TECHNICAL REPORT

ISO/TR 5659-3

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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 Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.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.

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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.

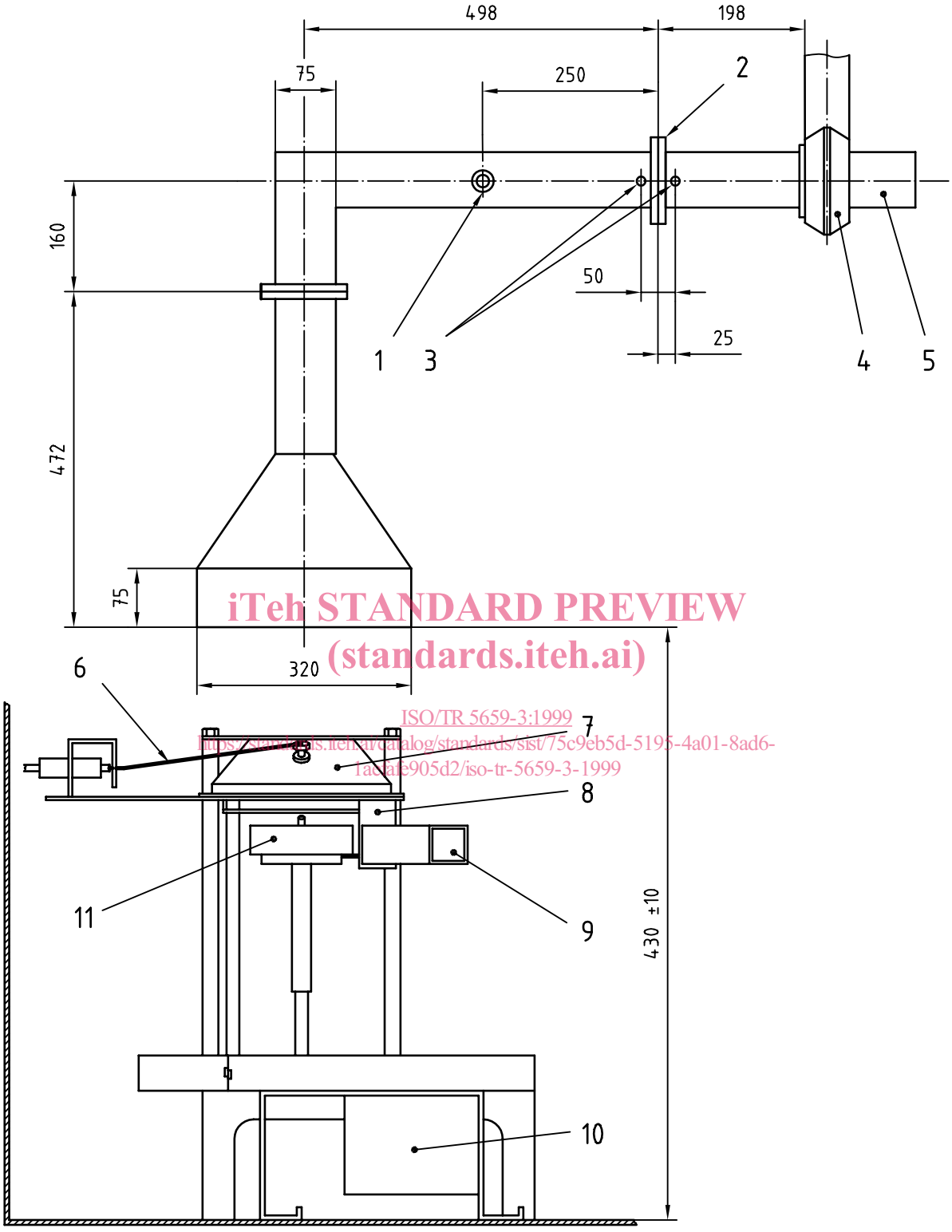
NOTE While phase angle control is allowed for the temperature controller of the radiator cone, it should be noted that this will usually require electrical filtering to avoid risk of low-level signal lines.

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.