INTERNATIONAL STANDARD

ISO 5659-2

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Plastics — Smoke generation —

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

Plastiques — Production de fumée —

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

Reference number
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Contents

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Foreword

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

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

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

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

— *Part 1: Guidance*

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

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

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

Introduction

Fire is a complex phenomenon: its development and its effects depend upon a number of interrelated factors. The behaviour of materials and products depends upon the characteristics of the fire, the method of use of the materials and the environment in which they are exposed (see also ISO/TR 3814 and ISO/IEC Guide 52).

A test such as is specified in this part of ISO 5659 deals only with a simple representation of a particular aspect of the potential fire situation, typified by a radiant heat source, and it cannot alone provide any direct guidance on behaviour or safety in fire. A test of this type may, however, be used for comparative purposes or to ensure the existence of a certain quality of performance (in this case smoke production) considered to have a bearing on fire behaviour generally. It would be wrong to attach any other meaning to results from this test.

The term "smoke" is defined in ISO/IEC Guide 52 as a visible suspension of solid and/or liquid particles in gases resulting from incomplete combustion. It is one of the first response characteristics to be manifested and should almost always be taken into account in any assessment of fire hazard as it represents one of the greatest threats to occupants of a building on fire.

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

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

Plastics — Smoke generation —

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

WARNING

1 Avoidance of misleading inferences

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

2 Avoidance of danger to test operators

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

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

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

1 Scope

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

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

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

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

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

2 Normative references

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

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

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

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

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

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

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

3 Definitions

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

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

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

1) To be published.

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

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

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

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

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

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

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

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

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

4 Principles of the test

Specimens of the product are mounted horizontally within a chamber and exposed to thermal radiation on their upper surfaces at selected levels of constant irradiance up to 50 kW/m^2; the test may be carried out in the absence or in the presence of a pilot flame.

The preferred conditions are as follows:

a) specimens are exposed to an irradiance of 25 kW/m^2 in the presence or absence of a pilot flame;

b) specimens are exposed to an irradiance of 50 kW/m^2 in the absence of a pilot flame;

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

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

5 Suitability of a material for testing

5.1 Material geometry

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

5.1.2 The method is sensitive to small variations in geometry, surface orientation, thickness (either overall or of the individual layers), mass and composition of the material, and so the results obtained by this method only apply to the thickness of the material as tested. It is not possible to calculate the specific optical density of one thickness of a material from the specific optical density of another thickness of the material.

5.2 Physical characteristics

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

6 Specimen construction and preparation

6.1 Number of specimens

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

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

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

6.2 Size of specimens

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

6.2.2 Materials of nominal thickness 25 mm or less shall be evaluated at their full thickness. For comparative testing, materials shall be evaluated at a thickness of 1,0 mm ± 0,1 mm.

All materials consume oxygen when they burn in the chamber, and the smoke generation of some materials (especially rapid-burning or thick specimens) is influenced by the reduced oxygen concentration in the chamber. As far as possible, materials shall be tested in their end-use thickness.

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

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

6.3 Specimen preparation

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

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

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

6.4 Wrapping of specimens

6.4.1 All specimens shall be covered across the back, along the edges and over the front surface periphery, leaving a central exposed specimen area of 65 mm × 65 mm, with a single sheet of aluminium foil (approximately 0,04 mm thick) with the dull side in contact with the specimen. Care shall be taken not to puncture the foil or to introduce unnecessary wrinkles during the wrapping operation. The foil shall be folded in such a way as to minimize losses of any melted material at the bottom of the specimen holder. After mounting the specimen in its holder, any excess foil along the front edges shall be trimmed off where appropriate.

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

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

6.4.4 When thin impermeable specimens, such as thermoplastic films, become inflated during the test due to gases trapped between the film and backing, they shall be maintained essentially flat by making two or three cuts (20 mm to 40 mm long) in the film to act as vents.

6.5 Conditioning

6.5.1 Before preparing the specimens for test, they shall be conditioned to constant mass at 23 °C ± 2 °C and (50 ± 5) % R.H., where constant mass shall be considered to have been reached when two successive weighing operations, carried out at an interval of 24 h, do not differ by more than 0,1 % of the mass of the test specimen or 0,1 g, whichever is the greater (see ISO 291).

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

NOTES

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

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

7 Apparatus and ancillary equipment

7.1 General

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

7.2 Test chamber

7.2.1 Construction

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

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

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

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

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

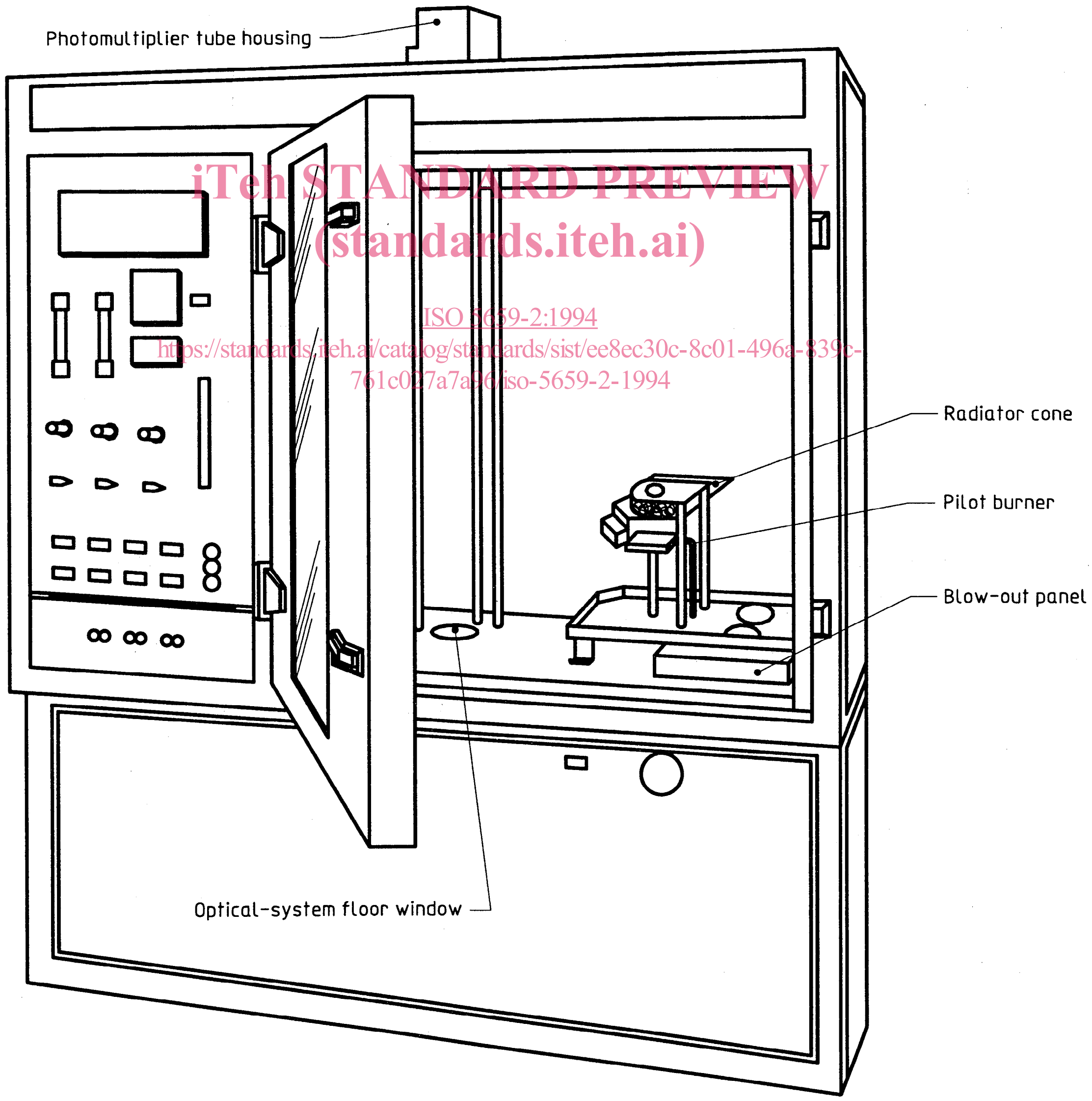

Figure 1 — Typical arrangement of test apparatus

Dimensions in millimetres
(not to scale)

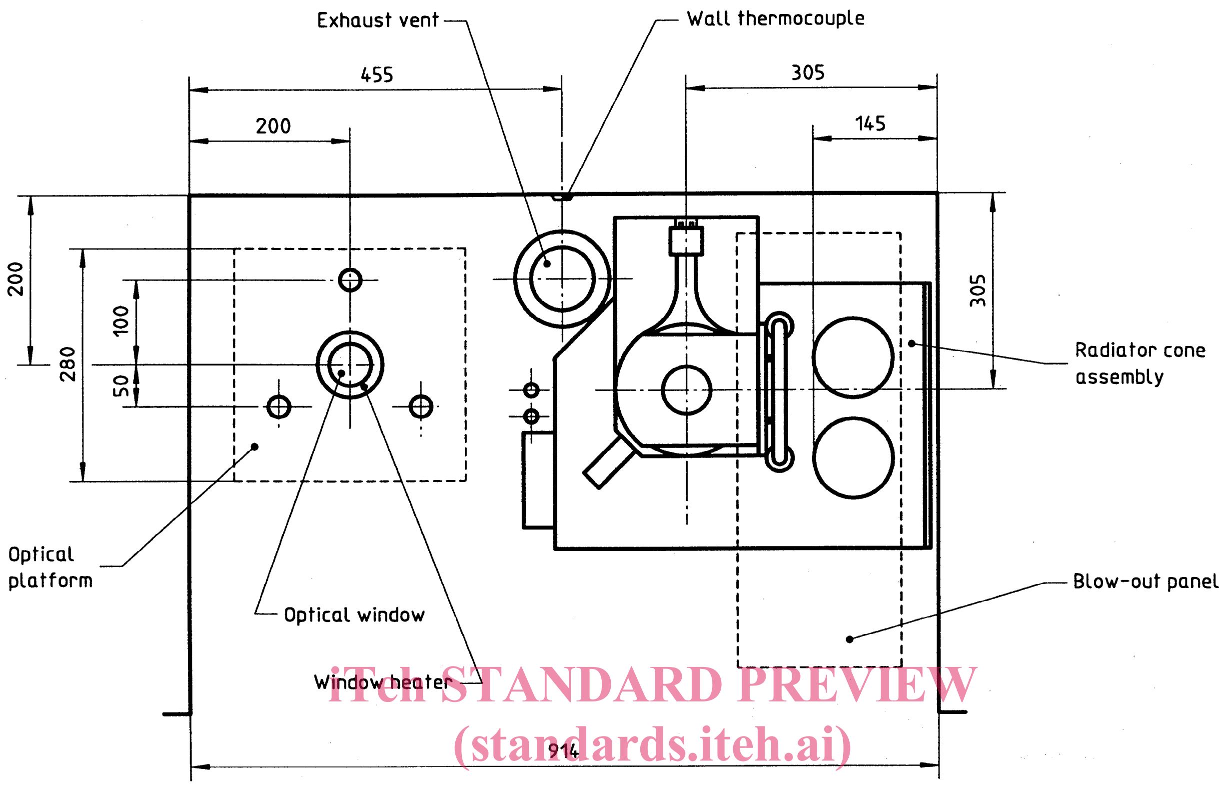

Figure 2 — Plan view of typical test chamber

7.2.2 Chamber pressure control facilities

Provision shall be made for controlling the pressure inside the test chamber. A water manometer, with a range of up to 1,5 kPa (150 mm water gauge) shall be provided for connection to a pressure regulator and to a tube in the top of the chamber.

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

7.2.3 Chamber wall temperature

A thermocouple measuring junction, made from wires of diameter not greater than 1 mm, shall be mounted on the inside of the back wall of the chamber, at the geometric centre, by covering it with an insulating disc (such as polystyrene foam) with a thickness of approximately 6,5 mm and a diameter of not more than 20 mm, attached to the wall of the chamber with a suitable cement. The thermocouple junction shall be connected to a recorder or meter and the system shall be suitable for measuring temperatures in the range 35 °C to 60 °C (see 10.1.2).

Dimensions in millimetres

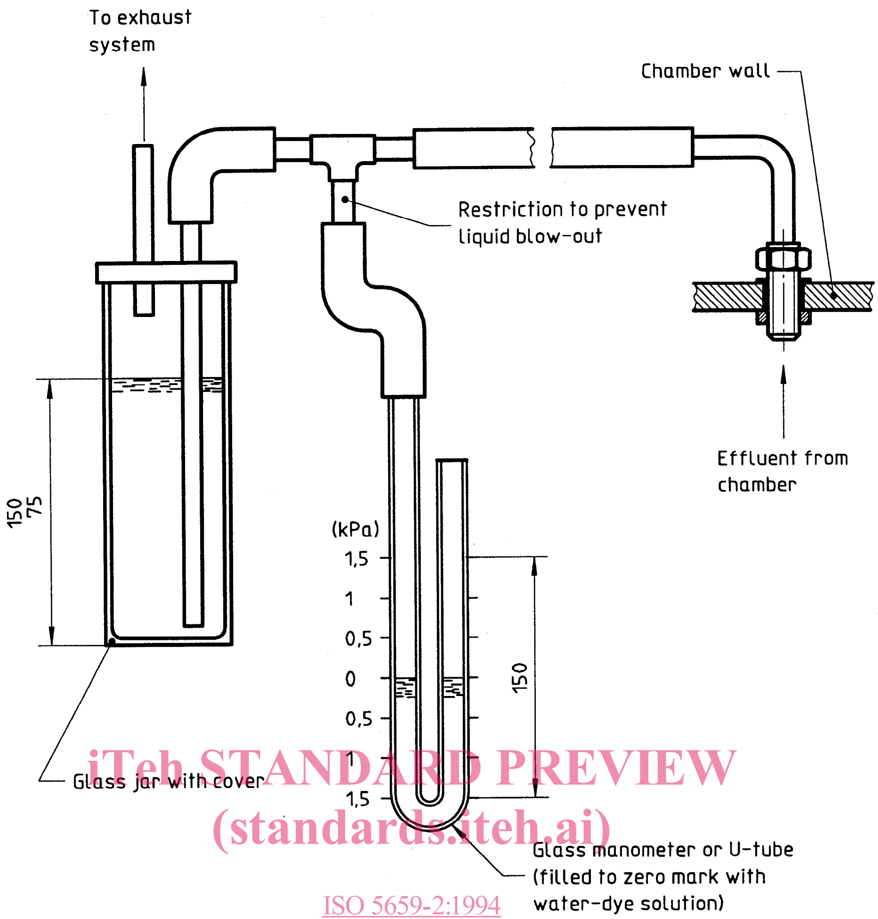

Figure 3 — Typical chamber pressure relief manometer

7.3 Specimen support and heating arrangements

7.3.1 Radiator cone

7.3.1.1 The radiator cone shall consist of a heating element, of nominal rating 450 W, contained within a stainless-steel tube, approximately 2 210 mm in length and 6,5 mm in diameter, coiled into the shape of a truncated cone and fitted into a shade. The shade shall have an overall height of ($45^{\ 0}_{-0,4}$) mm, an internal diameter of 55 mm ± 1 mm and an internal base diameter of 110 mm ± 3 mm. It shall consist of two layers of 1-mm-thick stainless steel with a 10 mm thickness of ceramic-fibre insulation of nominal density 100 kg/m^3 sandwiched between them. The heating element shall be clamped at the top and bottom of the shade.

7.3.1.2 The radiator cone shall be capable of providing irradiance in the range 10 kW/m^2 to 50 kW/m^2 at the centre of the surface of the specimen.

When the irradiance is determined at two other positions 25 mm each side of the specimen centre, the irradiance at these two positions shall be not less than 85 % of the irradiance at the centre of the specimen.

7.3.1.3 The temperature controller for the radiator cone shall be a proportional, integral and differential-type 3-term controller with thyristor stack fast-cycle or phase angle control of not less than 10 A maximum rating. Capacity for adjustment of integral time between 10 s and 50 s and differential time between 25 s and 30 s shall be provided to permit reasonable matching with the response characteristics of the heater. The temperature at which the heater is to be controlled shall be set on a scale capable of being held steady to ± 2 °C. An input range of temperature of 0 °C to 1 000 °C is suitable; an irradiance of 50 kW/m^2 will be given by a heater temperature in the range 700 °C to 750 °C. Automatic cold-junction compensation of the thermocouple shall be provided.

NOTE 4 While phase angle control is allowed for the temperature controller of the radiator cone, it should be noted that this will usually require electrical filtering to avoid risk of low-level signal lines.

7.3.1.4 The irradiance of the radiator cone shall be controlled by reference to the reading of two type K sheathed copper/alumel thermocouples mounted diametrically opposite and in contact with, but not welded to, the element. The thermocouples shall be of equal length and wired in parallel to the temperature controller and be positioned one-third of the distance from the top surface of the cone.

7.3.2 Framework for support of the radiator cone, specimen holder and heat flux meter

The radiator cone shall be located and secured from the vertical rods of the support framework so that the lower rim of the radiator cone shade is 25 mm ± 1 mm above the upper surface of the specimen when oriented in the horizontal position. Details of the radiator cone and supports are shown in figures 4 and 5.

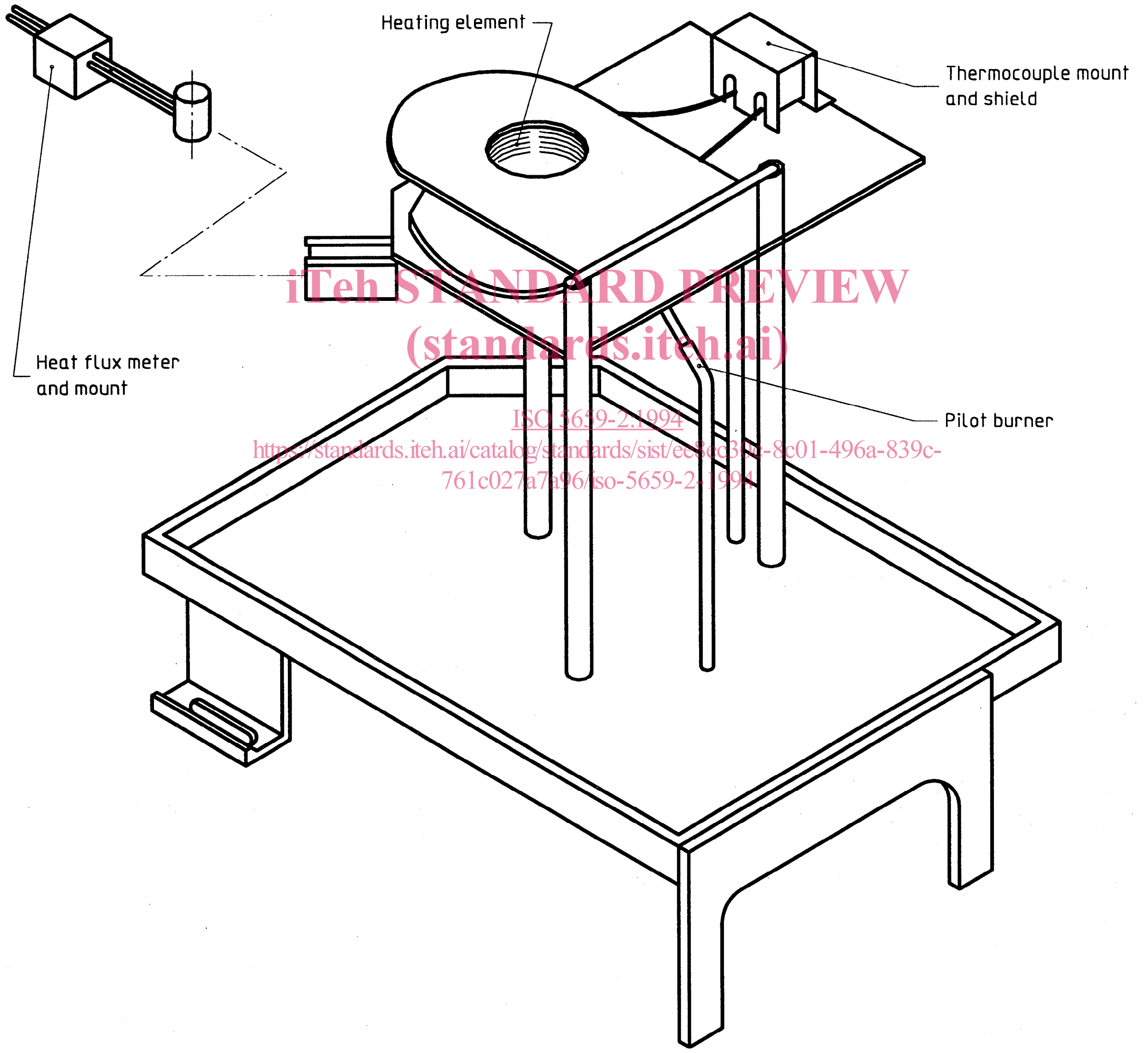

Figure 4 — Typical framework for support of radiator cone, specimen holder and flux meter