TECHNICAL REPORT

ISO/TR 5659-3

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1999-09-01

Plastics — Smoke generation —

Part 3:
Determination of optical density by a dynamic-flow method

Plastiques — Production de fumée —

Partie 3: Détermination de la densité optique par une méthode dynamique

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.

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

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

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 Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 5659-3, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour.*

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

— *Part 1: Guidance on optical-density testing*

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

— *Part 3: Determination of optical density by a dynamic-flow method*
[Technical Report]

Annex A forms a normative part of this part of ISO 5659.

It was decided to publish this document in the form of a Technical Report (type 2) in order to make the test method described available for use whilst data relating to precision is obtained by means of a programme of collaborative testing. It is envisaged that, when those data are available, this document will be reviewed and a precision statement included, and that it will eventually be reissued as an International Standard.

Introduction

Fire is a complex phenomenon: its behaviour 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.

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 13943 as a visible suspension of solid and/or liquid particles in gases resulting from incomplete combustion. It is one of the first response characteristics to be manifested and should almost always be taken into account in any assessment of fire hazard as it represents one of the greatest threats to occupants of a building on fire.

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

Plastics — Smoke generation —

Part 3:
Determination of optical density by a dynamic-flow method

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 apparatus to avoid inhalation of fumes or skin-contact with smoke deposits.

Attention is drawn to the hazards due to the high temperatures involved and the electric shock hazard.

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 under forced ventilation conditions. with or without the application of a pilot flame. This method of test is applicable to 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, such as end-use conditions, nor has any correlation been established with measurements derived from other test methods.

1.4 It is emphasized that smoke production from a material varies according to the ventilation conditions and 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 of 50 kW/m^2 under specific ventilation conditions.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 5659. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 5659 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*.

ISO 5659-1:1996, *Plastics — Smoke generation — Part 1: Guidance on optical-density testing*.

ISO 5659-2:1994, *Plastics — Smoke generation — Part 2: Determination of optical density by a single-chamber test*.

ISO 13943:—[1)], *Fire safety — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO 5659, the terms and definitions in ISO 13943 apply, plus the following:

3.1
assembly
a mechanical fabrication of materials and/or composites, for example sandwich panels

An assembly may include an air gap.

3.2
composite
a bonded combination of materials which are generally recognized as discrete entities, e.g. coated or laminated materials

3.3
essentially flat surface
a surface in which irregularity 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)
ratio of the radiant flux incident on an infinitesimal element of the surface containing the point and the area of that element

3.6
material
a basic single substance or uniformly dispersed mixture, for example timber, concrete, mineral fibre, polymer

3.7
optical density of smoke
D
a measure of the degree of opacity of smoke, expressed as the negative common logarithm of the relative transmission of light

3.8
product
a material, composite or assembly about which information is required

3.9
specimen
a representative piece of the product which is to be tested together with any substrate or treatment

A specimen may include an air gap.

1) To be published.

4 Principles of the test

Specimens of the product are mounted horizontally 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 Some materials will not ignite when exposed to the conditions given in a) or b).

The smoke evolved is conducted into an exhaust system consisting of a canopy hood, duct and fan. The duct contains both an orifice plate, the pressure across which is used to monitor the speed of air flow along the duct, and photometric equipment for measuring the optical density of the smoke effluent stream throughout the test. The results are reported in terms of the measured optical density over the period of the test.

The exhaust system can either be used bench-mounted with the decomposition apparatus described in clause 7 or it may be fitted to the test chamber described in ISO 5659-2, which is used with the chamber door closed but the blow-out panel removed. Whichever exhaust mounting configuration is used, the operating procedure is similar. Work has yet to be done to establish whether tests carried out under the same flow and heat-flux conditions but with different exhaust mounting configurations will give similar results.

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) (unless the sample is being tested at thicknesses greater than the thermal thickness of the material), 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 derive or calculate the optical density vs time profile for a material at one thickness from the measurements made on the same material at a different thickness.

5.2 Physical characteristics

Materials submitted for evaluation by this method could have surfaces which differ or could contain laminations of different materials arranged in a different order in relation to the two surfaces. If either of the surfaces is likely to be exposed to a fire condition when in use, then both surfaces 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 so that six specimens are tested at 25 kW/m^2 (i.e. three specimens with a pilot flame and three specimens without a pilot flame) and three specimens are 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 surface (see 5.2).

6.1.3 An additional nine specimens (i.e. three specimens per test mode) shall be held in reserve for use 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 mm ± 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 5,0 mm ± 0,1 mm.

If possible, materials shall be tested at their end-use thickness.

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

6.2.4 Specimens of multi-layer materials with a thickness greater than 25 mm and consisting of core material(s) with surfacing of different materials shall be prepared in accordance with 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 ± 1) mm × (65 ± 1) mm, with a single sheet of aluminium foil (approximately 0,04 mm ± 0,01 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 specimen holder in such a way that the exposed surface lies flush with the inside face of the opening of the holder. Materials with uneven exposed surfaces shall not protrude beyond the plane of the opening of the 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.

NOTE 1 Forced air movement in the conditioning chamber may be used to assist in accelerating the conditioning process.

NOTE 2 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.

NOTE 3 Specific conditioning procedures may be required for investigating the effects of moisture on specimen behaviour.

7 Apparatus and ancillary equipment

7.1 General

The apparatus (see Figure 1) consists of specimen-decomposition equipment coupled to an exhaust system. The exhaust system, which collects and monitors the smoke generated by the specimen-decomposition equipment, incorporates a canopy hood, a duct (housing an orifice plate and photometric equipment) and a variable-speed fan. The specimen-decomposition equipment consists of a specimen holder, a radiator cone, a pilot burner and ancillary facilities for controlling the conditions of operation during a test.

7.2 Specimen support and heating arrangements

NOTE The specimen-decomposition equipment is identical in most respects to that used in ISO 5659-2.

7.2.1 Radiator cone

7.2.1.1 The radiator cone shall consist of a heating element, of nominal rating 2 600 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 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 in place by two plates at the top and bottom of the element.

7.2.1.2 The radiator cone shall be capable of providing irradiance in the range of 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.

7.2.1.3 The temperature controller for the radiator cone shall be a proportional, integral and derivative-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.

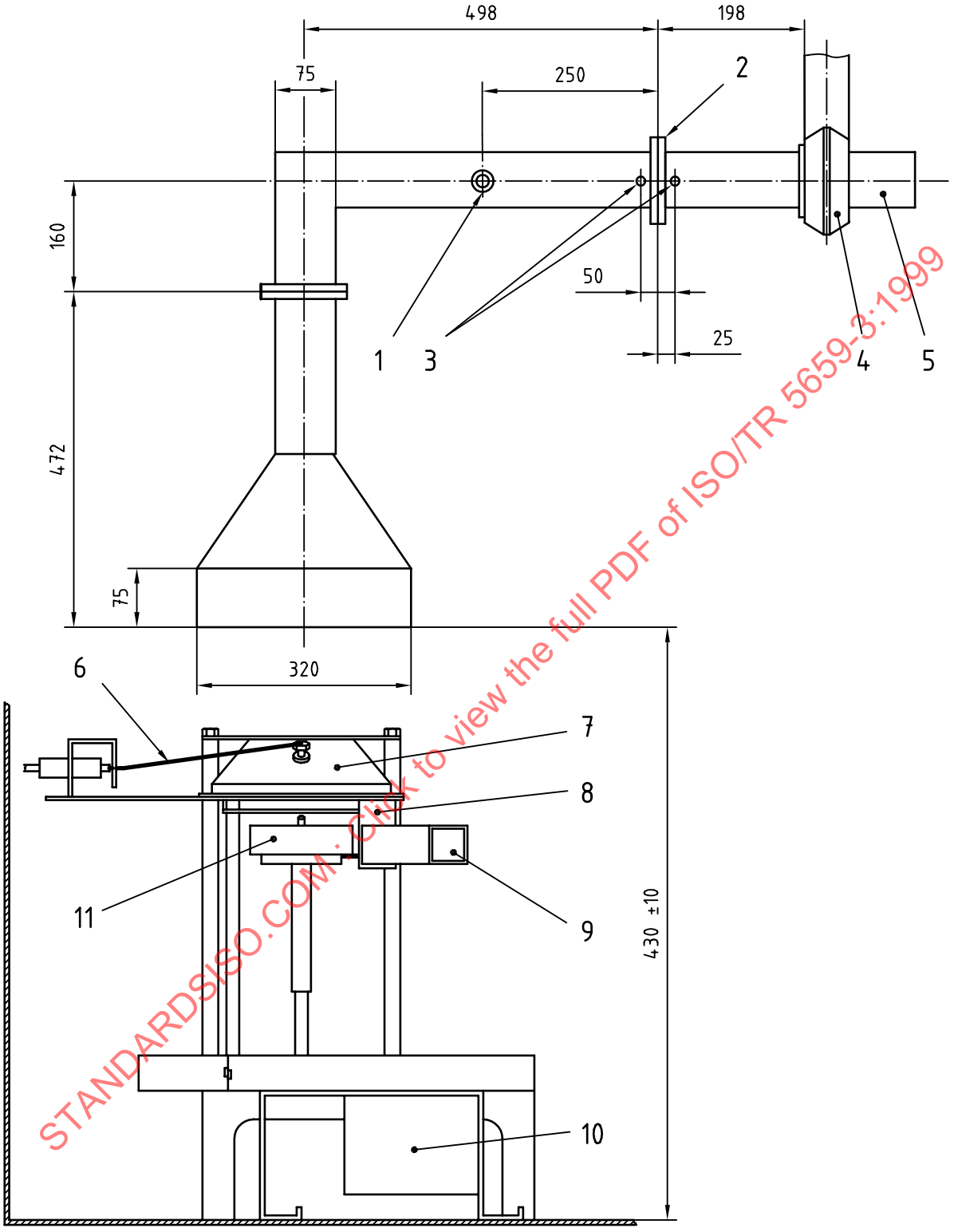
NOTE While phase angle control is allowed for the temperature controller of the radiator cone, it should be noted that this will usually require electrical filtering to avoid risk of low-level signal lines.

7.2.1.4 The irradiance of the radiator cone shall be controlled by reference to the reading of two type K sheathed NiCr/NiAl thermocouples mounted diametrically opposite and in contact with, but not welded to, the heating 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.

7.2.2 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.

Dimensions in millimetres



Key

1 Dynamic smoke-measurement system
2 Orifice plate (orifice diameter 37,5 mm)
3 Pressure ports
4 Fan
5 Fan motor
6 Thermocouple
7 Radiator cone
8 Radiation shield
9 Heat-flux meter holder
10 Spark-ignition housing
11 Specimen holder

Figure 1 — Typical arrangement of test apparatus

7.2.3 Radiation shield

A remotely controllable shield made of metallic and/or other inorganic material shall be provided to cut off the irradiance to the specimen at the end of the required exposure period.

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

7.2.4 Heat-flux meter

7.2.4.1 The heat-flux meter shall be of the Schmidt-Boelter type with design range of about 50 kW/m^2. The target receiving the radiation shall have a flat, circular face of 10 mm diameter, coated with a durable matt-black finish. The target shall be water-cooled.

7.2.4.2 The heat-flux meter shall be connected directly to a suitable recorder (7.7.6) 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 ± 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.

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

7.2.5 Specimen holder

Details of the specimen holder are shown in Figure 2. 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 Pilot burner

The single-flame burner shall have a flame length of 30 mm ± 5 mm and shall be positioned horizontally 10 mm above the top surface of the specimen.

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 50 cm^3/min and that for the air a value of 500 cm^3/min.

The colour of the flame shall be blue with a yellow tip. If using the ISO 5659-2 test chamber, 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 Exhaust system

7.4.1 The exhaust system is shown in Figure 1. It may be mounted in two different ways: on the bench over the decomposition apparatus described in 7.2 or fitted to the test chamber described in ISO 5659-2. In the latter case, tests shall be carried out with the chamber door closed but with the blow-out panel in the floor of the chamber removed to ensure correct ventilation.

Dimensions in millimetres

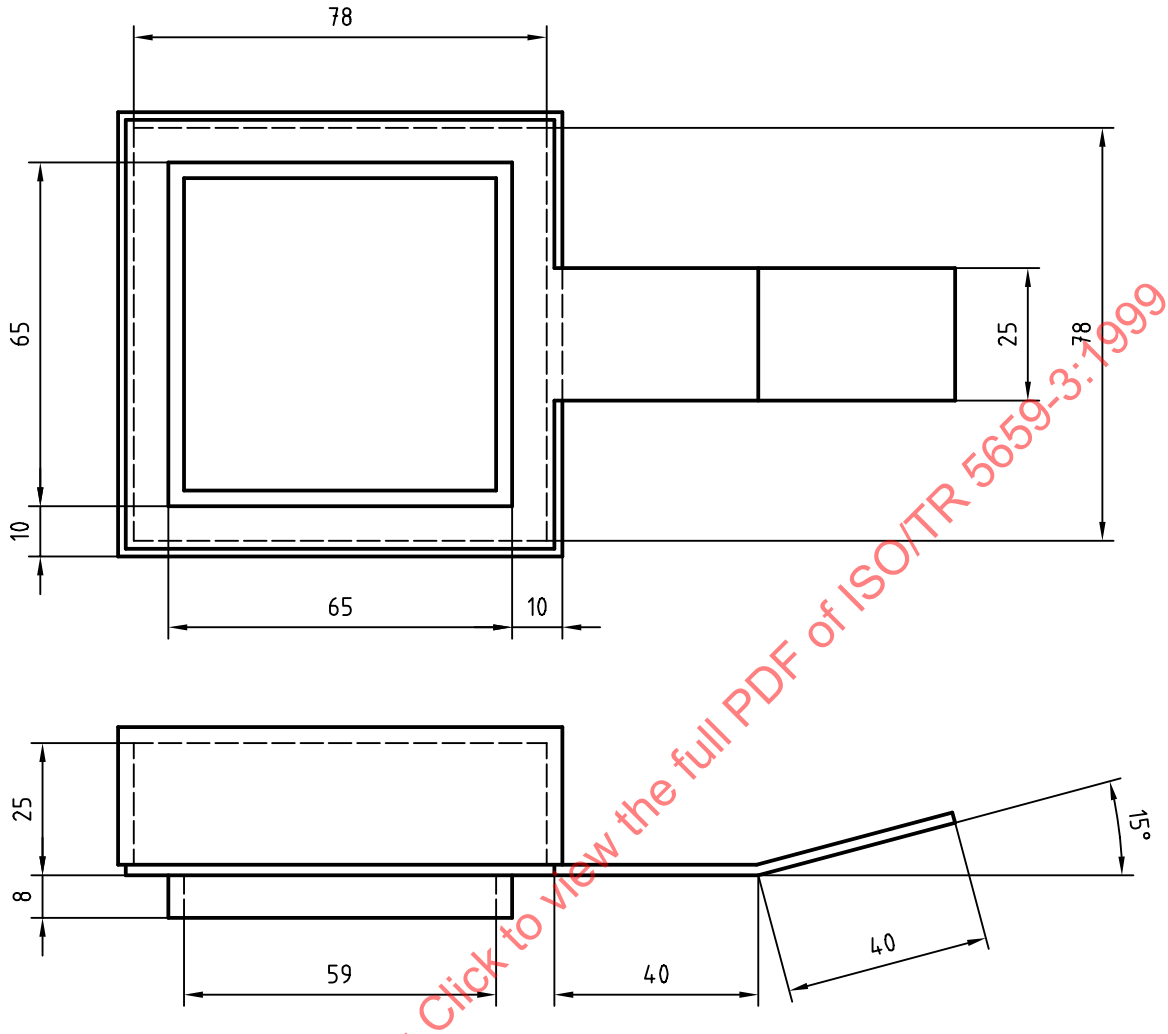
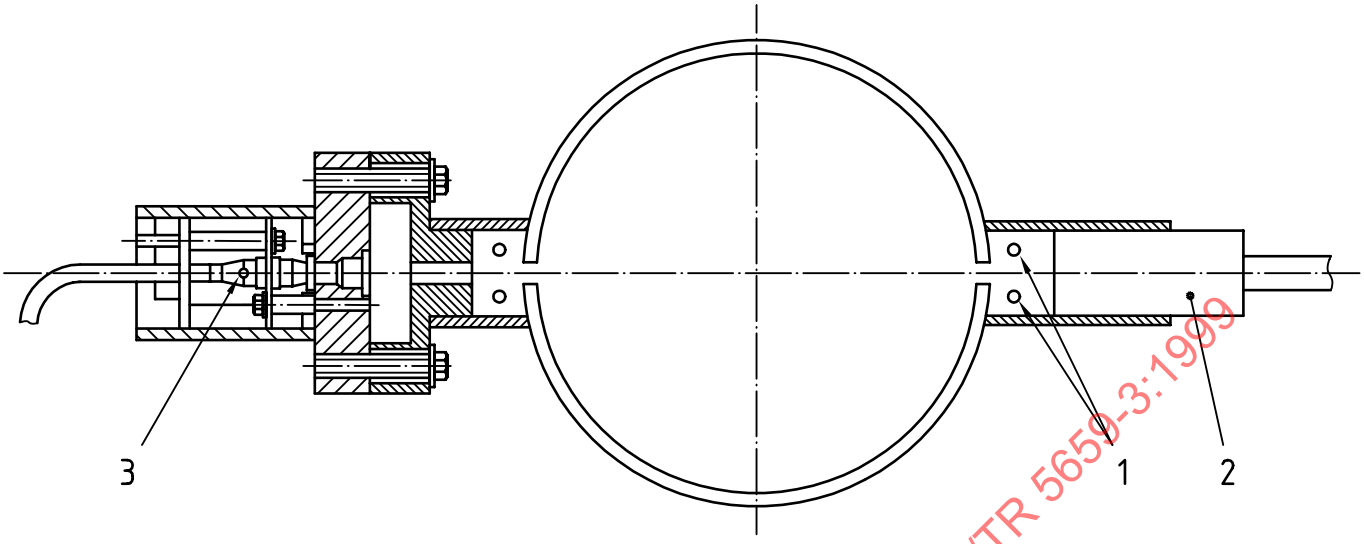


Figure 2 — Specimen holder

The exhaust system shall consist of a centrifugal exhaust fan, a canopy hood, an exhaust duct leading to the fan, and an orifice-plate flowmeter. The bottom of the hood shall be square with an area of (320 ± 10) mm × (320 ± 10) mm, and the hood shall be mounted so that its lower edges are 430 mm ± 10 mm above the bench or 475 mm ± 10 mm below the ceiling of the test chamber (if used). The exhaust duct shall have an internal diameter of 75 mm ± 5 mm and be constructed in three sections which are joined at two gasketed flange joints. The joints shall be located at the ceiling of the test chamber and at the orifice-plate location. The exhaust system shall be capable of developing flows that generate pressures across the orifice plate between 0,049 kPa (5 mm of water) and 0,196 kPa (20 mm of water). Two 25-mm-long, 25-mm-diameter tubes shall be welded on to opposite sides of the exhaust duct to house the light source and optics of the photometric system used to measure the density of the smoke. Four small air-bleed holes are drilled in each of the mounting tubes close to the duct (see Figure 3). These allow clean air to be drawn across the face of the detector and the light source, thus preventing soot deposition.

7.4.2 The exhaust system shall be checked for proper operation before testing and shall discharge into a building exhaust system with adequate capacity. Provision shall be made for collecting and venting any combustion products that fail to be collected by the hood.

Dimensions in millimetres



Key

1 Air-bleed holes
2 Light source
3 Detector

Figure 3 — Photometric system

7.5 Photometric system

7.5.1 General

The photometric system shall consist of a white light source and collimating lens, a silicon photodiode detector and appropriate electronics to derive the extinction coefficients and zero the system. The system shall be mounted as shown in Figure 3.

7.5.2 Light source

The light source shall be a 3,0 V incandescent lamp. Power for the lamp shall be provided by a stablized power supply producing 1,5 V. The lamp is housed, together with a suitable collimating lens, in one of the side tubes welded on to the duct (see 7.4.1), to give a parallel beam of light across the duct.

7.5.3 Photodetector

7.5.3.1 The light-measuring system shall consist of a silicon photodiode with a peak spectral response of 900 nm connected to a high-gain low-noise amplifier. It shall be capable of continuously measuring relative light intensity against time as percentage transmission over the ranges to be studied. The system shall have a linear response with respect to transmittance and an accuracy of better than ±3 % of the maximum reading. The photodiode shall be housed, together with a collimating lens and a suitable filter, in the second of the two side tubes on the exhaust duct (see 7.5.2).

7.5.3.2 Two neutral-density filters, with nominal optical densities of 0,3 and 0,8, shall be available for calibrating the photometric system. They shall be mounted in suitable mounts so that they can be introduced between the photodiode and the duct to completely cover the photodiode. Their actual optical density shall have been determined previously by calibration.

It is essential that all filters are handled by their edges, because fingerprints can greatly affect their rating. No attempt shall be made to clean the surface of a filter; once the surface has been damaged or spoilt, the filter shall be replaced.

7.6 Monitoring the smoke flow rate

The rate of flow of the smoke moving down the exhaust duct is not measured directly but is assumed to remain constant at the set rate once the system has reached equilibrium immediately prior to the test. The flow is set with reference to the pressure generated across the orifice plate. This may be done either with a calibrated pressure transducer or, more economically, by using a simple water manometer with a range of up to 50 mm water gauge. Flows generating 5 mm, 10 mm or 20 mm water gauge shall be used in smoke production rate measurements.

7.7 Ancillary equipment

7.7.1 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.

7.7.2 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.

7.7.3 Linear measuring devices

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

7.7.4 **Auxiliary heater** (for use with ISO 5659-2 test chamber)

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

7.7.5 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.

7.7.6 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 7.2.4.2) to the required accuracy.

7.7.7 Thermometer

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

7.7.8 Water-circulating device

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

7.8 Cleaning materials

Appropriate materials shall be available for cleaning the inside of the test chamber (if used) and the framework of the specimen-decomposition equipment.

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.

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 test zone 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 but do not allow it to heat up or remain operating without the radiation shield, 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

Carry out the procedure detailed here on initially setting up the apparatus, after replacement of the light source or after any accidental misalignment has occurred.

Check the optical housings for rigidity. Mount the housing containing the light source and collimator lens on the exhaust duct and connect to the power supply. Switch on the light source and hold a piece of dark card on the other side of the duct to view the beam transmitted across the duct.

Mount the photodiode housing in position on the duct and adjust the current to the light source so that the output from the photodiode is approximately 2 V.

9.3 Linearity check

Adjust the zeroing device to give a reading of 0 % transmission with no incident light. Set the full-scale reading to 100 % transmission with maximum incident light.

Place the filter of nominal optical density of 0,3 in the housing in front of the photodiode and measure the percentage transmission. Repeat this operation with the filter of nominal optical density 0,8. The difference between the observed reading and the actual value (that obtained by calibration of the filter), shall be within 5 % in each case. If either reading is outside this range, the scale is not linear.

9.4 Burner settings

Set the propane flow to 88,5 cm^3/min ± 1,0 cm^3/min and the air flow to 270 cm^3/min ± 20 cm^3/min (see 7.3).

9.5 Radiator-cone calibration

9.5.1 Clean the apparatus of any residues left from previous tests. Mount the heat-flux meter as specified in 7.2.4, connect to the electrical and water services and pass water through the heat-flux meter to cool the heat-flux meter body.

9.5.2 Bring the apparatus to its normal operation condition and move the radiation shield away from the cone.

9.5.3 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.

Allow about 10 min for stabilizing between adjustments.

9.5.4 Repeat the procedure of 9.5.3 as necessary to calibrate the equipment in three positions, i.e. at the centre and 25 mm each side of the centre.

9.5.5 Return the radiation shield to the position below the cone and remove the heat-flux meter from its housing 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.

9.6 Cleaning

Clean the inside walls of the test chamber (if used) 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 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. Even when testing specimens of the same material, accumulations of residues can reduce the amount of deposition of smoke, resulting in an increase in the measured value of the specific optical density.

9.7 Frequency of checking and calibration procedures

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

Table 1 — Frequency of checks and calibrations

Item of equipment	Maximum interval between checks and calibrations
Test chamber interior	Inspect before testing every specimen and before any calibration
Radiator cone	Once every test day and when renewed or replaced
Heat-flux meter	Every 3 months and when cleaned or re-coated
Photometric-system calibration	Before testing every specimen
Photometric-system alignment	Every 6 months and when light source is replaced or when damage occurs
Photometric-system linearity	Every 6 months and when transmission through windows deteriorates

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

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

10 Test procedure

10.1 Preparation of exhaust system

10.1.1 The test may be carried out with the exhaust system set up in two different ways: directly over the specimen-decomposition equipment standing on the lab bench, or fitted to the ISO 5659-2 test chamber. The preparation procedure for each case is described below:

a) Configuration 1, directly over specimen-decomposition equipment

Prepare the specimen-decomposition equipment as described in clause 9. Switch on the exhaust fan and adjust the fan speed until the manometer shows a constant pressure of 0,049 kPa, 0,098 kPa or 0,196 kPa (5 mm, 10 mm or 20 mm of water). Ensure this is stable for 10 min before proceeding any further. Set the cone irradiance at 25 kW/m^2 or 50 kW/m^2, as required.

b) Configuration 2, fitted to ISO 5659-2 chamber

The ducting shall be correctly mounted on the ISO 5659-2 chamber and the blow-out panel removed. Close the chamber door and keep it closed throughout the calibration and test period. It will be necessary to open the door briefly to introduce the specimen. Switch on the exhaust fan and adjust the fan speed until the manometer shows a constant pressure of 5 mm, 10 mm or 20 mm of water. Ensure this is stable for 10 min before proceeding any further. Prepare the specimen-decomposition equipment as described in clause 9 with the cone set at 25 kW/m^2 or 50 kW/m^2.

10.1.2 If a test chamber is being used, flush it with air until it is completely clear of smoke. Inspect the inside of the cabinet and clean the walls and the supporting framework, if necessary (see 9.6).

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 they are as required by 9.4.

10.3 Preparation of photometric system

Set the zero and check that the 100 % setting is 2 V.

10.4 Loading the specimen

Place a wrapped specimen, prepared in accordance with 6.3 and 6.4 and conditioned in accordance with 6.5, with its backing board, in its holder. Place the holder and specimen on the supporting framework below the radiator cone. Remove the radiation shield from below the cone and simultaneously start the recording-chart drive at a minimum chart speed of 10 mm/min. 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 transmission and time continuously from the start of the test (i.e. when the radiation shield was removed).

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.

NOTE 1 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.

NOTE 2 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, thus 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.

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, if the specimen is still generating smoke.