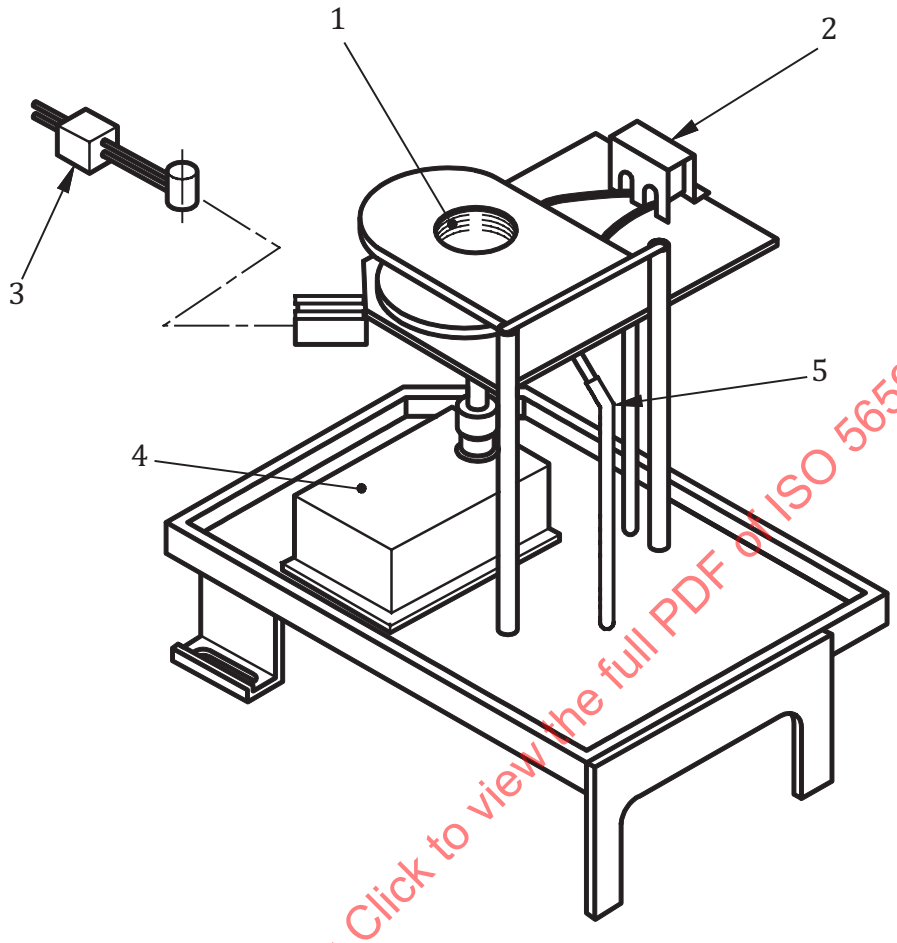
C.4.1 The load cell shall have a measuring range of 500 g to a weighing accuracy of ±0,1 g. The load cell shall be mounted in an enclosure (see Figure C.1, Figure C.2 and Figure C.3) with a close-fitting labyrinth seal between the sample support rod and the enclosure to minimize ingress of smoke particles and corrosive fumes.

The load cell assembly shall be easily removable from the smoke chamber so that the procedure for determination of specific optical density may be performed without unnecessary exposure of the load cell if mass optical density data are not required.

The load cell enclosure shall be fitted with one fixed foot and two adjustable feet to level the unit on the baseplate. The load cell shall also have means for centring the load cell assembly beneath the cone radiator.

C.4.2 The load cell shall have a safe operating temperature range from 15 °C to 70 °C. A mineral-fibreboard shield shall be positioned over the top and sides of the load cell enclosure during thermal exposure of the test specimen so that excessive temperature rise within the enclosure is prevented and drift of the load cell is avoided.

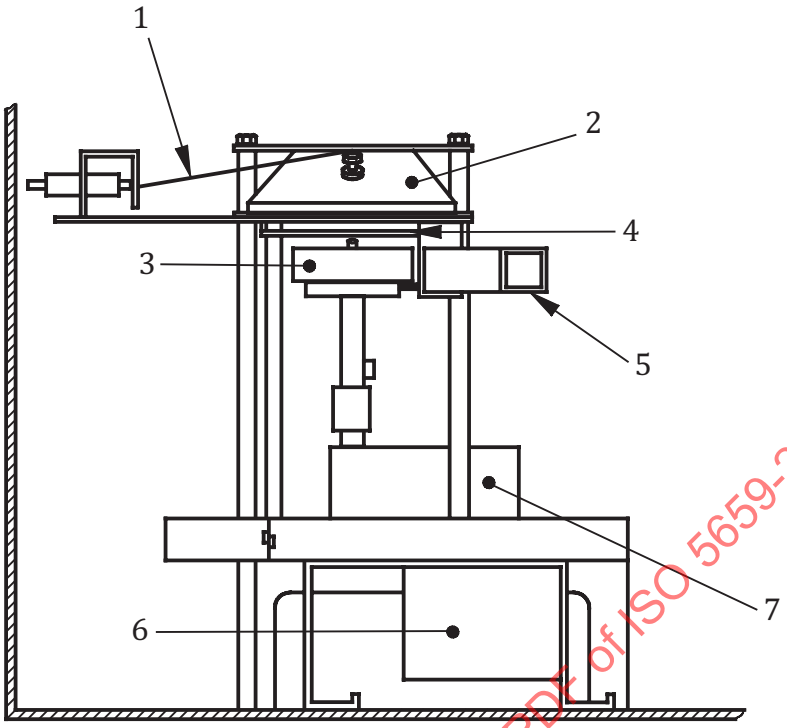
C.4.3 The load cell shall be connected to a controller which drives the load cell and which is situated outside the smoke chamber. This controller should preferably be fitted with a digital weight display, scalable millivolt output and tare facility.



Key

1 heating element
2 thermocouple mount and shield
3 heat flux meter and mount
4 load cell
5 pilot burner

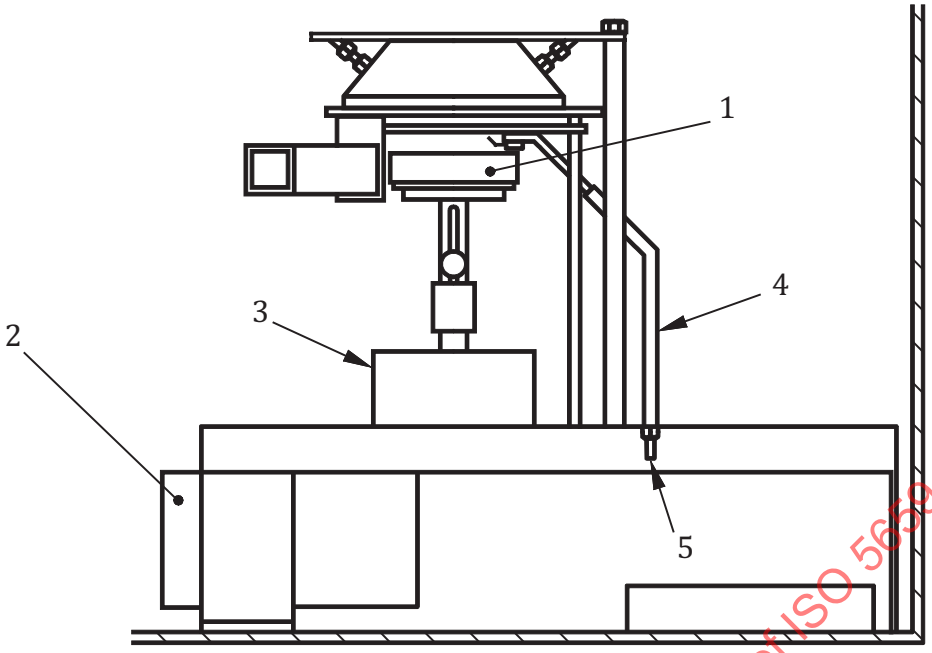
Figure C.1 — Typical framework for support of radiator cone, specimen and flux meter



Key

1 thermocouple
2 radiator cone heating element
3 specimen holder
4 radiator shield
5 heat flux meter holder
6 spark ignition supply
7 load cell

Figure C.2 — Typical arrangement of radiator cone, specimen holder and radiator shield with load cell for mass optical density determination (side view)



Key

1 specimen holder
2 spark ignition housing
3 load cell
4 pilot burner and ignition electrode
5 propane and air

Figure C.3 — Typical arrangement of radiator cone, specimen holder and radiator shield (front view)

C.5 Calibration procedure

The load cell calibration shall be checked with standard reference masses in the range of the test specimen mass before each series of tests.

C.6 Test procedure

C.6.1 Preparation of test chamber

Prepare the test chamber, pilot flame and photometric system as described in 10.1, 10.2, 10.3 and 10.4.

C.6.2 Loading the specimen

Place a wrapped specimen, prepared in accordance with 6.3 and 6.4, including backing fibre blanket if required, in its holder. Place the holder and specimen on the pan of the load cell below the radiator cone and immediately close the test chamber door. Set the load cell controller to record the initial mass (m_i) of the test specimen, backing board and specimen holder. Remove the radiator shield from below the cone and simultaneously start the data recording system and close the inlet vent.

Alternatively, the specimen holder and backing material mass may be tared before putting the wrapped specimen into the holder so that the mass of the specimen is measured by the load cell controller.

C.6.3 Recording of light transmission and mass loss

Record the percentage light transmission, mass of specimen and holder, and time continuously from the start of the test (i.e. when the radiation shield was removed) or at time intervals no greater than 30 s.

Perform the test and carry out the observations in accordance with 10.5 and 10.6 respectively.

C.6.4 Termination of test

C.6.4.1 Carry out the test for a period of 10 min (see 10.8.1) and extinguish the burner if the pilot flame has been used (see 10.8.2).

C.6.4.2 Move the radiation shield below the cone.

C.6.4.3 Switch on the exhaust fan to remove smoke and fumes from the test chamber (see 10.8.4).

C.6.4.4 Record the final mass (m_f) of the test specimen, backing board and specimen holder.

C.6.5 Repeat tests

The same criteria shall apply as in 10.9.1 and 10.9.2.

C.7 Expression of results

For each specimen, calculate the mass optical density MOD at 10 min, in square metres per kilogram (m^2/kg), using Formula (C.1):

$$\text{MOD} = \frac{D}{L} \times \frac{V}{\Delta m} \tag{C.1}$$

where

D is the optical density of the smoke (see 3.10);

L is the length of the light path;

V is the chamber volume;

Δm is the loss in mass of the test specimen (i.e. m_i - m_f).

The chamber volume V shall be taken as 0,51 m^3 and the length of the light path L as 0,915 m.

NOTE The mass optical density can be calculated at times other than 10 min, by using the specimen mass/time graph recorded during the test.

C.8 Test report

The test report shall include all the information required in Clause 13 and, for each valid specimen tested, the following information:

a) the graph of specimen mass against time;

b) the mass optical density at 10 min, from the start of the test.

Annex D
(informative)

Precision data from tests on intumescent materials

D.1 Background

An interlaboratory trial was organized in order to give background data for amendments to the test method for intumescent materials using specimen-heater distance of 50 mm. This interlaboratory trial has been performed on configuration proposed in edition 1 of ISO 5659-2. It is supposed that repeatability and reproducibility results have not been affected or may have been improved between recent versions of this document.

D.2 Specimens

Two types of specimen were used:

— polycarbonate, 6 mm thickness;

— polyvinyl chloride (PVC) floor covering, 3 mm thickness.

D.3 Participating laboratories

Nine laboratories participated in the tests for PVC flooring, and 10 laboratories participated in the test for polycarbonate.

D.4 Test method

Tests were conducted according to this document except that the specimen supporting system was adjusted to have 50 mm distance between the specimen exposed surface and the conical radiant heater bottom edge. Calibration of heat flux level to specimen surface was conducted by heat flux meters set at the specimen position (50 mm below the bottom edge of the conical radiant heater), and the conical heater temperature was set to deliver a heat flux of 25 (kW/m^2) and 50 (kW/m^2) to the specimen at that position.

The pilot burner was kept at the position specified in this document, i.e. 15 mm down from the cone heater bottom edge.

Tests were conducted in three test conditions:

a) heat flux to the specimen: 25 kW/m^2, and with pilot flame;

b) heat flux to the specimen: 25 kW/m^2, and without pilot flame;

c) heat flux to the specimen: 50 kW/m^2, and without pilot flame.

D.5 Test results

Tables D.1 and D.2 show the test results. Repeatability and reproducibility were calculated according to ISO 5725-2. Outliers were eliminated in accordance with ISO 5725-2. Table D.3 gives the cone heater temperature and the inside-wall temperature of the smoke chamber, which were measured during the interlaboratory trial.

Table D.1 — Test results for polycarbonate

Test condition	Parameter	Average A	Repeatability r	r/A %	Reproducibility R	R/A %	Number of laboratories
25 kW/m^2 With pilot flame	D_s10	8,4	1,6	20,1	3,8	45,2	6
	$D_s$max	17,1	2,1	10,4	5,4	31,8	6
25 kW/m^2 Without pilot flame	D_s10	8,7	1,2	15,9	2,5	28,4	5
	$D_s$max	22,2	1,8	8,1	3,7	16,7	6
50 kW/m^2 Without pilot flame	D_s10	[a]	[a]	[a]	[a]	[a]	[a]
	$D_s$max	[a]	[a]	[a]	[a]	[a]	[a]

[a] Most of the laboratories reported that the D_s10 and $D_s$max exceeded 500.

Table D.2 — Test results for PVC flooring

Test condition	Parameter	Average A	Repeatability r	r/A %	Reproducibility R	R/A %	Number of laboratories
25 kW/m^2 With pilot flame	D_s10	260,8	47,8	18,8	74,7	28,6	9
	$D_s$max	296,0	57,9	20,1	96,3	32,5	9
25 kW/m^2 Without pilot flame	D_s10	472,6	41,6	9,8	124,0	26,2	9
	$D_s$max	504,0	22,7	4,8	101,9	20,2	9
50 kW/m^2 Without pilot flame	D_s10	376,6	26,8	6,8	110,4	29,3	8
	$D_s$max	491,6	28,7	6,0	95,9	19,5	8

Table D.3 — Smoke chamber temperatures during test

Heat flux level to specimen kW/m^2	Conical heater temperature °C	Maximum inside wall temperature of the smoke chamber during the test °C
25	from 658 to 716	63
50	from 855 to 919	90

Annex E
(informative)

Guidance on optical density testing

E.1 General

Smoke represents a major hazard in fires due to its capacity to obscure vision by the absorption and scattering of light. Consequently, two threats are obvious: the inhalation of hazardous gases and fumes and the obscuration of light by smoke particulates leading to disorientation. These threats interact in a complicated manner, but are usually dealt with by separate procedures.

Smoke particulates reduce the visibility due to light absorption and scattering. Consequently, people can experience difficulties in finding exit signs, doors and windows. Visibility is often determined as the distance at which an object is no longer visible. It depends on many factors, such as temperature, humidity and smoke irritancy. Of particular interest for fire safety are the close relationships that have been established between visibility and measurements of the optical density of smoke. Results in Reference [3] are depicted simply in Figure E.1. Visibility is approximately inversely proportional to the extinction coefficient k so that $w = y/k$ where w is the visibility and y is the constant of proportionality. There is a broad spread in the experimental data for visibility since it depends on other factors such as external illumination, the brightness of light-emitting signs and the reflectance of light-reflecting signs. Calculations of visibility using this relationship should be regarded cautiously as estimates. As a further example of these effects, a y-value of 3 for light-reflecting signs and a y-value of 8 for light-emitting signs were chosen in Reference [3]; the spread of data for these signs is shown in Figure E.2, where the lower spread for light-emitting signs typifies the conditions used in the smoke chamber.

The generation of smoke and the measurement of the optical density are often measured simultaneously with other fire properties, such as heat release or flame spread. The measurements may be in small, intermediate, large or real scale. They may be performed in small-scale, closed systems and are called cumulative or static methods. They may also be performed in a flow-through system, and these are called dynamic methods.

The smoke chamber, as in this document, is also suitable used for fire effluent measurements when effluent gases are extracted and analysed at specified times during a test (see References [10], [11], [12] and [13]). Nevertheless, there is no way to directly relate these measurements to a fire stage according to ISO 19706.

A distinction should be made between smoke, which includes visible part of fire effluents and soot, which is particulate matter produced and deposited during and after combustion. ISO 29904 describes with more details all measurements related to smoke particles. Smoke is measured by optical means and soot is determined by actual weighing of particulates collected (gravimetric means). Since fire safety concerns are often with optical smoke measurements, the guidance on smoke tests will focus on obscuration of visibility. This document does not provide guidance on the determination of soot particles or on their potential health risks to occupants of a space affected by smoke.