

TECHNICAL REPORT

**ISO
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1989-09-01

Fire tests — Reaction to fire — Smoke generated by building products (dual-chamber test)

*Essais au feu — Réaction au feu — Fumée générée par les produits de bâtiment
(essai en chambre double)*



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International Organization for Standardization
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Foreword

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

The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development, requiring wider exposure;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports are accepted for publication directly by ISO Council. Technical Reports types 1 and 2 are subject to review within three years of publication, to decide if they can be transformed into International Standards. Technical Reports type 3 do not necessarily have to be reviewed until the data they provide is considered no longer valid or useful.

ISO/TR 5924, a Technical Report type 2, was prepared by Technical Committee ISO/TC 92, *Fire tests on building materials*.

Annexes A to D of this Technical Report are for information only.

Introduction

This method of test is one of a series being developed by ISO/TC 92/SC 1 concerning fire tests on building materials, components and structures, to help assess the contribution made by building products to the growth of a fire during their own decomposition.

Progress in this work was reported in ISO/TR 3814, *The development of tests for measuring "reaction to fire" of building materials*. This test is one of those outlined in that Technical Report.

Further methods of test included in this series are given in the following standards:

ISO 1182: 1983, *Fire tests — Building materials — Non-combustibility test*;

ISO 5657: 1986, *Fire tests — Reaction to fire — Ignitability of building products*;

ISO 5658: —¹⁾, *Reaction to fire tests — Spread of flame test*;

ISO 5660: —¹⁾, *Reaction to fire tests — Rate of heat release*.

This test was developed in close connection with ISO 5657, using the same decomposition apparatus and similar exposure conditions, together with the same specimen size and preparation. In this way, the acquisition of the test equipment is made easier for smaller laboratories and the experience gained on a material with one of these tests can be transferred to some extent to the other tests, thus helping to reduce the number of tests necessary.

This Technical Report should be read in conjunction with ISO/TR 6585, *Fire hazard and the design and use of fire tests*, which explains the general background and use of this series.

At the time this Technical Report was drafted, development work was still in progress in several laboratories, e.g. on

- pilot flame ignition and/or the application of higher levels of constant irradiance;
- the measuring distance of an optical measuring system;
- the performance of a greater variety of building products in the test.

Some of the data concerning repeatability and reproducibility of the test method were gathered by using a first-generation dual-chamber box of a design slightly different from that described in this Technical Report, using different optical measuring equipment. The different design of the box did not influence the mean values of the optical density, nor the repeatability of the test method, and improved its reproducibility.

1) To be published.

Fire is a complex phenomenon : its behaviour and its effect 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 to which they are exposed.

A test such as that specified in this Technical Report 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 can, however, be used for comparative purposes or to ensure the existence of a certain quality of performance (in this case smoke production behaviour) considered to have a bearing on fire performance generally. It would be wrong to attach any other meaning to performance in this test.

The term "smoke" is defined in ISO 3261 as a visible suspension in air of solid and/or liquid particles resulting from incomplete combustion. It is one of the first fire properties to be manifested and should 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.

This test does not rely upon the use of asbestos-based materials.

Fire tests — Reaction to fire — Smoke generated by building products (dual-chamber test)

WARNING — So that suitable precautions may be taken to safeguard health, the attention of all concerned in fire tests is drawn to the possibility that toxic or otherwise harmful gases may be evolved during exposure of test specimens. The advice on safety given in annex A, clause A.8, should also be noted.

1 Scope

This Technical Report specifies a method of test for examining the smoke production behaviour of the exposed surface of specimens of essentially flat materials, composites or assemblies not exceeding 70 mm in thickness, when placed in a horizontal orientation and subjected to specified levels of thermal irradiance.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards listed 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 : 1975, *The development of tests for measuring "reaction to fire" of building materials*.

ISO 5657 : 1986, *Fire tests — Reaction to fire — Ignitability of building products*.

ISO/TR 6585 : 1979, *Fire hazard and design and use of fire tests*.

DIN 5031, Teil 3, *Strahlungsphysik im optischen Bereich und Lichttechnik; Größen, Formelzeichen und Einheiten der Lichttechnik (Optical radiation physics and illuminating engineering; quantities, symbols and units of illuminating engineering) (March 1982)*.

DIN 5033, Teil 7, *Farbmessung; Meßbedingungen für Körperfarben (Colorimetry; measuring conditions for object colours) (July 1983)*.

3 Definitions

(See also annex A, clause A.1.)

For the purposes of this Technical Report, the definitions given in ISO 3261 apply, together with the following :

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

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

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

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

3.5 exposed surface: That surface of the product subjected to heating in the test.

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

3.7 essentially flat surface: A surface whose irregularity from a plane does not exceed ± 1 mm.

3.8 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.

3.9 ignition: The inception of any flame.

3.10 optical density D : A measure of the attenuation of a beam of light passing through the smoke during a test run. It can be computed from the transmitted light flux T in percent, using the formula

$$D = \log_{10} (100/T)$$

3.11 maximum optical density D_m : The maximum value of the optical density D during a single test run (See 12.10).

3.12 mean maximum smoke density D_{mm} : The arithmetic mean of all five values of maximum optical density D_m measured at one irradiance (see 12.4).

3.13 highest mean maximum smoke density D_{hm} : The highest value of all the mean maximum smoke densities D_{mm} at all the levels of irradiance at which tests were carried out (see 12.4).

4 Principle

(See also annex A, clause A.2.)

Specimens of the product are mounted horizontally and exposed to thermal radiation on their upper surfaces at selected levels of constant irradiance within the range 10 kW/m² to 50 kW/m².

The smoke evolved is collected in a box and the attenuation of a light beam passing through the smoke is measured. The results are reported in terms of optical density.

5 Suitability of a product for testing

(See also annex A, clause A.3.)

5.1 Surface characteristics

5.1.1 A product having one of the following surface characteristics is suitable for testing:

- a) an essentially flat exposed surface;
- b) a surface irregularity which is evenly distributed over the exposed surface provided that:

at least 50 % of the surface of a representative 150 mm diameter area lies within a depth of 10 mm from a plane taken across the highest points on the exposed surface

and/or

for surfaces containing cracks, fissures or holes not exceeding 8 mm in width nor exceeding a depth of 10 mm, the total area of such cracks, fissures or holes at the surface does not exceed 30 % of a representative 150 mm diameter area of the exposed surface.

5.1.2 When an exposed surface does not meet the requirements of either 5.1.1 a) or 5.1.1 b), the product shall, if practicable, be tested in a modified form complying as nearly as possible with the requirements given in 5.1.1. The test report (clause 13) shall state that the product has been tested in a modified form and clearly describe the modification.

5.2 Asymmetrical products

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

6 Specimen construction and preparation

(See also annex A, clause A.4.)

6.1 Specimens

6.1.1 Five specimens shall be tested at each level of irradiance selected and for each different exposed surface.

6.1.2 The specimens shall be representative of the product and square with sides measuring 165 $\frac{0}{5}$ mm.

6.1.3 Materials and composites of normal thickness 70 mm or less shall be tested using their full thickness.

6.1.4 For materials and composites of normal thickness greater than 70 mm, the requisite specimens shall be obtained by cutting away the unexposed face to reduce the thickness to 70 $\frac{0}{3}$ mm.

6.1.5 When cutting specimens from products with irregular surfaces, the highest point on the surface shall be arranged to occur at the centre of the specimen.

6.1.6 Assemblies shall be tested as specified in 6.1.3 or 6.1.4 as appropriate. However, when thin materials or composites are used in the fabrication of an assembly, the presence of air or an air gap and/or the nature of any underlying construction may significantly affect the ignition characteristics of the exposed surface. The influence of the underlying layers should be understood and care taken to ensure that the test result obtained on any assembly is relevant to its use in practice (see A.4.1).

When the product is a material or composite which would normally be attached to a well defined substrate, then it shall be tested in conjunction with that substrate using the recommended fixing technique, e.g. bonded with the appropriate adhesive or mechanically fixed.

6.2 Baseboards

6.2.1 One baseboard will be required for each test specimen. However, since it will sometimes be possible to re-use the baseboard after test, the total number required will depend on the frequency of testing and the type of product being tested.

6.2.2 The baseboards shall be square with sides measuring 165 $\frac{0}{5}$ mm and shall be made of non-combustible insulation board of oven-dry density 825 kg/m³ $\pm$ 125 kg/m³ and nominal thickness 6 mm.

6.2.3 Before use in a test, a baseboard shall be placed for at least 24 h in an atmosphere at a temperature of 23 $\pm$ 1 °C and a relative humidity of 50 % $\pm$ 5 % R.H., with free access of air to both sides.

6.3 Conditioning of specimens

(See also annex A, sub-clause A.4.3.)

Before test, the specimens shall be conditioned to constant mass¹⁾ at a temperature of $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, and a relative humidity of $50\% \pm 5\%$ R.H.

6.4 Preparation

6.4.1 A conditioned specimen shall be placed on a baseboard treated in accordance with 6.2.3 and the combination shall be wrapped in a single piece of aluminium foil of nominal thickness 0,02 mm from which a circle 140 mm in diameter has been previously cut (see figure 1). The circular cut-out zone shall be centrally positioned over the upper surface of the specimen. After preparation, the specimen/baseboard combination shall be returned to the conditioning atmosphere until required for test.

6.4.2 When a product will normally be backed by air (see 6.1.6), then the specimen shall, where practicable, be backed by an air gap in the test. The air gap shall be formed by including a spacer between the specimen and the baseboard. A possible construction of a spacer comprises a piece of non-combustible insulation board of the same size and density as the baseboard, from the centre of which a square area of side $120 \pm 5\text{ mm}$ has been removed.

The thickness of the spacer shall correspond to the size of the air gap, if this is known, except that the total thickness of the spacer plus specimen shall not exceed 70 mm. If the size of the air gap is not known or the total thickness of the air gap plus specimen exceeds 70 mm, then the specimen shall be tested with a spacer which will give a total thickness for the specimen and spacer of $70 \pm 3\text{ mm}$.

A suitable spacer can be constructed of two blocks of the non-combustible board measuring $160\text{ mm} \times 20\text{ mm}$ and two blocks measuring $120\text{ mm} \times 20\text{ mm}$, with the thickness of the required air gap and fixed at the edges by screws or by glueing. The spacer and baseboard shall be placed for at least 24 h in an atmosphere at a temperature of $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and a relative humidity of $50\% \pm 5\%$ R.H. with free access of air to both sides of each.

The spacer shall then be interposed between the baseboard and the specimen and the combination shall be wrapped in aluminium foil as described in 6.4.1. A clean spacer shall be used for each specimen tested. After preparation, the combination shall be returned to the conditioning atmosphere until required for test.

6.4.3 Baseboards and/or spacers used to back the test specimens may be re-used if they are not contaminated. Immediately before re-use, however, they shall have been in the conditioning atmosphere specified in 6.2.3 and 6.4.2 for at least 24 h.

If there is any doubt about the condition of a baseboard or spacer, it may be placed in a ventilated oven at a temperature of approximately $250\text{ }^{\circ}\text{C}$ for a period of 2 h to remove any volatile residue. If there is still any doubt about the condition, it shall be discarded.

7 Test apparatus

7.1 General

7.1.1 All dimensions given in the following description of the test apparatus are nominal unless tolerances are specified.

7.1.2 The test apparatus shall consist of three main components:

smoke box (case);

decomposition apparatus (radiator with specimen holder, identical to the ignitability test apparatus as specified in ISO 5657, but without pilot flame arrangement);

light measuring (optical density) equipment.

The general arrangement of the test apparatus is given in figure 2a.

7.2 Smoke box

The smoke box²⁾ is divided into two sections, the decomposition chamber and the measuring chamber, connected by an upper and a lower opening to allow smoke movement to the measuring chamber. Mixing of air and smoke is effected by a cylindrical fan³⁾ (see figures 2a and 2b).

The measuring chamber is constructed of 18 mm plywood coated with thermosetting resin. The inside walls are painted matt black. The dimensions of the measuring chamber are: height 1,3 m, width 0,6 m and length 1,5 m giving a volume of this part of the box of $1,17\text{ m}^3$. In the middle of the side walls two openings are made where the optical system is mounted. The whole back can hinge open.

1) 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.

2) General arrangement drawings can be obtained from the secretariat of ISO/TC 92. A complete set of detailed drawings can be purchased from BASF AG, Abteilung Brandschutztechnik D-6700 Ludwigshafen, Germany F.R.

3) A type EQN 68-15-4 cross-flow fan made by Messrs Ziehl-Abegg OHG, Germany F.R., equipped with speed control and set at 600 rpm, has been found suitable. This information is given for the convenience of users of this Technical Report and does not constitute an endorsement of this product.

At the front side of the measuring chamber the decomposition chamber is also fastened by a hinge over the whole height of the box. The decomposition chamber has double walls and is constructed of anodized aluminium sheet, protected at the inside by means of an epoxy coating. The volume of this part is 0,23 m³. In the front a sliding door measuring 0,5 m × 0,5 m is mounted, with a heat resistant glass window of 0,2 m × 0,2 m.

The decomposition chamber is equipped with a removable double walled aluminium partition leaving passage for smoke of 0,15 m × 0,55 m open to the measuring chamber at the upper and lower side.

On top of the decomposition chamber an explosion relief of the same construction as the walls is applied, sealed with self adhesive aluminium tape.

The edges of the decomposition chamber and the back-door are sealed with profiled neoprene rubber. The door is sealed with silicone foam rubber strips.

On the top of the measuring chamber an exhaust-valve is mounted, opening automatically at an overpressure of approximately 150 Pa (free flow area 100 mm diameter) (figure 2c).

7.3 Decomposition apparatus

7.3.1 General

The decomposition apparatus shall be identical to the test apparatus used in the ignitability test (ISO 5657) but without pilot-flame equipment. It shall consist essentially of a support framework which clamps the test specimen horizontally between a pressing plate and a masking plate such that a defined area of the upper surface of the specimen is exposed to radiation. This radiation shall be provided by a radiator cone positioned above and supported by the specimen support framework. A specimen insertion and location tray shall be used to position the specimen accurately on the pressing plate of the specimen support framework, and a screening plate shall be used to shield the surface of the specimen during its insertion into the apparatus. A general arrangement of a suitable apparatus is shown in figure 3, with detailed drawings in figures 4 to 6.

7.3.2 Specimen support framework, masking plate and pressing plate

7.3.2.1 The specimen support framework and the other parts of the system to hold the specimen in position shall be constructed from stainless steel. The specimen support framework shall have a rectangular base frame made from 25 mm × 25 mm square tube of 1,5 mm wall thickness. The base frame shall have overall dimensions of 275 mm × 230 mm. A horizontal masking plate, 220 mm square and 4 mm thick, shall be mounted centrally and 260 mm above the top of the base frame on four 16 mm diameter legs positioned at the corners of the masking plate. A 150 mm diameter circular opening shall be cut centrally in the masking plate, the edges of the hole being chamfered on the top surface of the plate at an angle of 45° and to a horizontal width of 4 mm.

7.3.2.2 Two vertical guide rods not less than 355 mm long and of 20 mm diameter steel shall be mounted on the base frame, one at the mid-length of each of the short sides of the frame. A horizontal adjustable bar measuring 25 mm × 25 mm, which can slide on the rods and be locked in position by bolts capable of being tightened by hand, shall be mounted below the masking plate and between the vertical guide rods. A vertical central hole and sleeve in the adjustable bar shall be used to locate a sliding vertical rod 12 mm in diameter and 148 mm long surmounted by a 180 mm square pressing plate 4 mm thick. The pressing plate shall be pushed upwards against the underside of the masking plate by a counterweighted pivot arm which shall be mounted below the adjustable horizontal bar and shall press against the bottom of the sliding vertical rod. This can be achieved by an arm about 260 mm long. It shall contain at one end a roller which shall bear against a boss on the bottom of the sliding vertical rod and at the other end an adjustable counterweight.

The counterweight shall be capable of compensating for different masses of specimens and of maintaining a force of approximately 20 N between the upper surface of the specimen and the masking plate. A counterweight of about 3 kg has been found suitable. An adjustable stop shall be provided to limit upward movement of the pressing plate, due to collapse, softening or melting of the specimen during its exposure, to 5 mm. Alternatively, spacing blocks between the pressing plate and the masking plate may be used.

7.3.2.3 Figure 5 shows details of the support framework.

7.3.3 Radiator cone

7.3.3.1 The radiator cone shall consist of a heating element, of nominal rating 3 kW, contained within a stainless steel tube approximately 3 500 mm in length and 8,5 mm in diameter coiled into the shape of a truncated cone and fitted into a shade. The shade shall have an overall height of 75 mm ± 1 mm, an internal diameter of 66 mm ± 1 mm and an internal base diameter of 200 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/m³ sandwiched between them. The heating element shall be fastened to the inside face of the shade by steel pins. Clamps shall be used to prevent additional sagging of the lower coil below the base of the shade.

The upper turn of the heating element shall not obstruct the horizontal projected area of the top aperture of the shade by more than 10 % when projected vertically.

7.3.3.2 The radiator cone shall be capable of providing irradiances in the range 10 kW/m² to 50 kW/m² at the centre of the aperture in the masking plate and in a reference plane coinciding with the underside of the masking plate, when measured as described in 10.2. The distribution of the irradiance provided by the cone at the reference plane shall be such that the variation of irradiance within a circle of 50 mm diameter, drawn from the centre of the masking plate aperture, shall be not more than ± 3 % of that at the centre. The variation of irradiance within a circle of 100 mm diameter shall be not more than ± 5 % of that at the centre.

The distribution of the irradiance shall be determined from readings at the centres of 10 mm squares forming the grids shown in figure 7. The tolerances given shall apply to the readings within the grid comprising all the squares shown in figure 7.

For these measurements, the opening in the masking plate must be completely filled, and it will be necessary to employ a number of calibration boards of special horizontal shapes and sizes.

7.3.3.3 The radiator cone shall be located by and secured to the vertical guide rods of the specimen support framework by means of clamps which position the lower rim of the radiator cone shade $22 \text{ mm} \pm 1 \text{ mm}$ above the upper surface of the masking plate.

7.3.3.4 Details of the radiator cone are shown in figure 6a.

7.3.3.5 The temperature of the radiator cone shall be controlled (see 8.1) by reference to the reading of a thermocouple (primary thermocouple) in close and stable thermal contact with the heater element tube. A second thermocouple (secondary thermocouple) shall be attached similarly, mounted in a diametrically opposite position. The thermocouples shall have a speed response no worse than that of a thermocouple with insulated hot junction in a stainless steel sheath 1 mm in diameter. Each thermocouple shall be attached to a coil of the heater element tube which places them between one-third and half way down from the top of the radiator cone. The end 8 mm at least of the thermocouple shall lie in a region of approximately uniform temperature.

A description of methods of attaching thermocouples which have been found satisfactory in practice is given in annex A, sub-clause A.5.2.

7.4 Specimen insertion and location tray

7.4.1 The specimen insertion and location tray shall be used to facilitate rapid insertion of the specimen on to the pressing plate and to locate accurately the exposed area of the specimen in relation to the aperture in the masking plate.

7.4.2 It shall consist essentially of a flat metal plate having lugs on its upper surface to position and hold the specimen. Guides shall be fixed to the lower surface to locate the tray in the apparatus and a stop shall also be provided to bear against the pressing plate, thus limiting the distance of insertion. The tray shall be provided with a handle to make it easy to use. The handle shall not protrude so far that it touches the inside of the insertion flap of the smoke box when the smoke box is closed.

7.4.3 A suitable device is shown in figure 8.

7.5 Specimen screening plate

7.5.1 The screening plate shall be designed to slide over the top of the masking plate during the insertion of the specimen, thus shielding the specimen from radiation until commencement of the test.

7.5.2 The plate shall be made from 2 mm thick polished aluminium or stainless steel and have overall dimensions which allow it to cover the masking plate. It shall be provided with a stop, to limit its insertion against the masking plate, and a handle.

7.5.3 A suitable design is shown in figure 9.

7.6 Light measuring system

7.6.1 General

Smoke production shall be determined in the measuring chamber over a distance of 300 mm across a horizontal axis 700 mm above floor level and 700 mm from the rear wall (see figures 2a and 2b) by means of a photometric system.¹⁾

The layout of the photometric system and the main dimensions are shown in figures 10a to 10c. The light source and the receiver shall be secured on a frame that is sufficiently rigid and mounted on the outside of the measuring chamber (figure 10a). The method of attachment shall allow adjustment and centering of the light beam on an optical bench or similar device.

7.6.2 Illumination unit

The illumination unit shall consist of an electric light source and a system of lenses that produces an almost parallel light beam with a diameter of 25 mm at the emitter outlet (figure 10b). The light source shall be a gas-filled tungsten filament lamp in accordance with standard illuminant A as defined in DIN 5033 part 7, with a colour temperature of 2 856 K at the voltage applied²⁾ (see A.5.3).

The light source shall have an adjustable aperture, by means of which the luminous intensity can be reduced. As a result, the luminous flux density at the receiver can be set to the desired value for calibration over various distances.

The light source shall be capable of producing an incident luminous flux density at the light receiver lens of $1\,500 \text{ cd/m}^2$.

7.6.3 Light receiver

The light receiver shall consist of an achromatic system of lenses and a silicon photo-electric cell in front of which a spectral filter is located to accommodate the human eye luminosity function on viewing in daylight³⁾ (figure 10b).

1) Information on suppliers can be obtained from DIN in Berlin.

2) e.g. General Electric type 2604/5 V, 10 W. This light source is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

3) See DIN 5031 part 3.

The photo-electric cell shall be placed in the focussing cone of the light beam in such a way that its surface matches the cross-section of the beam at this point. It shall be temperature-compensated.

The non-linearity of the receiver shall not exceed 1,5 % up to 1 500 cd/m² incident luminous flux density.

7.6.4 Power pack

The power pack shall contain a voltage stabilizer to ensure that the light source is fed to within an accuracy of 0,1 %.

7.6.5 Measuring device

The measuring device shall be fitted with an amplifier that can be tuned to display the voltage of the photo-electric cell as a percentage of the initial value (transmission). The accuracy of the display shall be within $\pm 1,5$ % of the final value. There shall also be a voltage output for external recording of the measured values (0-1 V).

The luminous flux density shall be displayed in candelas per square metre in order to allow the intensity of illumination by the light source to be adjusted.

In order to simplify evaluation of the measurements, the instrument may have a logarithmic output to allow the optical density to be recorded externally.

7.6.6 Purging system

Care shall be taken to prevent soot deposits on the lenses of the light measuring system. A suitable means for this is an air purging system for the illumination unit and the light receiver as shown in figure 10c. The air flow rate of each system shall be adjusted to a value of (6 ± 2) l/s, which is approximately $(2,0 \pm 0,5) \cdot 10^{-2}$ m³/h.

7.7 Ignition indicating device

A 1 mm diameter sheathed thermocouple shall be placed above the radiator to monitor ignition of the specimen (see 8.6).

7.8 Test environment and extinguishing box

The smoke box should be placed under an extraction hood. To prevent pollution of the air in the laboratory and to permit the mass loss of specimens to be measured, specimens taken out at the end of the test shall be placed in an extinguishing box. This is placed directly below the sliding door, is maintained full of an inert gas (for example CO₂ or nitrogen) and is closed by a lid. To allow safe evacuation of smoke and gases after the test, the exhaust valve of the smoke box shall be connected to an exhaust fan.

8 Additional equipment

8.1 Temperature controller

The temperature controller for the radiator cone shall be of the proportional integral and derivative type ("3-term" controller) with thyristor stack fast-cycle or phase angle control

(see A.5.6) of not less than 15 A maximum rating. Capacity for the adjustment of integration times between about 10 s and 150 s, and differential times between about 2 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 operate shall be set on a scale capable of being read to ± 2 °C. An input range of temperature of about 0 °C to 1 000 °C is suitable (an irradiance of 50 kW/m² will be given by a heater at a temperature in the region of 800 °C). Automatic cold junction compensation for the thermocouple shall be provided.

Desirable features are a meter to indicate the output to the heater and a control which, in the event of an open circuit in the thermocouple line, will cause the temperature to fall to near the bottom of its range.

To monitor heater temperature, particularly to show the operator when the heater has attained temperature equilibrium, the temperature shall be indicated by a meter capable of being read to ± 2 °C. This may be incorporated in the controller or separate.

8.2 Radiometer (heat flux meter)

The radiometer shall be of the Gardon (foil) type with a design range of about 100 kW/m². The target receiving radiation, and possibly to a small extent convection, shall be flat, circular, not more than 10 mm in diameter and coated with a durable matt black finish. The target shall be contained within a water-cooled body whose front face shall be of highly polished metal, flat, coinciding with the plane of the target and circular, with a diameter of about 25 mm.

Radiation shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, insensitive to draughts, and stable in calibration. The instrument shall have an accuracy of within ± 3 % and a repeatability of within $\pm 0,5$ %.

The calibration of the radiometer shall be checked whenever a recalibration of the apparatus is carried out (see 10.2), by comparison with an instrument held as a reference and not used for any other purpose. The reference instrument shall be fully calibrated at yearly intervals.

8.3 Millivolt measuring device

This shall be compatible with the output from the radiometer specified in 8.2. It shall have a full-scale deflection, sensitivity and accuracy which enable the irradiance measured by the radiometer to be resolved to 0,05 W/cm².

8.4 Smoke density recording device

To record transmittance and optical density as measured by the optical system, a potentiometric recording device having an accuracy of at least 0,25 % shall be used. For a pen recorder, a minimum registration speed of 10 mm/min shall be used. Other data collecting systems should provide a comparable resolution in time.

8.5 Light filters

To check the optical system, a set of calibrated neutral grey absorption filters shall be used (optical densities 0,10; 0,40; 0,70; 1; 2; 3).

8.6 Secondary-thermocouple monitoring device

To monitor the secondary thermocouple, an instrument is required with a resolution equivalent to $\pm 2^\circ\text{C}$. This may read directly in temperature or in millivolts. Allowance or automatic compensation for cold junction temperature shall be made. If a separate device is used to monitor heater temperature, this may, with a suitable switch connection, also be used to monitor the secondary thermocouple.

8.7 Ignition time recording device

To indicate and to register the time of ignition monitored by the sheathed thermocouple (see 7.7), a recorder (e.g. a pen recorder) with an adequate response time and a minimum registration speed of 10 mm/min shall be used. The same instrument can be used to monitor the secondary thermocouple (see 8.6).

8.8 Calibration board

The board shall be made of ceramic fibre of density $200\text{ kg/m}^3 \pm 50\text{ kg/m}^3$, and shall be square with sides measuring $165 \pm 5\text{ mm}$ and of thickness not less than 20 mm.

A suitable hole or groove cut to fit closely around the radiometer shall be cut in the centre of the board. The target of the radiometer shall be in the plane of the upper surface of the board. If additional support for the radiometer is required, it shall be provided from below the calibration board.

8.9 Dummy specimen board

This shall be constructed as specified in figure 11. The necessary total thickness of ceramic fibre board may be built up from a number of thinner sheets attached to each other by cement or long fine pins.

8.10 Extinguishing board

This shall be made of the same material as the baseboards (see 6.2) and shall have nominal dimensions of $300\text{ mm} \times 185\text{ mm} \times 6\text{ mm}$.

8.11 Oven

This shall be ventilated and capable of maintaining a temperature of 250°C to meet the recommendation given in 6.4.3.

8.12 Specimen conditioning cabinet

This shall be capable of maintaining a constant temperature of $23^\circ\text{C} \pm 2^\circ\text{C}$ and a relative humidity of $50\% \pm 5\% \text{ R.H.}$

8.13 Balance

This shall have a nominal capacity of 5 kg and shall be readable and accurate to 0,1 g.

8.14 Timing device

This shall be capable of recording elapsed time to the nearest second and shall be accurate to within 1 s in 1 h.

9 Setting-up procedure and requirements

9.1 Siting of apparatus

The decomposition apparatus shall be placed in the middle of the decomposition chamber. The inner walls of the smoke box and the mixing fan shall be kept free from soot and other deposits. The frequency of their cleaning depends on the type of material tested and the amount of soot and/or tar evolved.

The light absorption measuring system shall be thoroughly cleaned. During pre-heating, when changing the level of radiation and between subsequent tests, the sliding door shall be kept open and a dummy specimen board (8.9) shall be inserted in the specimen holder instead of a specimen. The exhaust fan shall be switched off. The mixing fan shall run at a constant speed of 600 rpm. Changes of the room temperature should be avoided.

9.2 Electrical requirements

9.2.1 The heating element of the radiator cone (7.3.3) shall be connected to the output from the thyristor of the temperature controller as shown in figure 12. No element or wiring in this circuit shall be changed between calibration and testing. The primary thermocouple shall be connected to the temperature controller and its temperature monitoring device. The secondary thermocouple shall be connected to its monitoring device (8.6).

9.2.2 The framework of the apparatus shall be provided with a good electrical earth.

9.3 Precautions against electrical interference

The radiometer shall be connected to the millivolt measuring device (8.3) using leads which are screened to minimize any electrical interference to the signal. The radiometer shall be earthed back to the millivolt measuring device and by no other route (i.e. not to the earthed frame of the apparatus). All connections shall be thoroughly checked to ensure good electrical contact.

10 Calibration

10.1 Installation of radiometer

For calibration of the apparatus, the radiometer (8.2) shall be installed in the hole or groove of the calibration board (8.8).