INTERNATIONAL STANDARD

ISO 5659-2

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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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Contents

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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.

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.

International Standard ISO 5659-2 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

ISO 5659 consists of the following parts, under the general title *Plastics — Smoke generation*:

— *Part 1: Guidance*

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

— *Part 3: Determination of optical density by dynamic flow*

Annex A forms an integral part of this part of ISO 5659. Annexes B and C are for information only.

Introduction

Fire is a complex phenomenon: its development and its 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 (see also ISO/TR 3814 and ISO/IEC Guide 52).

A test such as is specified in this part of ISO 5659 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/IEC Guide 52 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 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.

The attention of all users of this test is drawn to the warnings which immediately precede the "Scope" clause.

Plastics — Smoke generation —

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

WARNING

1 Avoidance of misleading inferences

This standard method of test should be used solely to measure and describe the properties of materials, products or systems in response to heat or flame under controlled laboratory conditions, and should not be considered or used by itself for describing or appraising the fire hazard of materials, products or systems under actual fire conditions or as the sole source on which regulations pertaining to smoke production can be based.

2 Avoidance of danger to test operators

So that suitable precautions to safeguard health are taken, the attention of all concerned in fire tests is drawn to the fact that harmful gases are evolved in combustion of test specimens. Care must also be taken during cleaning operations on the smoke chamber to avoid inhalation of fumes or skin-contact with smoke deposits.

Attention is drawn to the hazards arising from the hot radiator cone, and the use of a mains-voltage electricity supply.

A safety blow-out panel, as specified in 7.2.1.1, is essential for the protection of operators from the risk of explosion from sudden pressure surges.

1 Scope

1.1 This part of ISO 5659 specifies a method of measuring smoke production from the exposed surface of specimens of essentially flat materials, composites or assemblies not exceeding 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 and may also be used for the evaluation of other materials (e.g. rubbers, textile-coverings, painted surfaces, wood and other building materials).

1.2 Values of optical density determined by this test are specific to the specimen or assembly material in the form and thickness tested, and are not to be considered inherent, fundamental properties.

1.3 The test is intended for use in research and development and not primarily as a basis for ratings for building codes or other purposes. No basis is provided for predicting the density of smoke which may be generated by the materials upon exposure to heat and flame under other exposure conditions, nor has any correlation been established with measurements derived from other test methods.

The fact that this test procedure excludes the effect of irritants on the eye should also be taken into account when applying the test results.

1.4 It is emphasized that smoke production from a material varies according to the irradiance level to which the specimen is exposed. In making use of the results of this method, it should be borne in mind that the results are based on exposure to the specific irradiance levels of 25 kW/m^2 and 50 kW/m^2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 5659. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 5659 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 3261:1975, *Fire tests — Vocabulary.*

ISO/TR 3814:1989, *Tests for measuring "reaction-to-fire" of building materials — Their development and application.*

ISO 5659-1:—[1], *Plastics — Smoke generation — Part 1: Guidance.*

ISO 5725:1986, *Precision of test methods — Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests.*

ISO/IEC Guide 52:1990, *Glossary of fire terms and definitions.*

3 Definitions

For the purposes of this part of ISO 5659, the definitions given in ISO/IEC Guide 52 and the following definitions apply.

3.1 assembly: A fabrication of materials and/or composites, for example sandwich panels. This may include an air gap.

3.2 composite: A combination of materials which are generally recognized in building construction as discrete entities, for example coated or laminated materials.

3.3 essentially flat surface: A surface in which departure from a plane does not exceed ± 1 mm.

3.4 exposed surface: That surface of the product subjected to the heating conditions of the test.

3.5 irradiance (at a point on a surface): The radiant flux incident on an infinitesimal element of the surface containing the point divided by the area of that element.

3.6 material: A basic single substance or uniformly dispersed mixture, for example metal, stone, timber, concrete, mineral fibre, polymers.

3.7 mass optical density (MOD): A measure of the degree of opacity of smoke in terms of the mass loss of the material under the conditions of the test.

3.8 optical density of smoke (D)**:** A measure of the degree of opacity of smoke; the negative common logarithm of the relative transmission of light.

3.9 product: The material, composite or assembly about which information is required.

3.10 specific optical density (D_s)**:** The optical density multiplied by a factor which is calculated by dividing the volume of the test chamber by the product of the exposed area of the specimen and the path length of the light beam (see 11.1.1).

3.11 specimen: A representative piece of the product which is to be tested together with any substrate or treatment. This may include an air gap.

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 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 absence of a pilot flame;

NOTE 1 Some materials will not ignite when exposed to the conditions given in a) and b).

1) To be published.

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 for testing

5.1 Material geometry

5.1.1 The method is applicable to essentially flat materials, composites and 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 as tested. It is not possible to calculate the specific optical density of one thickness of a material from the specific optical density of another thickness of the material.

5.2 Physical characteristics

Materials submitted for evaluation by this method could have faces which differ or could contain laminations of different materials arranged in a different order in relation to the two faces. If either of the faces is likely to be exposed to a fire condition when in use, then both faces shall be evaluated.

6 Specimen construction and preparation

6.1 Number of specimens

6.1.1 The test sample shall comprise a minimum of nine specimens: six specimens shall be tested at 25 kW/m^2 (three specimens with a pilot flame and three specimens without a pilot flame) and three specimens shall be tested at 50 kW/m^2 without a pilot flame.

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 nine specimens (i.e. three specimens per test mode) shall be held in reserve if required by the conditions specified in 10.8.2.

6.2 Size of specimens

6.2.1 The specimens shall be square, with sides measuring (75 $^{0}_{-1}$) mm.

6.2.2 Materials of nominal thickness 25 mm 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 $^{0}_{-1}$) mm, in such a way that the original (uncut) face can be evaluated.

6.2.4 Specimens of multilayer 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.

6.4 Wrapping of specimens

6.4.1 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, with 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 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 where appropriate.

6.4.2 All wrapped specimens shall be backed with one or more sheets of non-combustible insulating board of oven-dry density 850 kg/m^3 ± 100 kg/m^3 and nominal thickness 12,5 mm to ensure that the top edges of the specimen are pressed against the retaining lips of the specimen holder. As an exception to this requirement, wrapped specimens of foam plastics of 25 mm thickness may be tested without a backing-board. Wrapped specimens less than 25 mm thick shall be backed by at least one sheet of non-combustible board with or without a layer of mineral-fibre blanket underneath to accommodate a wider variety of specimen thicknesses.

6.4.3 With 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 of the specimen holder.

6.4.4 When thin impermeable specimens, such as thermoplastic films, become inflated during the test due 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.

6.5 Conditioning

6.5.1 Before preparing the specimens for test, they shall be conditioned to constant mass at 23 °C ± 2 °C and (50 ± 5) % R.H., where constant mass shall be considered to have been 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 specimen or 0,1 g, whichever is the greater (see ISO 291).

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

NOTES

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

3 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.

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 figures 1 and 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. 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 stainless-steel wire mesh. It is important that such a 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 cabinet 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 cabinet 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 of the chamber at the top and away from the radiator cone, and an exhaust vent with shutter shall be provided in the bottom of the chamber to lead, via flexible tubing with a diameter of 50 mm to 100 mm, to an extraction fan capable of creating a negative pressure of at least 0,5 kPa (50 mm water gauge).

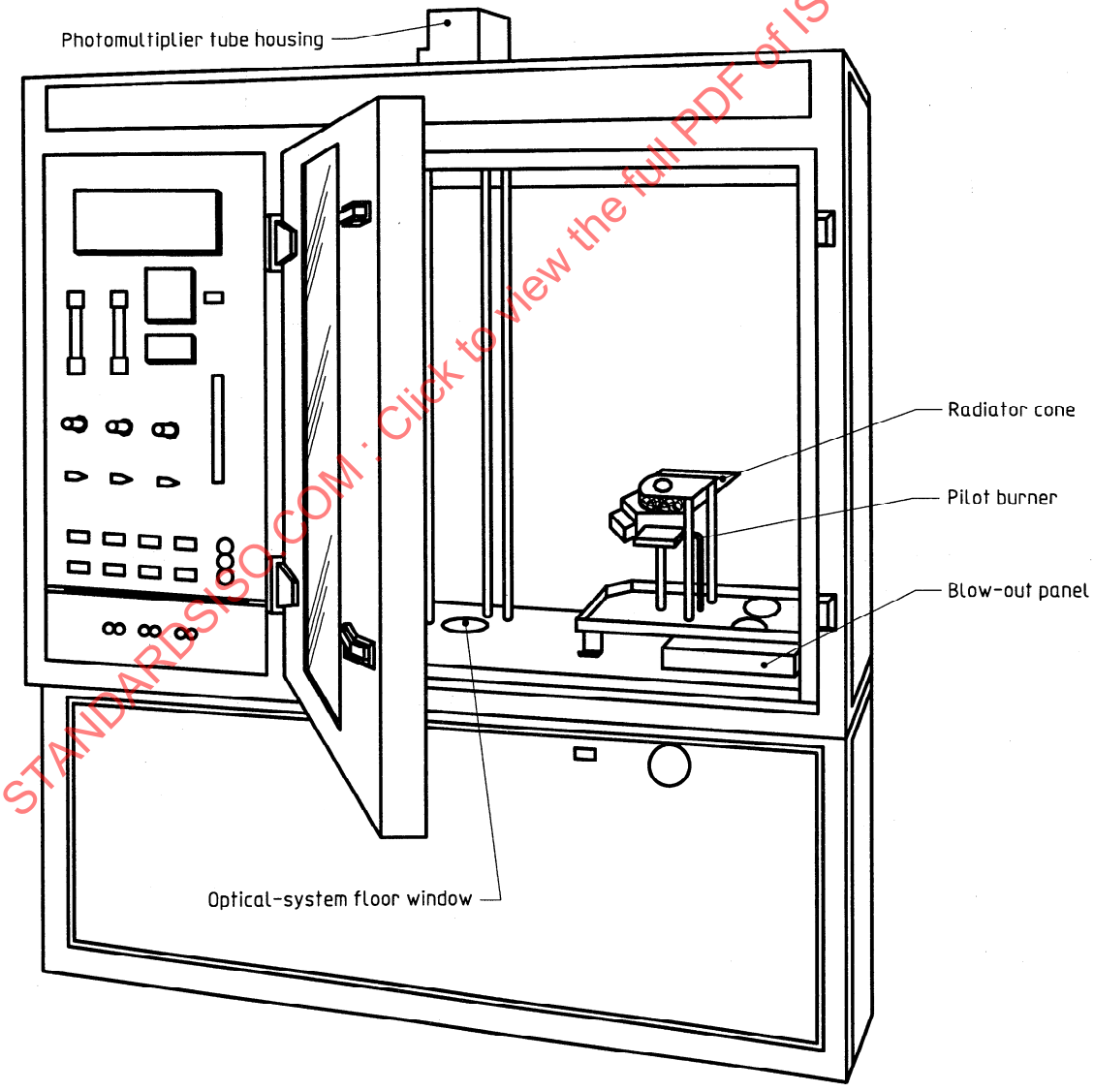

Figure 1 — Typical arrangement of test apparatus

Dimensions in millimetres
(not to scale)

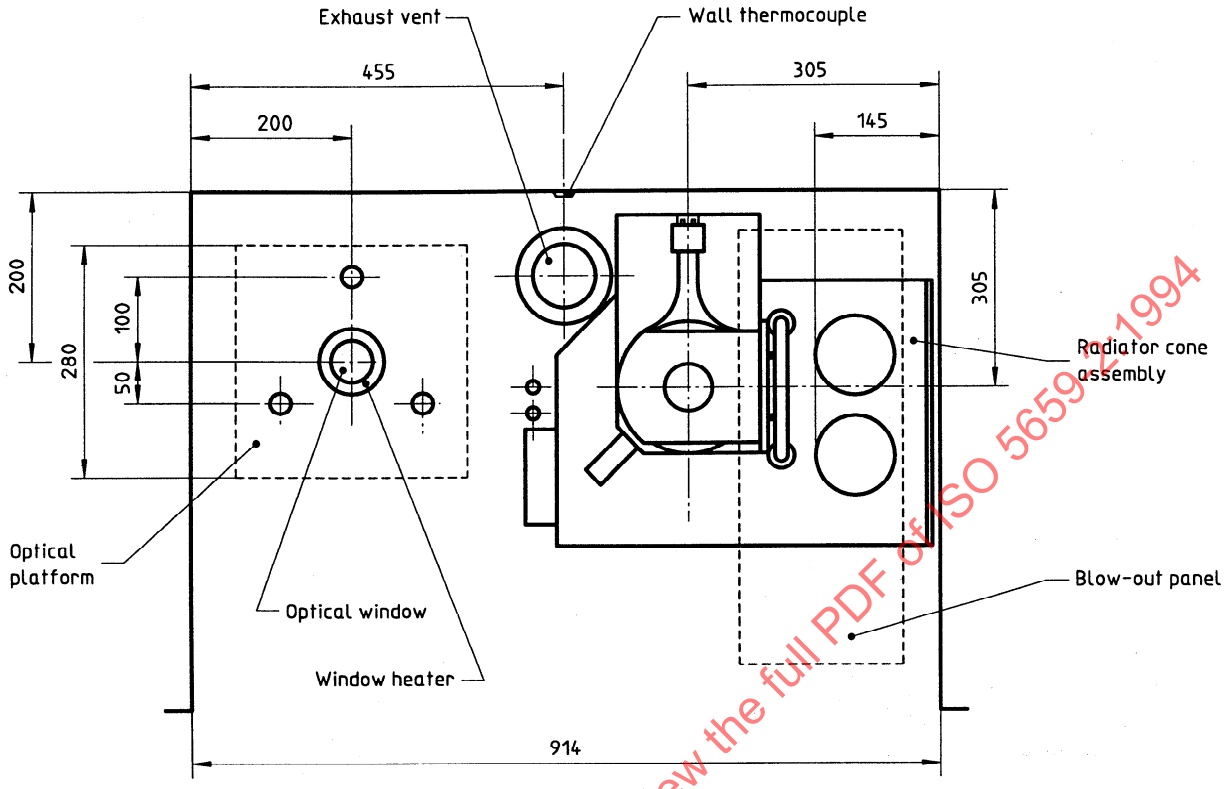

Figure 2 — Plan view of typical test chamber

7.2.2 Chamber pressure control facilities

Provision shall be made for controlling the pressure inside the test chamber. A water 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.

A suitable pressure regulator (see figure 3) consists of an open 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.

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) with 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 60 °C (see 10.1.2).

Dimensions in millimetres

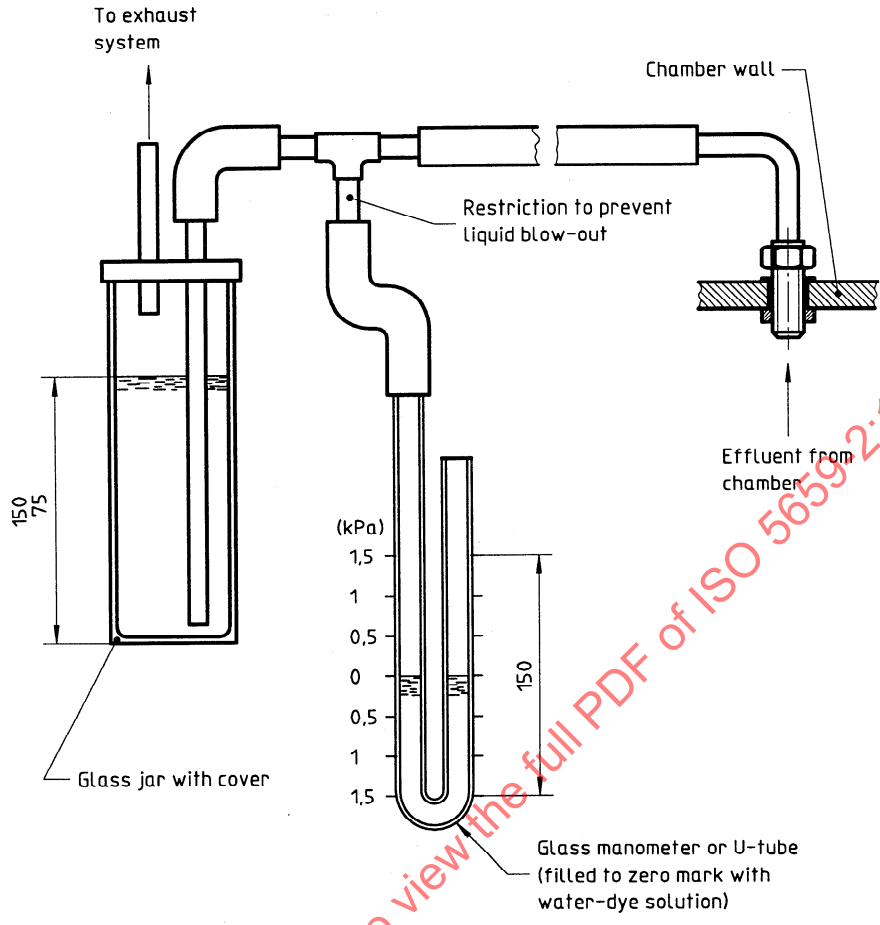

Figure 3 — Typical chamber pressure relief manometer

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 450 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 $(45\ ^{0}_{-0,4})$ 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.

7.3.1.3 The temperature controller for the radiator cone shall be a proportional, integral and differential-type 3-term controller with thyristor stack fast-cycle or phase angle control of not less than 10 A maximum rating. Capacity for adjustment of integral time between 10 s and 50 s and differential time between 25 s and 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 will be given by a heater temperature in the range 700 °C to 750 °C. Automatic cold-junction compensation of the thermocouple shall be provided.

NOTE 4 While phase angle control is allowed for 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.

7.3.1.4 The irradiance of the radiator cone shall be controlled by reference to the reading of two type K sheathed copper/alumel 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.

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 the lower rim of the radiator cone shade is 25 mm ± 1 mm above the upper surface of the specimen when oriented in the horizontal position. Details of the radiator cone and supports are shown in figures 4 and 5.

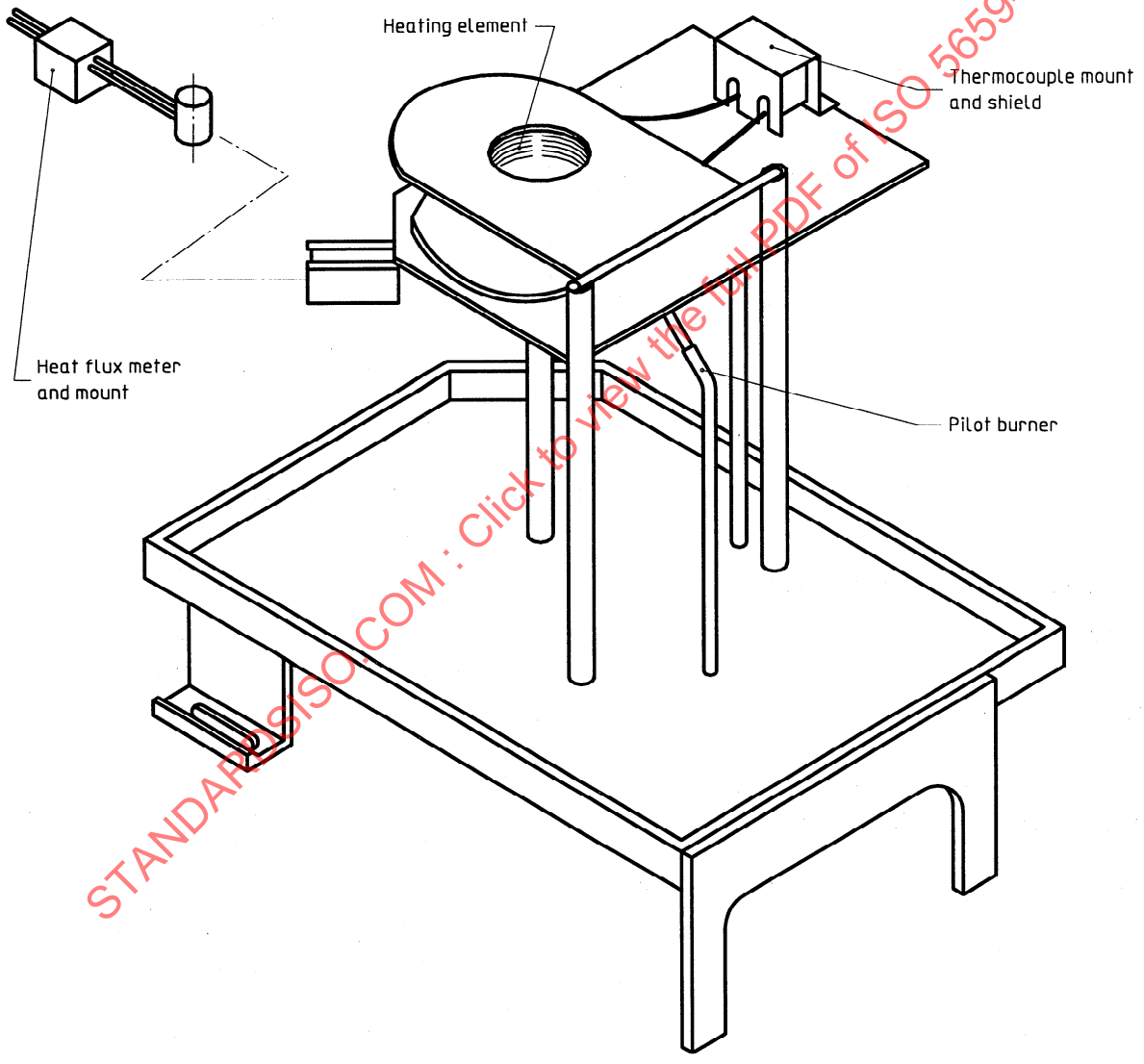

Figure 4 — Typical framework for support of radiator cone, specimen holder and flux meter

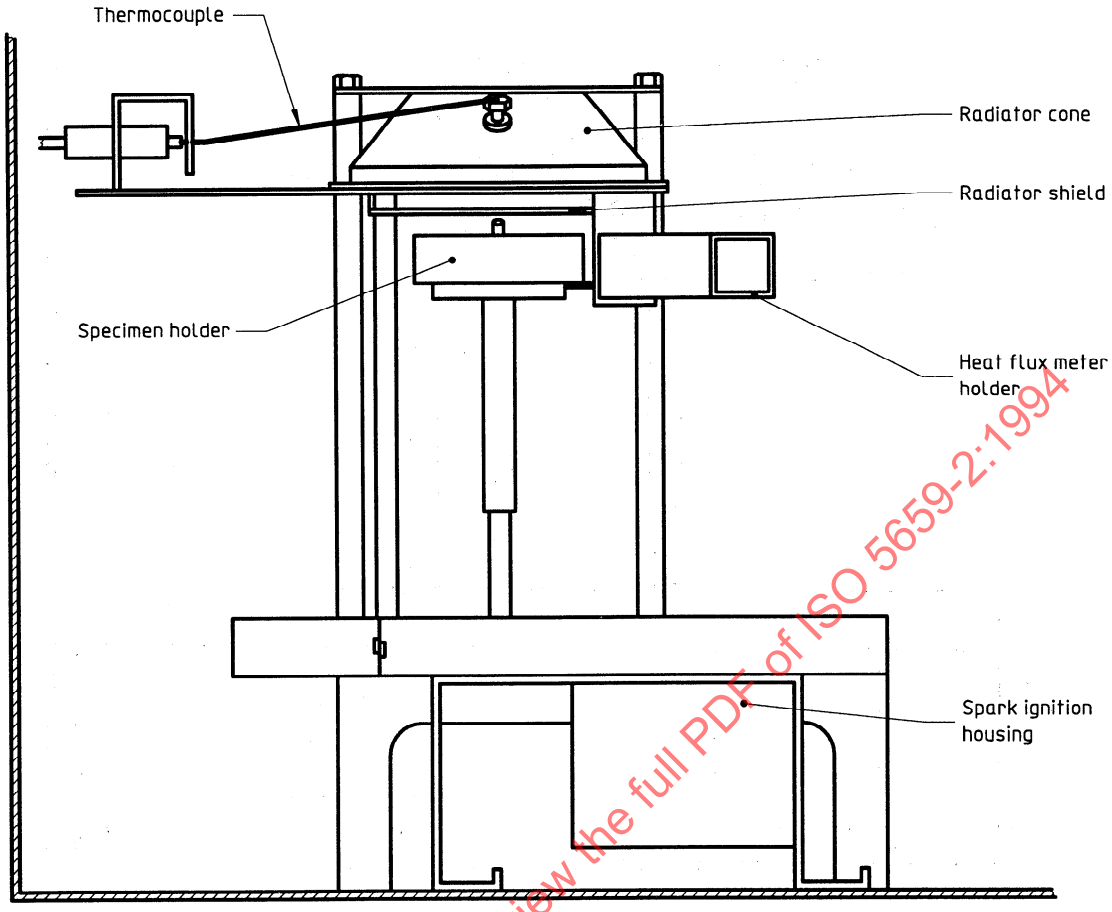

Figure 5 — Typical arrangement of radiator cone, specimen holder and radiator shield (side view)

7.3.3 Radiator shield

A remotely controllable metallic and/or inorganic shield (see figures 5 and 6) of minimum diameter 130 mm and upper surface situated (when in place) approximately mid-way between the base of the radiator cone and the specimen surface shall be provided to cut off the irradiance to the specimen before and after the required exposure period.

NOTE 5 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 the foil (Gardon) or thermopile (Schmidt-Boelter) type with a design range of about 50 kW/m^2. The target receiving the radiation (see figure 4) shall have a flat, circular face of 10 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 (7.8.6) or meter, 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 $\pm$ 1 kW/m^2.

If a recorder which only displays a millivolt output is used, the millivolt value shall be converted to kW/m^2 using the calibration factor (or equation 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 $\pm$ 1 kW/m^2 and 50 kW/m^2 $\pm$ 1 kW/m^2 averaged over the 10 mm diameter area of the heat flux meter (see annex A).

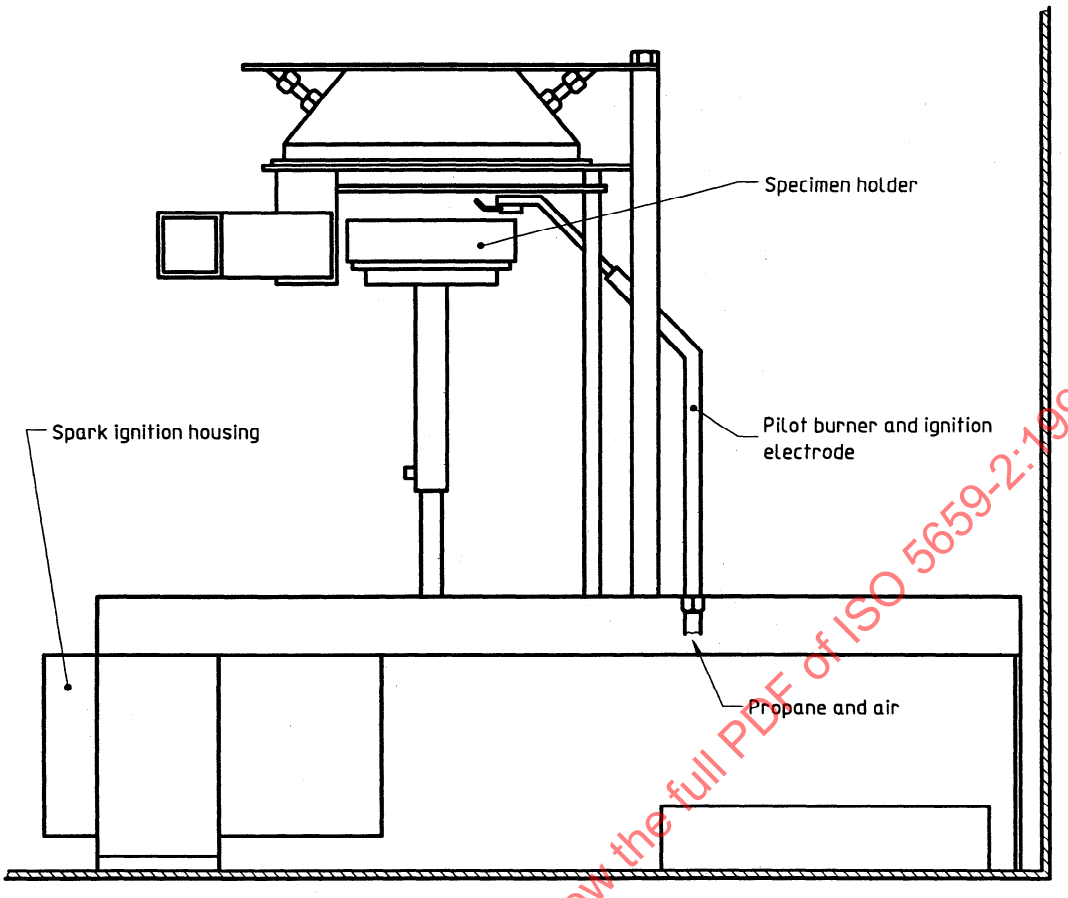

Figure 6 — Typical arrangement of radiator cone, specimen holder and radiator shield (front view)

7.3.5 Specimen holder

Details of the specimen holder are shown in figure 7. The base shall be lined with low-density (nominal 65 kg/m^3) refractory fibre blanket with a minimum thickness of 10 mm. A retainer frame and wire grid shall be used when testing intumescing specimens and can be used to reduce unrepresentative edge-burning of composite specimens or for retaining specimens prone to delamination. The wire grid shall be 75 mm square with 20-mm-square holes constructed from 2 mm stainless-steel rod welded at all intersections.

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 shall be positioned horizontally 10 mm above the top face of the specimen. 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.

7.4 Gas supply

A mixture of propane of at least 95 % purity and at a 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 calibrated flowmeters to a point at which they are mixed and supplied to the burner. The flowmeter 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.

Dimensions in millimetres

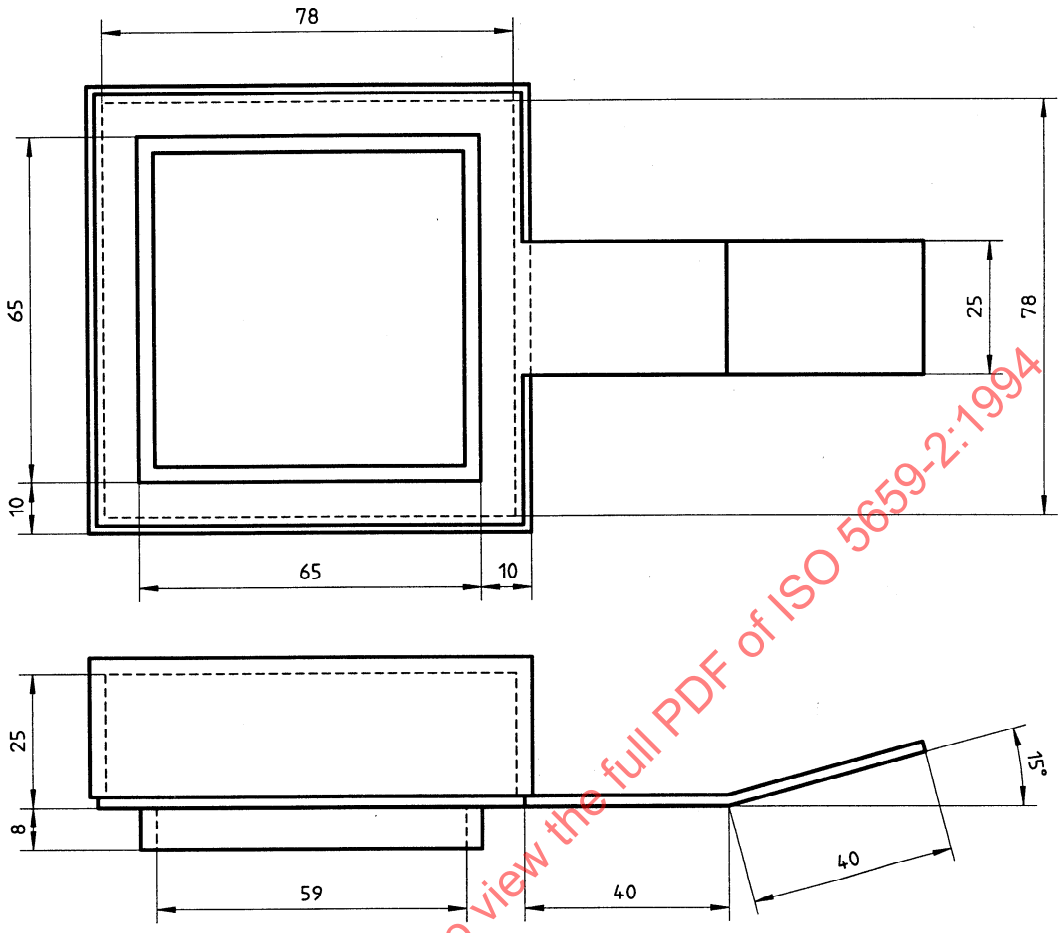

Figure 7 — Specimen holder

7.5 Photometric system

7.5.1 General

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

The system shall be as shown in figure 8. Equipment shall be provided to control the output of the light source, and to measure the amount of light falling on the photodetector.

7.5.2 Light source

The light source shall be a 6,5 V incandescent lamp. Power for the lamp shall be provided by a transformer producing 6,5 V and a rheostat so that the r.m.s. voltage across the lamp, as determined by a voltmeter, is maintained at 4 V $\pm$ 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.

Dimensions in millimetres

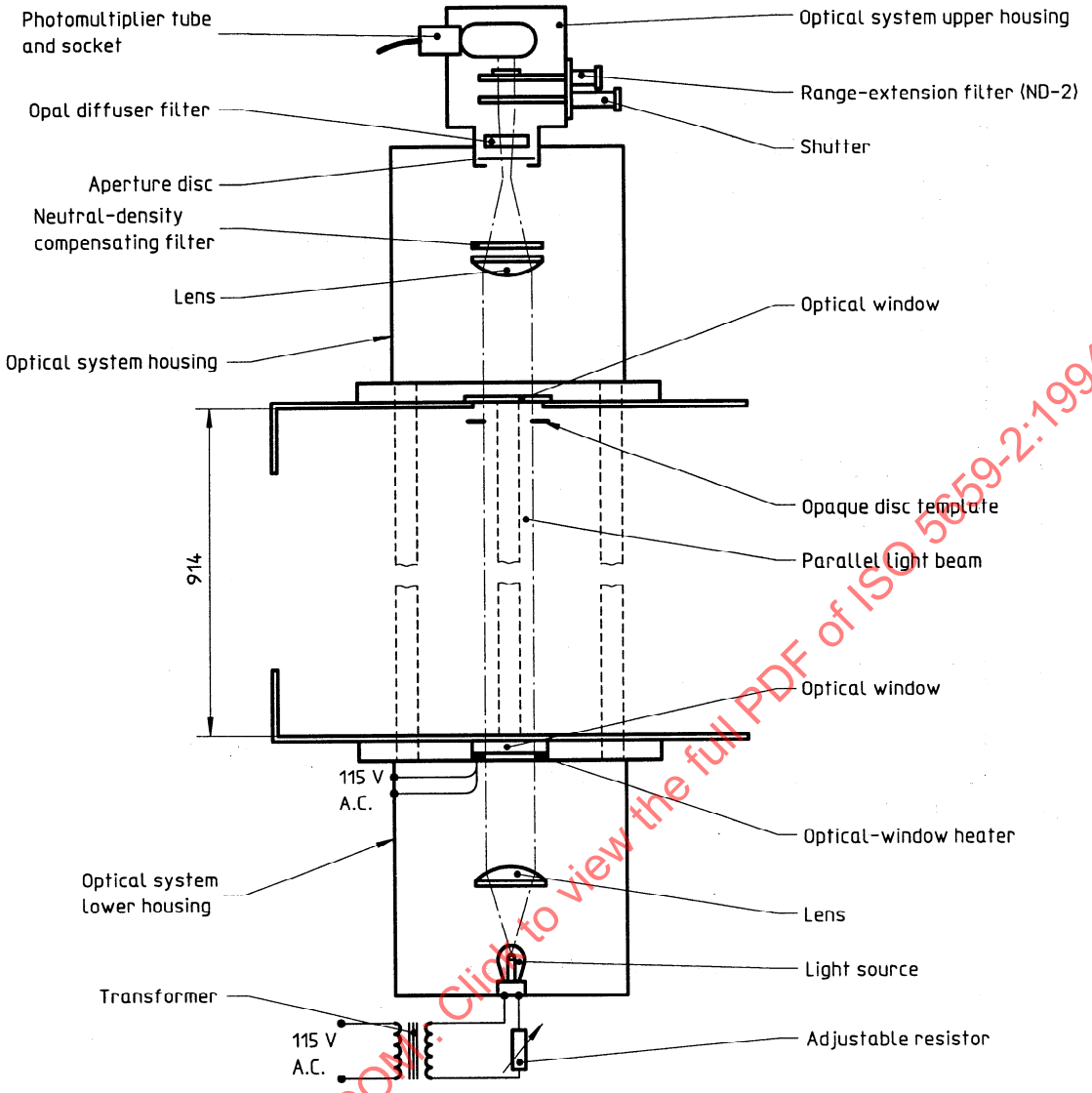

Figure 8 — Photometric system

7.5.3 Photodetector

7.5.3.1 The light-measuring system shall consist of a photomultiplier tube connected to a multi-range amplifier coupled to a recording device (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 $\pm$ 3 % of the maximum reading on any range.

For selection of photomultiplier tubes, as applicable, the minimum sensitivity shall allow a 100 % reading to be obtained with a 0,5 neutral-density filter and an 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 6 The required accuracy of the photodetector 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.

7.5.3.2 The photomultiplier tube shall be mounted in the upper section of the detector housing. Below it, there shall be an assembly which provides for the rapid positioning of a filter and of a shutter, in or out of the path of the collimated light beam, each being operated separately. 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 photomultiplier tube. An opal diffuser shall be permanently mounted below the shutter.

7.5.3.3 The lower part of the upper housing shall support a 51-mm-diameter lens 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 gelatin 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, the actual optical density having been determined by calibration, shall be available for calibrating the photometric system.

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.

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 neutral-density filter 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, the chamber shall be sufficiently air-tight to comply with the requirements of the leakage rate test given in 9.6.

NOTE 7 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 8 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.

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 an 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 can be used if required to help the chamber to reach the stabilized temperature more rapidly under adverse conditions.

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 photodetector (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 Thermometer

The thermometer shall be capable of measuring over the range 20 °C to 100 °C to an accuracy of ± 0,5 °C.

7.8.8 Water-circulating device

To cool the heat flux meter, a device for water circulation shall be provided, as necessary.

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 the 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 in front of 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 the appropriate compensating filter(s) (see 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.

NOTE 9 In cases of severe maladjustment, it may be necessary to reposition the lamp socket also.

9.2.2.3 Refix 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 photodetector 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 photodetector 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 photomultiplier 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 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.

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 100 % transmission; switch the instrument to the other ranges to check that the recorded transmission remains 0 %.

Place the calibrated filter, with a nominal optical density of 3,0, in the light path over the lower optical window, open the shutter and measure the percentage transmission. The difference between the observed reading and the calibrated value, when expressed as a percentage of the average of the two values, shall be within 5 %.

9.5 Calibration of range-extension filter

Bring the apparatus to its normal operating condition (see 10.1) 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 open. Switch the amplifier to its 100 % transmission range. Place the white cloth, sheets of tissue or filter with an optical density of about 2,5 (see 7.5.3) over the lower optical window, and switch to the 1 % transmission range. Set the reading to 0,5 % by adjusting the instrument. Without disturbing the cloth, tissue or filter, 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 table 1, the value of the appropriate correction factor C_f for readings obtained when the range-extension filter is not in the light path.

NOTE 10 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 (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 flowrates of propane and air to achieve the flame length specified in 7.3.6.

NOTE 11 Flowrates 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 as specified in 7.3.2, and connect to the electrical and water services.

9.8.2 Bring the apparatus to its normal operation condition (see 10.1) with the chamber wall temperature remaining steady (see 10.1.2), and move the radiation shield away from the cone.

Table 1 — Correction factors with neutral-density filter (ND-2) removed

Meter reading, T_s	Optical density of neutral-density filter	Correction factor, C_f
31	2,21	+ 27
32	2,19	+ 25
33	2,18	+ 24
34	2,17	+ 22
35	2,16	+ 20
36	2,14	+ 19
37	2,13	+ 17
38	2,12	+ 15
39	2,11	+ 14
40	2,10	+ 13
41	2,09	+ 11
42	2,08	+ 10
43	2,06	+ 8
44	2,06	+ 7
45	2,05	+ 6
46	2,04	+ 5
47	2,03	+ 3
48	2,02	+ 2
49	2,01	+ 1
50	2,00	0
51	1,99	− 1
52	1,98	− 3
53	1,97	− 4
54	1,965	− 5
55	1,96	− 6
56	1,95	− 7
57	1,94	− 8
58	1,935	− 9
59	1,93	− 10
60	1,92	− 11
61	1,91	− 12
62	1,905	− 13
63	1,90	− 14
64	1,90	− 14
65	1,89	− 15
66	1,88	− 16
67	1,87	− 17
68	1,865	− 18
69	1,86	− 19
70	1,85	− 20

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 12 With some water circulators, 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 Repeat the procedure of 9.8.3 as necessary to calibrate the equipment in three positions, i.e. at the centre and 25 mm each side of the centre.

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.

NOTE 13 Because the test is sensitive to variations in the composition of specimens, it is desirable to 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. 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 procedures

9.10.1 Undertake regular checking and calibration at periods as given in table 2.

NOTE 14 Products of combustion of some materials may cause corrosion of the cone heating element which may 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 Preparation of test chamber

10.1.1 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.

10.1.2 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.

NOTE 15 If the temperature is too high, the exhaust fan may be used to draw in cooler air from the laboratory.

10.2 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 flow rates and, if necessary, adjust the flow rates to ensure that the flame is as specified in 7.3.6.

Table 2 — Frequency of checks and calibrations

Item of equipment	Minimum frequency of checks and calibrations	Procedure (clause 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 3 months and when meter is cleaned or recoated	7.3.4.3 and annex A
Photometric system:		
calibration	Before testing every specimen	10.3
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

10.3 Preparation of 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.

10.4 Loading the specimen

Place a wrapped specimen, prepared in accordance with 6.3 and 6.4, with its backing board, in its holder. Place the holder and specimen on the supporting framework below the radiator cone and immediately close the test chamber door. Remove the radiation shield from below the cone and simultaneously start the recording-chart drive at a minimim chart speed of 10 mm/min and close the inlet vent.

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

10.5 Recording of light transmission

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

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.

10.6 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.

NOTES

16 The smoke generation from some materials differs significantly depending on whether combustion occurs in a non-flaming or flaming mode (see ISO 5659-1). It is important, therefore, to record as much information as possible about the mode of combustion during each test.

17 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 reignite 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 6.4.4) has occurred, the results from that specimen shall be ignored and an extra cut specimen tested.

10.7 Termination of test

10.7.1 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, when minimum light transmittance values have not been reached during a 10 min exposure.

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

NOTE 18 The burner is extinguished in order to obviate the possibility of air mixing with combustion products present and causing an explosion.

10.7.3 Move the radiation shield below the cone.

10.7.4 Switch on the exhaust fan and, when the water 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 correcting for deposits on the optical windows.

10.8 Repeat tests

10.8.1 Unless otherwise stated in the report, measure the percentage light transmission of three 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

10.8.2 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 at 10 min 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.

11 Expression of results

11.1 Specific optical density D_s

11.1.1 For each specimen, take a continuous record of light transmission against time and convert the results at 10 min to specific optical density D_s10 by calculation to two significant figures using the following equation:

$$D_s10 = 132 \log_{10} \frac{100}{T}$$

where

T is the percentage light transmittance, taken from the continuous record, at 10 min;

132 is a factor derived from V/AL for the test chamber, where V is the volume of the chamber, A is the exposed area of the specimen and L is the length of the light path.

11.1.2 To each value of 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 ($T \geqslant 0{,}01$ %)

or

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

or

3) if the ND-2 filter is found to be of the correct optical density of 2;

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 10.7.4) to determine the correction factor D_c. Calculate D_c as for D_s10 in 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). Further repeatability and reproducibility data are being obtained from a second round-robin, and a precision statement will be added when this exercise is complete.

13 Test report

The test report shall include a reference to this International Standard 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 F;

h) the mode of testing (see 10.8.1), 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 10.8);

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 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 10.7);

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 10.6), together with details of any invalid tests and the reasons for these;

o) the mean value of D_s10 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

The calibration of the heat flux meter shall be carried out whenever a check is done 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 figures 4 and 5). It shall be positioned at a location equivalent to the centre of the specimen face during this procedure.

The intercomparison of working and reference standard heat flux meters required in 7.3.4.3 may be made using the conical heater (7.3.1) with each heat flux meter mounted in turn in the calibration position (7.3.1.2), care being taken to allow the whole apparatus to attain thermal equilibrium. Alternatively, an apparatus specially built for comparative purposes may be used (see e.g. BS 6809:1987, *Method for calibration of radiometers for use in fire testing*).

NOTE 19 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 part of ISO 5659 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 demonstrated the ability of ISO 5659-2 to discriminate between materials which generate low and high levels of smoke. Tables B.1 and B.2 give the repeatabilities and reproducibilities of D_s10 for five plastics and five building materials, derived in accordance with ISO 5725.

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 must 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	11	4	38	10	91
		25 + pf	55	13	24	29	53
		50	54	11	20	17	32
ABS	1,1	25	312	77	25	311	100
		25 + pf	441	146	33	205	46
		50	435	102	23	192	44
Rigid polyurethane foam (28 kg/m³)	25,0	25	49	16	32	61	124
		25 + pf	48	24	51	26	54
		50	145	48	33	97	67
Flexible polyurethane foam (27 kg/m³)	25,0	25	178	49	27	114	64
		25 + pf	80	28	35	56	70
		50	127	46	36	80	63
Expanded polystyrene (non-fire-retardant; 14 kg/m³)	25,0	25	112	75	67	196	175
		25 + pf	102	75	74	130	128
		50	270	88	33	195	72

+ 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	1,0	25	403	97	24	300	74
		25 + pf	26	15	55	56	211
		50	196	191	98	191	98
Chipboard	1,1	25	411	47	12	187	45
		25 + pf	58	59	102	88	153
		50	481	96	20	464	97
Plywood	25,0	25	251	31	12	132	52
		25 + pf	33	15	47	58	175
		50	113	58	51	82	72
Medium-density fibreboard	25,0	25	420	127	30	281	67
		25 + pf	68	42	62	72	106
		50	688	114	17	413	60
Paper-faced plasterboard	25,0	25	20	8	42	21	107
		25 + pf	8	8	104	25	314
		50	17	11	64	23	132

+ pf indicates a test carried out in mode 2 (i.e. with pilot flame).