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Method for

Measurement, in the laboratory, of the specific optical density of smoke generated by materials

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The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Electric Cable Makers Confederation	Yarsley Technical Centre Ltd.
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Foreword

This British Standard has been prepared under the direction of the Fire Standards Committee, and describes a laboratory method for the measurement of the specific optical density of smoke produced by burning materials. Other methods for the measurement of smoke emission are under study in conjunction with the International Organization for Standardization (ISO) TC 92.

In the vital period of development of a fire in a building (i.e. from the initiation of the fire, during the evacuation of the occupants and before fire fighting operations are fully developed), smoke contribution is likely to arise more from furniture and furnishings than from building materials, but the contribution from the latter should not be overlooked. This aspect, and the need for a method to evaluate it, has been emphasized in the Home Office Report "Fire risk of new materials"¹⁾.

It will be some time before the ISO and other methods have been fully developed and tried out to ensure proper reproducibility of the test and adequate comparability of test results. In the circumstances, the responsible British Standard technical committee considered that an existing method should be adopted as a British Standard method to enable information needed for research and development of building materials to be acquired in a standardized way. It is anticipated that this method will fulfil a useful role at least until work on the other methods has been completed.

Versions of this method are already in use in many different countries throughout the world and this British Standard is based on ASTM E 662 (see **B.2.23**). This method uses photometric measurement of light attenuation by smoke to measure smoke obscuration only. It gives no information about the effects of irritants on the eye and on nasal and bronchial passages. However, the method can give useful guidance about smoke propensity from materials, for use in smoke hazard assessments and can be of practical help to all concerned with building design.

Since the aim of this standard is basically to make use of an existing method based on a precisely defined apparatus, the temptation to adjust the sizes of dimensions and other details to suit SI units has been avoided on the whole. A few values have been "rounded" off however where exact conversions are not essential.

During the preparation of this British Standard, it was decided to include a commentary on the text which is given in Appendix A and indicates the inter-laboratory precision which has been attained with this method. A bibliography on this and other related methods is given in Appendix B.

The apparatus described in this standard is available commercially and for further information BSI should be contacted.

Attention is drawn to the Health and Safety at Work etc. Act 1974, and the need to ensure that the methods of test specified in this standard are carried out under suitable environmental conditions to provide adequate protection to personnel against the risk of fire, inhalation of smoke and/or toxic products of combustion.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 34, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ Issued by the Home Office, Fire Department, Queen Anne's Gate, London SW1H 9AT.

1 Scope

1.1 This British Standard specifies a method for measuring the specific optical densities of smoke generated by materials when a specimen of specified form and thickness, of up to 25 mm in thickness, is exposed vertically to a radiant heat source of 2.5 W/cm^2 in a closed cabinet, with or without the application of a pilot flame.

1.2 This method is not applicable to the testing of insulated wire and cable as it is not possible to obtain a satisfactory distribution of heat flux with such products.

1.3 Materials which melt and flow away from the direct impingement of heat flux do not give a smoke emission which is representative of current knowledge from real fire situations, and for these materials, this method may not be applicable.

1.4 The values of specific optical density measured by this method are specific to the form and thickness of the product tested. They are not necessarily valid when other variables are involved; in particular, different material thicknesses and densities.

1.5 The method is intended for research and development and not as a basis for building control purposes. No basis is provided for predicting the optical density of smoke which may be generated by the materials upon exposure to heat and flame under fire conditions nor has any correlation been established with measurements derived from other test methods (see **B.1.7**).

1.6 The repeatability of the measurement given by this method, both within and between laboratories tends to vary with the physical structure and chemical composition of the materials tested as well as the mode of test. In view of the poor inter-laboratory reproducibility attainable by this method, the resolution of the method tends to be poor and so is only applicable to distinguishing between materials which have substantial differences in smoke emission for each mode of test and which do not melt or drip during the test.

1.7 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 one irradiance level (2.5 W/cm^2) only. For details of the effect of heat flux variations, using the apparatus described in this method see **B.2**.

NOTE The titles of the publications referred to in this British Standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 4422 apply together with the following:

2.1

combustion

the exothermic reaction of a substance with an oxidizer, accompanied by flame and/or glowing and/or emission of smoke

2.2

pyrolysis

the irreversible chemical decomposition of a material due to an increase in temperature without oxidation

2.3

combustion products

the total gaseous, particulate or other aerosol effluent from a fire or pyrolysis reaction

2.4

smoke

a visible suspension in air of solid and/or liquid particles resulting from combustion or pyrolysis

2.5

optical density of smoke (D)

a measure of the degree of opacity of smoke; the negative common logarithm of the relative transmission of light

2.6

specific optical density (D_s)

the optical density multiplied by a factor which depends on the instrument and on the specimen size

NOTE See 9.1.

3 Suitability of a material for testing

3.1 Materials with particular burning characteristics

3.1.1 This method requires valid results to be obtained from three specimens for the two modes: with and without pilot flame application. If during the evaluation one or more of the three specimens shows any unusual behaviour, in particular the following:

- the specimen falls out of the holder;
- the melted product overflows the specimen holder trough;
- ignition occurs without the application of the pilot flame;
- there is a loss of pilot flame impingement on the specimen during pilot flame application;
- the specimen becomes displaced from the zone of controlled irradiance;

then up to a total of six specimens shall be tested in an attempt to obtain three valid results for the particular mode being measured.

3.1.2 Failure to obtain three valid results according to 3.1.1 shall deem the material unsuitable for evaluation under the particular mode(s) and this shall be stated in the test report.

NOTE Materials showing these characteristics do not necessarily behave poorly in fire situations, and should be assessed by other methods more appropriate to their intended use.

3.2 Material geometry

3.2.1 The method is applicable to essentially flat materials.

3.2.2 The method is sensitive to small variations in geometry, surface orientation, thickness (either overall or individual layer), 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 when the specific optical density of another thickness of the same material is known. (See A.2.6.)

3.3 Physical characteristics

3.3.1 The results obtained from this method are sensitive to small differences in specimen conditioning. It is important therefore to ensure that the requirements of 4.5 are followed carefully.

3.3.2 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.

3.3.3 If visual inspection of the material indicates a pronounced grain pattern, process-induced surface orientation, or other non-isotropic property, the specimens prepared from the material shall be tested in two or more orientations. The highest smoke density value so obtained and the specimen orientation shall be that reported (see clause 10).

3.4 Test procedure variations. This method is sensitive to small variations of the position of the specimen and radiometer relative to the radiant heat source.

4 Specimen construction and preparation

4.1 Number of specimens

4.1.1 The test sample shall comprise a minimum of three and a maximum of six specimens for each mode tested (i.e. with and without a pilot flame).

4.1.2 An additional number of specimens as specified in 4.1.1 shall be used for each face and/or orientation according to the requirements of 3.3.2 and 3.3.3.

4.2 Size of specimens

4.2.1 The specimens shall be square, with sides 75^{+0}_{-1} mm.

4.2.2 Materials of normal thickness 25 mm or less shall be evaluated to their full thickness.

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

4.2.4 Specimens of multilayer materials with a thickness greater than 25 mm, consisting of a core material(s) with facings of different materials shall be prepared according to 4.2.3. (See also 3.3.2.)

4.3 Specimen preparation

4.3.1 The specimen shall be representative of the material and shall be prepared in accordance with the procedures described in 4.3.2 to 4.3.4. 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 (see 9.3).

4.3.2 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.

4.3.3 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 separations affecting their smoke generation. When supplementary tests are performed on a scored (slit) exposed surface, or on interior layers or surfaces, of the specimens in order to evaluate these effects, the manner of performing such supplementary tests, and the results obtained, shall be included in the test report.

4.3.4 When coating materials, including paints and adhesives, are used without 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, number of coats and type of substrate shall be included in the test report.

4.4 Wrapping of specimens

4.4.1 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 holder. After mounting the specimen into its holder, any excess foil along the front edges shall be trimmed off where appropriate. A flap of foil shall be cut and bent forward at the cut-out in the lower lip as a spout to permit flow from melting specimens.

NOTE For determining the mass loss of specimens, it is advisable to weigh the sample in the aluminium foil, not to trim off the excess foil, merely folding it back on the holder, and reweigh the residue in the foil.

4.4.2 All wrapped specimens shall be backed with a sheet of non-combustible insulating board of oven dry density $850 \pm 100 \text{ kg/m}^3$ and nominal thickness 12.5 mm. The wrapped specimen and its backing board shall be secured with the spring and retaining rod. A "C" shaped retaining rod shall be used with specimens from 16 mm to 25 mm thick. Flexible specimens shall not be compressed beyond their normal thickness.

4.4.3 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.

4.4.4 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 putting two or three cuts (20 mm to 40 mm long) in the film to act as vents.

4.5 Conditioning

4.5.1 Before preparing the specimens for test they shall be conditioned to constant mass²⁾ at a temperature of $23 \pm 3^\circ\text{C}$ and a relative humidity of $50 \pm 10\%$.

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

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

²⁾ 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.

5 Apparatus and ancillary equipment

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

NOTE 1 All dimensions given in the following description of the apparatus are nominal unless tolerances are given.

NOTE 2 The apparatus described here is commercially available. For further information apply to Central Enquiries Section, British Standards Institution, 2 Park Street, London W1A 2BS, enclosing a stamped addressed envelope for reply.

5.2 Test chamber

5.2.1 Construction

5.2.1.1 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 $914 \pm 3 \text{ mm}$ long by $610 \pm 3 \text{ mm}$ wide by $914 \pm 3 \text{ mm}$ high. It shall be provided with a hinged front-mounted door with an observation window and a removable opaque 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 $80\,600 \text{ mm}^2$, shall be provided in the floor of the chamber fastened in such a way as to provide an airtight seal.

NOTE The blow-out panel may be protected by stainless steel wire mesh above it.

5.2.1.2 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 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.

5.2.1.3 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 of up to 1.5 kPa (150 mm water gauge) above atmospheric pressure can be developed inside the chamber (see **5.2.2**) and maintained when checked in accordance with **5.6** and **7.6**. All components of the chamber shall be capable of withstanding a greater internal positive pressure than the safety blow-out panel.

5.2.1.4 An inlet vent with shutter shall be provided in the front of the chamber at the top and away from the furnace, and an exhaust vent with shutter shall be provided in the bottom of the chamber to lead, via flexible pipe 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). A horizontal rod for displacing specimens from directly in front of the heat flux to one side (see Figure 2) shall enter the chamber through a gland in the rear wall, at the position shown, and shall be capable of being operated from the front of the chamber.

5.2.2 *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.

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

5.2.3 *Chamber 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 means of 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 with a suitable cement. The thermocouple junction shall be connected to a recorder or meter and the system shall be suitable for measuring temperatures around 35 °C.

5.3 *Specimen support and heating arrangements*

5.3.1 *Framework for support of the furnace and specimen holder*

5.3.1.1 The framework shall be as in Figure 4 and fixed inside the chamber to the floor at the position shown in Figure 2. A steel tube with an external diameter of 127 mm, a wall thickness of 6 mm and a length of 51 mm shall be welded to the framework with its axis horizontal. Radial holes, positioned equidistantly around the support tube, shall be tapped and provided with screws to support the radiant heat furnace described in **5.3.2** and to allow the furnace to be positioned and aligned accurately.

5.3.1.2 Two transverse rods made of stainless steel of 9.5 mm diameter shall be provided to support the radiometer (**5.3.3**) and the specimen holders (**5.3.4**). Two adjustable spacing stops shall be provided on the upper rod to permit quick and accurate lateral positioning of the radiometer or a specimen holder. The arrangement shall be such that a specimen holder can be supported with the exposed specimen area parallel and central to the opening of the furnace, and with their planes 38 ± 1 mm apart.

5.3.1.3 A spacing gauge shall be provided for checking and adjusting the relative positions of the furnace and sample holder (see Figure 5).

5.3.1.4 The framework shall be properly electrically earthed.

5.3.1.5 A tray shall be provided below the furnace and specimen holder in order to catch debris from a specimen, and shall not interfere with the operation of the blow-out panel (see **5.2.1**).

5.3.2 Radiant heat furnace

5.3.2.1 The furnace shall be as in Figure 6 and shall consist of a ceramic tube with an external diameter of 86 mm, an internal diameter of 76 mm and a length of 41 mm with its axis horizontal. One end shall be bored out to a depth of 16 mm and an internal diameter of 77 mm to accommodate a heating element assembly. The heating element itself shall consist of either a coil made from wire with a resistance per unit length of 22.5 Ω/m , or some other suitable electrical heating element with a minimum output of 525 W at approximately 110 V. It shall be backed and supported by at least two stainless steel disc reflectors and stainless steel washers separated from the coil by a non-combustible insulating gasket 1.6 mm thick. A stainless steel bolt on the axis of the heating element assembly and lock nuts shall be used for locating the heating element assembly. Provision shall be made to ensure that proper electrical insulation exists between all electrical connections to the heating element and the stainless steel reflector plates and other parts of the furnace surround.

5.3.2.2 The ceramic tube and heating element assembly shall be built into a housing consisting of a stainless steel tube with an external diameter of 102 mm, a wall thickness of 2 mm and a length of 105 mm, at the ends of which is fixed internally a spacing ring and a rear cover made of a non-combustible insulation board, 9.5 mm thick, and fixed to the tube by means of three screws in each ring. A third disc of insulation board 9.5 mm thick and with a diameter of 98 mm, drilled to accommodate the stainless steel bolt of the heating element assembly and leads to the element, shall be located inside the housing tube and separated from the rear cover by a spacing ring made of the insulation board. The ceramic tube and heating element assembly shall be located firmly within the housing by adjustment of the locking nuts. The cavity surrounding the ceramic tube and the heating element assembly shall be packed with glass wool.

5.3.2.3 The output from the furnace shall be controlled by means of a variable transformer and a voltmeter capable of reading to an accuracy of 0.5 % of the operating voltage. The radiance level shall be capable of being maintained within the specified limits of $2.5 \pm 0.05 \text{ W/cm}^2$ (see 7.8).

NOTE A constant-voltage transformer of at least 650 W capacity may be required.

5.3.3 Radiometer

5.3.3.1 A suitable radiometer for calibrating the output of the radiant heat furnace is shown in Figure 7.

5.3.3.2 The radiometer shall be capable of integrating the thermal irradiance of the furnace over a circular plane with a diameter of 38 mm. The sensing element of the radiometer shall consist of copper foil 0.25 mm thick, spray-coated with an infra-red-absorbing black paint. The foil shall be mounted on a 12.5 mm thick copper base over a recess of 38 mm diameter by 3 mm deep. It shall be protected by a heat shield made from stainless steel 0.9 mm thick with a circular aperture of 38 mm diameter and separated from the foil by spacing washers and an annulus of aluminium foil. A brass well, into which a thermometer (5.8.7) (see 7.8.4) fits snugly, shall be mounted on the back of the copper base near one vertical edge. A metal container, with fins inside to act as a cooler when supplied with compressed air, shall be attached to the back of the copper base on the axis of the aperture. Compressed air shall be supplied to the cooler via a needle valve and a flowmeter capable of measuring up to 100 L/min.

NOTE 1 Silicone grease may be used to provide a good contact between the thermometer bulb and the brass well into which the thermometer is inserted.

NOTE 2 A sheet convection shield should be attached to the back of the base above the cooler. Channel and angle-section guides should be attached to enable the radiometer to be supported firmly on the transverse rods of the specimen holder framework, so that the plane of the foil receiving surface is in the same relative position as the exposed surface of the specimen mounted in the specimen holder in position on the framework.

5.3.3.3 The radiometer shall be connected directly to a suitable recorder (5.8.6), or meter, so that it is capable, when calibrated, of recording a heat flux of 2.5 W/cm^2 to an accuracy of $\pm 0.05 \text{ W/cm}^2$. The leads from the radiometer to the recorder or meter shall be screened to minimize any electrical interference to the signal. Earthing of the radiometer, if necessary, shall be via the recorder, or meter, and not by any other route (e.g. the earthed frame of the apparatus).

5.3.3.4 The radiometer system shall be calibrated by comparing its response with that of a primary reference standard when exposed to a heat flux of $2.5 \pm 0.05 \text{ W/cm}^2$ averaged over the 38 mm diameter area of the radiometer.

NOTE It is recommended that this calibration is carried out by either the radiometer supplier or another suitable laboratory.

5.3.4 Specimen holders

5.3.4.1 At least six specimen holders, as shown in Figure 8, shall be provided. Each shall be fabricated from 0.6 mm thick stainless steel sheet by bending and brazing (or spot welding) to provide an open container with internal dimensions 78 mm × 78 mm × 38 mm and with a lip to each side to provide a symmetrical opening 65 ± 0.5 mm square on the front face. Guides shall be fixed to the top and bottom sides to support the specimen holder firmly on the transverse rods of the specimen holder frame. A trough shall be fixed below and in front of the 65 mm square opening.

5.3.4.2 A piece of non-combustible insulating board having an oven-dry density of 850 ± 100 kg/m³ and dimensions of 76 mm × 76 mm × 12.5 mm, a spring bent from phosphor-bronze sheet with dimensions of 75 mm × 75 mm × 0.25 mm and two different retaining rods, made from steel bar of 3 mm diameter and shaped as shown in Figure 8, shall be provided with each specimen holder. Three holes of 3 mm diameter shall be provided on the axis of the top and bottom faces of the holder to accommodate the retaining rod with its axis 6 mm, 12 mm and 18 mm, from the back of the holder.

5.3.4.3 One specimen holder, referred to as the “blank” specimen holder shall contain the non-combustible insulating board held against the lips by the retaining rod in the appropriate holes.

5.3.5 Burner

5.3.5.1 The burner shall consist of six tubes constructed as shown in Figure 9. The tubes shall be made from stainless steel with an external diameter of 3.2 mm and a wall thickness of 0.8 mm; they shall be drawn at the tip to reduce the opening diameter to 1.4 mm. They shall be connected to a manifold section, consisting of stainless steel tubing with an external diameter of 6.4 mm and a wall thickness of 0.9 mm. The manifold section shall be so shaped and fixed to the base of the test chamber that the orifices of the six tubes can be positioned accurately with respect to the specimen in a specimen holder in position on the specimen-holder framework. The two outer tubes shall be bent so that the axis of each orifice is perpendicular to the surface of the specimen; the two intermediate tubes shall be bent so that the axis of each orifice is vertically downward into the trough of the specimen holder; and the two inner tubes shall be bent so that the axis of each orifice is at an angle of 45° downwards towards the exposed face of the specimen.

5.3.5.2 The burner shall be positioned in front of a specimen holder in the test position, so that the tips of the two outer tubes are centred 6.4 mm above the lower lip of the holder and 6.4 mm away from the specimen surface. Provision shall be made to enable the burner to be moved easily out of position during non-flaming tests.

5.3.5.3 Six burner cleaners shall each consist of a tempered spring-steel wire with a diameter of 0.35 mm and a length of 90 mm with one end crimped or brazed to a knob to facilitate handling and prevent possible loss of the wire by complete insertion in a burner tube (see Figure 9).

5.3.5.4 A bath containing suitable solvent shall be available for immersing the complete burner to assist cleaning of the burner tubes after the testing of specimens which create hardened residues.

NOTE As the solvent may be hazardous, proper facilities should be available for the protection of the personnel cleaning the burners.

5.4 Gas supply. A mixture of propane of at least 95 % purity and at a pressure of 3.5 ± 1 kPa (350 ± 100 mm water gauge), and air under a pressure of 170 ± 30 kPa (17 ± 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 50 cm³/min and that for the air, a value of 500 cm³/min.

NOTE The supply of air may be from the same source as is used for cooling the radiometer (5.3.3).

5.5 Photometric system

5.5.1 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 photo-detector 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 10. Equipment shall be provided to control the output of the light source, and to measure the amount of light falling on the photo-detector.

5.5.2 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 ± 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 upwards 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.

5.5.3 Photo-detector

5.5.3.1 The light-measuring system shall consist of a photo-multiplier tube connected to a multi-range amplifier coupled to a recording device (5.8.6), capable of measuring continuously 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, and the most sensitive range shall be capable of giving a full scale reading with the change of light transmission resulting from the placing of a 0.5 optical density compensating filter (ND-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 can be obtained more easily if the measuring system incorporates scale ranges of 30, 3, 0.3, etc. as well as ranges of 100, 10, 1, etc.

5.5.3.2 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 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 exclude all light in the test chamber from reaching the photo-multiplier tube. An opal diffuser filter shall be permanently mounted below the shutter.

5.5.3.3 The lower part of the 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.

5.5.3.4 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.

NOTE All filters should be handled by their edges because finger prints can greatly affect their rating. No attempt should be made to clean the surface of a filter; once the surface has been damaged or spoilt, the filter should be replaced.

5.5.4 Additional equipment

5.5.4.1 A template for checking the collimated light beam shall consist of an opaque disc marked with a concentric ring of 51 mm diameter, and shall be 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.

5.5.4.2 A piece of white cloth, tissues 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-extender filter.

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

5.6 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 7.6.

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.

5.7 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.

5.8 Ancillary equipment

5.8.1 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.

5.8.2 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.

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

5.8.4 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.

5.8.5 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.

5.8.6 Recorder. The recorder shall be capable of recording continuously the millivolt output of the photo-detector (5.5.3) to an accuracy of better than 0.5 % full range deflection. The recorder shall also be capable of recording the radiometer output (see 5.3.3.3) to the required accuracy.

5.8.7 Thermometer. The thermometer shall be capable of measuring over the range 20 °C to 100 °C to an accuracy of ± 0.5 °C.

6 Test environment

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

6.2 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.