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

*Plastiques — Production de fumée —*

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

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 5659-2 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

This third edition cancels and replaces the second edition (ISO 5659-2:2006), which has been technically revised. It also replaces ISO 5659-1:1996 (*Plastics — Smoke generation — Part 1: Guidance on optical-density testing*), which will be withdrawn upon publication of this edition.

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

- *Part 2: Determination of optical density by a single-chamber test*
- *Part 3: Determination of optical density by a dynamic-flow method* (Technical Report)

## Introduction

Fire is a complex phenomenon: its development and effects depend upon a number of interrelated factors. The behaviour of materials and products depends upon the characteristics of the fire, the method of use of the materials and the environment in which they are exposed (see also ISO/TR 3814<sup>[1]</sup> and ISO 13943).

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 or other enclosure, such as a ship or train, on fire.

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

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# Plastics — Smoke generation —

## Part 2:

# Determination of optical density by a single-chamber test

## 1 Scope

**1.1** This part of ISO 5659 specifies a method of measuring smoke production from the exposed surface of specimens of materials, composites or assemblies. It is applicable to specimens that have an essentially flat surface and do not exceed 25 mm in thickness when placed in a horizontal orientation and subjected to specified levels of thermal irradiance in a closed cabinet with or without the application of a pilot flame. This method of test is applicable to all plastics and may also be used for the evaluation of other materials (e.g. rubbers, textile-coverings, painted surfaces, wood and other materials).

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

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

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

**1.4** It is emphasized that smoke production from a material varies according to the irradiance level to which the specimen is exposed. The results yielded from the method specified in this part of ISO 5659 are based on exposure to the specific irradiance levels of 25 kW/m<sup>2</sup> and 50 kW/m<sup>2</sup>.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13943, *Fire safety — Vocabulary*

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

## 3 Terms and definitions

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

### 3.1

#### **assembly**

fabrication of materials and/or composites

**NOTE 1** Sandwich panels are an example of an assembly.

**NOTE 2** The assembly may include an air gap.

3.2

**composite**

combination of materials which are generally recognized in building construction as discrete entities

NOTE Coated or laminated materials are examples of composites.

3.3

**essentially flat surface**

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

3.4

**exposed surface**

surface of the product subjected to the heating conditions of the test

3.5

**irradiance**

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

3.6

**material**

basic single substance or uniformly dispersed mixture

NOTE Metal, stone, timber, concrete, mineral fibre and polymers are examples.

3.7

**mass optical density**

**MOD**

measure of the degree of opacity of smoke in terms of the mass loss of the material

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3.8

**optical density of smoke**

**D**

measure of the degree of opacity of smoke, taken as the negative common logarithm of the relative transmission of light

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3.9

**product**

material, composite or assembly about which information is required

3.10

**specific optical density**

$D_s$

optical density multiplied by a factor which is calculated by dividing the volume of the test chamber by the product of the exposed area of the specimen and the path length of the light beam

NOTE See 11.1.1.

3.11

**specimen**

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

NOTE The specimen may include an air gap.

3.12

**intumescent material**

dimensionally unstable material, developing a carbonaceous expanded structure of thickness > 10 mm during the test, with the cone heater 25 mm from the specimen



## 4 Principles of the test

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

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

## 5 Suitability of a material for testing

### 5.1 Material geometry

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

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

**NOTE** It is not possible to calculate the specific optical density of one thickness of a material from the specific optical density of another thickness of the material.

### 5.2 Physical characteristics

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

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## 6 Specimen construction and preparation

### 6.1 Number of specimens

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

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

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

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

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

### 6.2 Size of specimens

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

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

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

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

### 6.3 Specimen preparation

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

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

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

### 6.4 Wrapping of specimens

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**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  $65 \text{ mm} \times 65 \text{ mm}$ , using a single sheet of aluminium foil (approximately  $0,04 \text{ mm}$  thick) with the dull side in contact with the specimen. Care shall be taken not to puncture the foil or to introduce unnecessary wrinkles during the wrapping operation. The foil shall be folded in such a way as to minimize losses of any melted specimen material at the bottom of the specimen holder. After mounting the specimen in its holder, any excess foil along the front edges shall be trimmed off.

**6.4.2** Wrapped specimens of a thickness less than 25 mm shall be backed with a low density (nominal  $65 \text{ kg/m}^3$ ) refractory fibre blanket.

Wrapped specimens of a thickness of 25 mm shall be tested without a refractory fibre blanket.

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

**6.4.4** When thin impermeable specimens, such as thermoplastic films, become inflated during the test owing to gases trapped between the film and backing, they shall be maintained essentially flat by making two or three cuts ( $20 \text{ mm}$  to  $40 \text{ mm}$  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  $23 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$  and a relative humidity of  $(50 \pm 10) \%$  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.

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

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

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

## 7 Apparatus and ancillary equipment

### 7.1 General

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

### 7.2 Test chamber

#### 7.2.1 Construction

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

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

**NOTE** A design with a wide door occupying a complete side of the smoke chamber has been found suitable for facilitating cleaning and maintenance operations.

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

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

**7.2.1.4** An inlet vent with shutter shall be provided in the front of the chamber at the top or on the roof of the chamber and away from the radiator cone, and an exhaust vent with shutter shall be provided in the bottom of the chamber lead, via flexible tubing with a diameter of 50 mm to 100 mm, to an extraction fan capable of creating a negative pressure of at least 0,5 kPa (50 mm water gauge).

## **7.2.2 Chamber pressure control facilities**

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

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

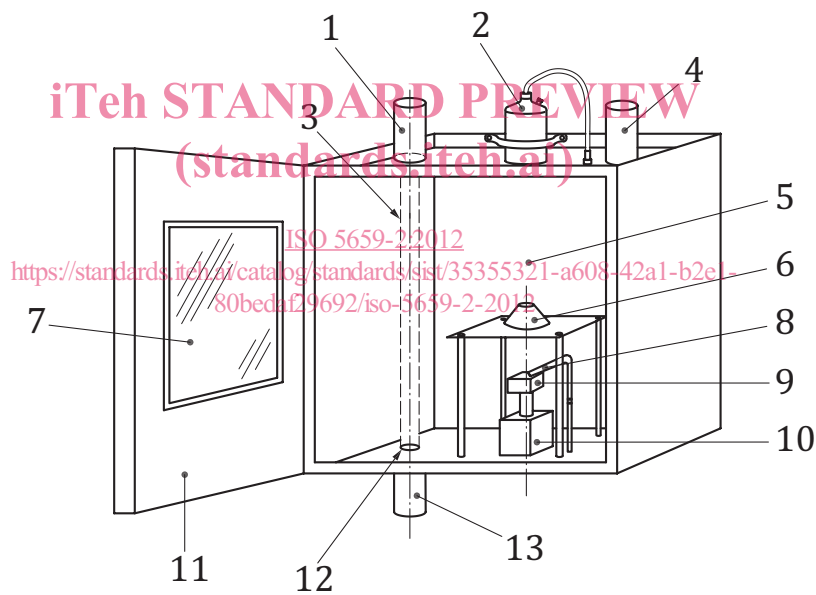
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a) Typical example of commercially available test apparatus



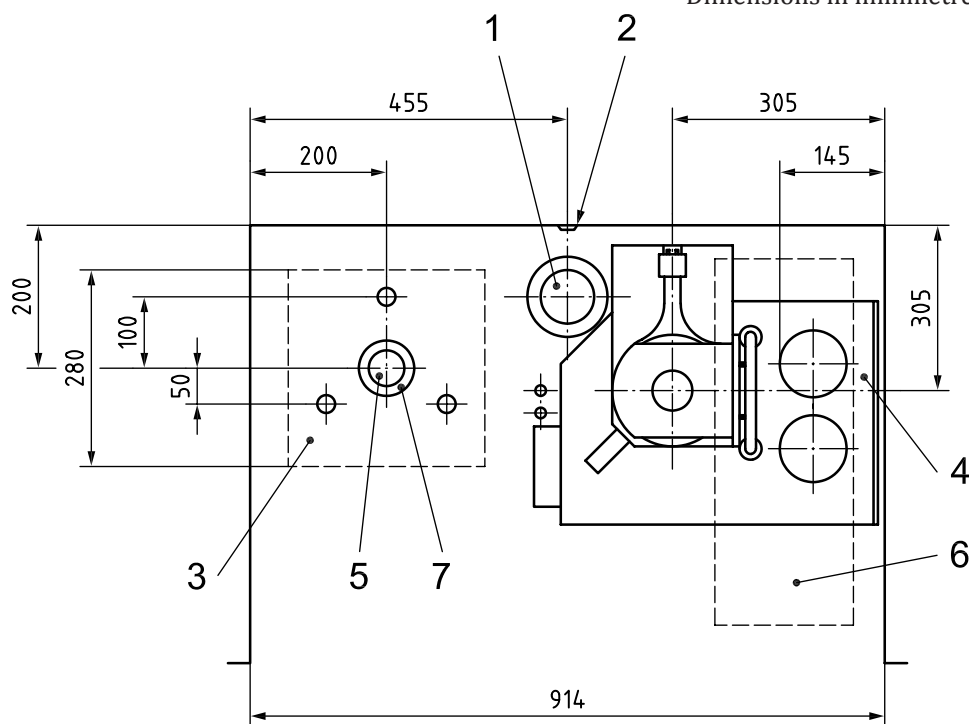
b) Schematic drawing of typical test apparatus

**Key**

- |                              |                                |
|------------------------------|--------------------------------|
| 1 optical measurement system | 8 pilot burner                 |
| 2 pressure controller        | 9 specimen in specimen holder  |
| 3 optical path               | 10 weighing device             |
| 4 exhaust                    | 11 full front open door        |
| 5 chamber                    | 12 optical system floor window |
| 6 conical heater             | 13 light source                |
| 7 window                     |                                |

**Figure 1 — Test apparatus**

Dimensions in millimetres (not to scale)



**Key**

- 1 exhaust vent
- 2 wall thermocouple
- 3 optical platform
- 4 radiator cone assembly

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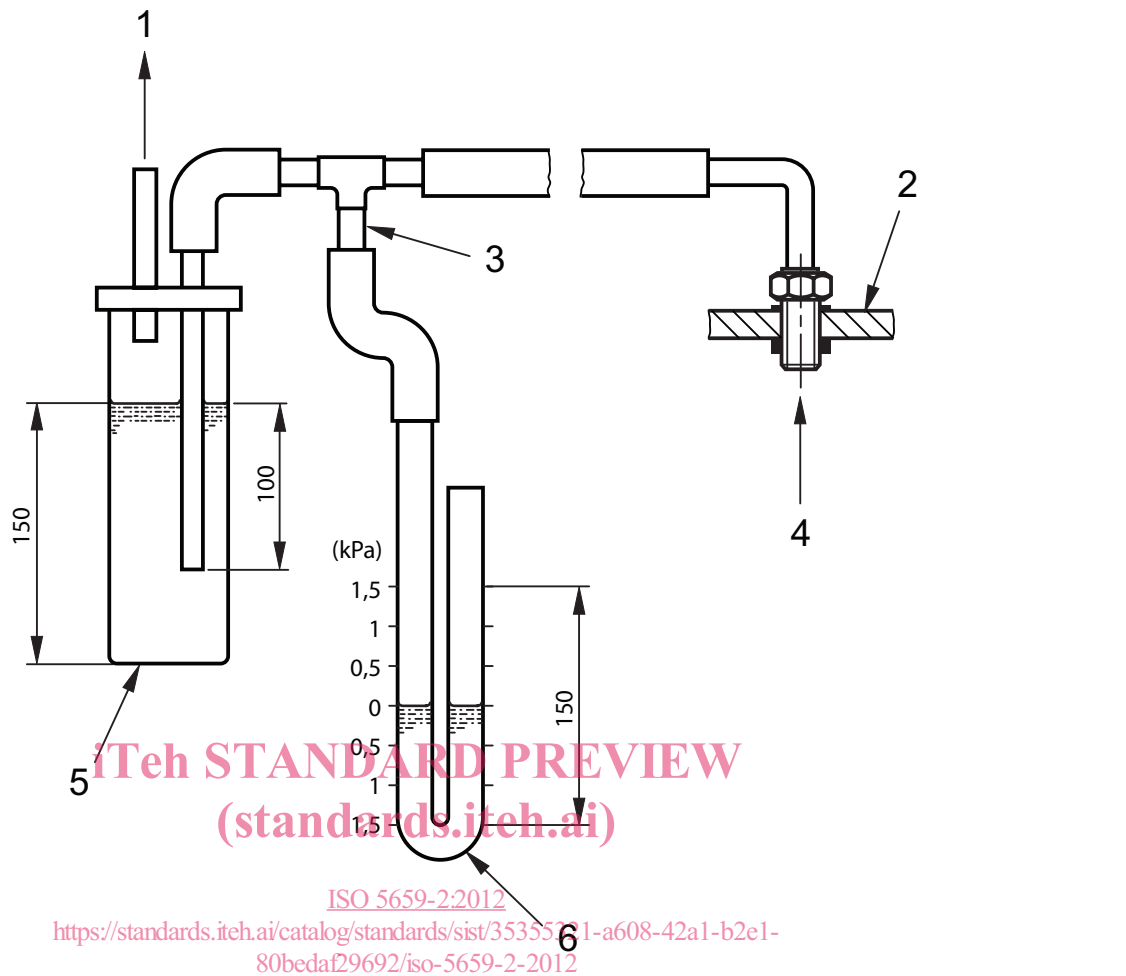
- 5 optical window
- 6 blow-out panel
- 7 window heater

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**Figure 2 — Plan view of typical chamber**

Dimensions in millimetres



**Figure 3 — Typical chamber pressure relief manometer**

### 7.2.3 Chamber wall temperature

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

## 7.3 Specimen support and heating arrangements

### 7.3.1 Radiator cone

**7.3.1.1** The radiator cone shall consist of a heating element, of nominal rating 2600 W, contained within a stainless-steel tube, approximately 2 210 mm in length and 6,5 mm in diameter, coiled into the shape of a truncated cone and fitted into a shade. The shade shall have an overall height of  $45 \pm 0,4$  mm, an internal