INTERNATIONAL STANDARD

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Reaction to fire tests — Room corner test for wall and ceiling lining products —

Part 1:
Test method for a small room configuration

Essais de réaction au feu — Essai dans le coin d'une pièce pour les produits de revêtement pour murs et plafonds —

Partie 1: Méthode d'essai pour une configuration de petite pièce

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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 procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

This first edition of ISO 9705–1 cancels and replaces ISO 9705:1993, which has been technically revised. It also incorporates the Corrigendum ISO 9705:1993/Cor 1:1993.

ISO 9705 consists of the following parts, under the general title *Reaction to fire tests — Room corner test for wall and ceiling lining products*:

— *Part 1: Test method for a small room configuration*

— *Part 2: Technical background and guidance* [Technical Report]

Introduction

This part of ISO 9705 is intended to describe the fire behaviour of a product under controlled laboratory conditions.

The test method may be used as part of a fire hazard assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

Reaction to fire tests — Room corner test for wall and ceiling lining products —

Part 1:
Test method for a small room configuration

WARNING — So that suitable precautions can be taken to safeguard health, the attention of all concerned in fire tests is drawn to the possibility that toxic or harmful gases can be evolved during combustion of test specimens. The test procedures involve high temperatures and combustion processes from ignition to a fully developed room fire. Therefore, hazards can exist for burns, ignition of extraneous objects or clothing. The operators should use protective clothing, helmet, face-shield and equipment for avoiding exposure to toxic gases. Means of extinguishing a fully developed fire should be available.

1 Scope

This part of ISO 9705 specifies the test method to evaluate the reaction of wall and ceiling products to fire when installed at the surface of a small room and exposed directly to a specified ignition source. The test represents a fire scenario, which starts under well-ventilated conditions in a corner of a specified room with a single open doorway.

Tests performed in accordance with the method specified in this part of ISO 9705 provide data for the early stages of a fire from ignition up to flashover. The method does not evaluate the fire resistance of products.

The method is not intended to evaluate floor coverings. This method is not suitable for sandwich panel building systems, pipe insulation and façades for which specific ISO standards (i.e. ISO 13784, ISO 20632 and ISO 13785, respectively) are available.

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*

EN 13238, *Reaction to fire tests for building products — Conditioning procedures and general rules for selection of substrates*

3 Terms and definitions

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

3.1
exposed surface
surface of the product subjected to the heating conditions of the test

3.2
material
single substance or uniformly dispersed mixture

EXAMPLE This includes metal, stone, timber, concrete, mineral fibre, and polymers.

3.3
product
material, composite or assembly about which information is required

3.4
specimen
representative piece of the product which is to be tested together with any substrate or treatment

Note 1 to entry: The specimen may include an air gap.

3.5
wall and ceiling lining product
wall and ceiling products, installed at the surface of a room and exposed directly to a specified ignition source

3.6
flashover
point in the fire history when the sum of the heat release rate from the ignition source and the product reaches 1 000 kW

Note 1 to entry: Heat release rate calculated as a 30-second sliding average, HRR_{smooth}, as given in Annex E.

3.7
Fire Growth Rate
FIGRA
growth rate of the fire during a specified time period

3.8
Smoke Growth Rate
SMOGRA
growth rate of the smoke during a specified time period

3.9
burning droplets
continuous occurrence of flaming droplets/particles from the specimen for at least 10 s or until a pool fire forms on the floor

4 Principle

The hazard of fire growth is evaluated by the measurement of the rate of heat release of the fire based on calculation of oxygen consumption.

The hazard of reduced visibility is estimated by the measurement of production of light-obscuring smoke.

Phenomena attributed to the fire growth, for example flame spread and emission of burning droplets, are visually documented by photographic and/or video recording.

NOTE If further information is required, measurements, for example of heat flux to the floor, toxic gas species, the gas temperature in the room and the mass flow in and out the doorway, can be performed. See also ISO/TR 9705-2.

5 Fire test room

5.1 Dimensions

The room (see Figure 1) shall consist of four walls at right angles, a floor and a ceiling and shall have the following inner dimensions:

a) length: 3,6 m ± 0,05 m;

b) width: 2,4 m ± 0,05 m;

c) height: 2,4 m ± 0,05 m.

The room shall be placed indoors in an essentially draught free, heated space, large enough to ensure that there is no influence on the test fire. In order to facilitate the mounting of the instruments of the ignition source, the test room may be placed so that the floor can be reached from beneath.

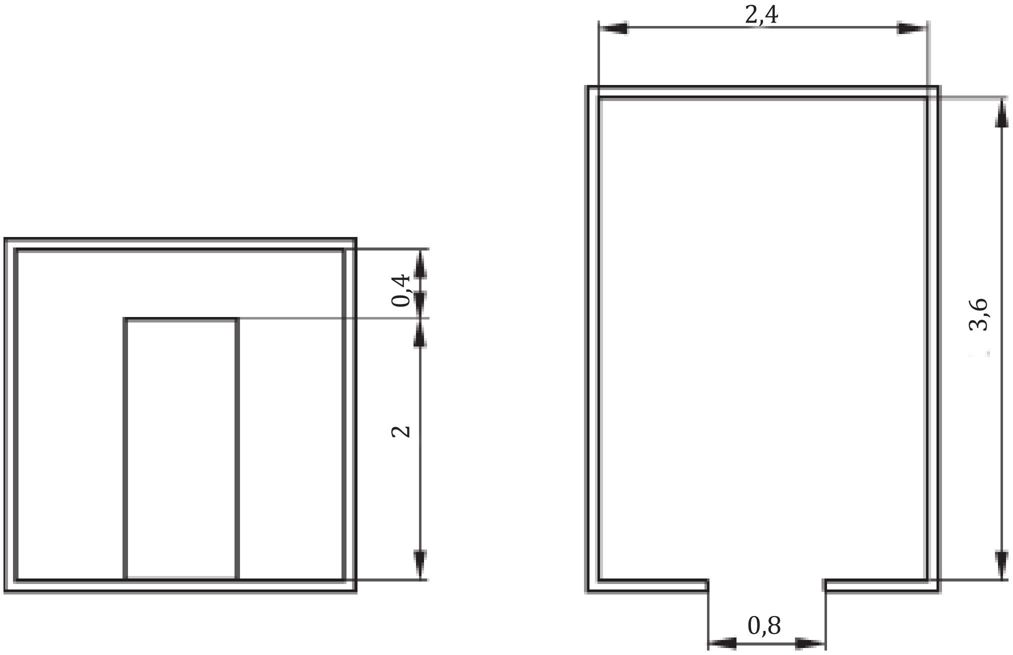
5.2 Doorway

There shall be a doorway in the centre of one of the 2,4 m × 2,4 m walls and no other wall, floor or ceiling shall have any openings that allow ventilation. The doorway shall have the following dimensions:

a) width: 0,8 m ± 0,01 m;

b) height: 2,0 m ± 0,01 m.

Dimensions in metres



a) Front view **b) Top view**

Figure 1 — Fire test room

5.3 Construction material

The test room shall be constructed of non-combustible material with a density of (600 ± 200) kg/m^3. The minimum thickness of the construction shall be 20 mm.

6 Ignition source

6.1 General

The ignition source design is specified in Annex A.

The ignition source shall be a propane gas burner having a nominal 170 mm × 170 mm square top surface layer of a porous, inert material. The top portion of the porous material shall be a minimum 45 mm of sand. The construction shall be such that an even gas flow is achieved over the entire opening area.

The burner shall be ignited with a remote-controlled ignition device, for example a pilot burner or a spark igniter. The burner shall be provided with controls for gas supply shut-off if flameout occurs or if there is a gas leak.

Because the propane gas burner consumes relatively large amounts of gas, the attention is therefore drawn to the following warning.

WARNING — All equipment such as tubes, couplings, flowmeters, etc. shall be approved for propane. The installations shall be performed in accordance with existing regulations.

6.2 Location

The burner shall be placed on the floor in a corner opposite to the doorway wall. The top surface of the burner through which the gas is supplied shall be located horizontally, (146 ± 3) mm off the floor, and the burner enclosure shall be in contact with both walls in the corner.

6.3 Gas

The burner shall be supplied with natural grade propane (95 % purity). The gas flow to the burner shall be measured throughout the test with an accuracy of at least ±3 %. The heat output to the burner shall be controlled within ±5 % of the prescribed value. Flow rates of gas shall be calculated using a net heat of combustion of propane of 46,4 MJ/kg.

6.4 Heat output

The net heat output shall be 100 kW during the first 10 min after ignition and then shall be increased to 300 kW for a further 10 min.

7 Hood and exhaust duct

The system for collecting the combustion products shall have a capacity and be designed in such a way that all of the combustion products leaving the fire room through the doorway during a test are collected. The system shall not disturb the fire-induced flow in the doorway. The maximum exhaust capacity shall be at least 3,5 m^3s^{-1} at normal pressure and a temperature of 25 °C.

NOTE An example of one design of hood and an exhaust duct is given in Annex C.

8 Instrumentation in the exhaust duct

8.1 General

This Clause specifies minimum requirements for instrumentation in the exhaust duct. Additional information and designs can be found in Annex D.

8.2 Volume flow rate

The volume flow rate in the exhaust duct shall be measured to an accuracy of at least ±5 %.

The response time of the measurement system to a stepwise change of the duct flow rate shall be a maximum of 3 s at 90 % of the final value.

8.3 Gas analysis

8.3.1 Sampling line

The gas samples shall be taken in the exhaust duct at a position where the combustion products are uniformly mixed. The sampling line shall be made from an inert material which will not influence the concentration of the gas species to be analysed (see Annex D).

8.3.2 Oxygen

The O_2 analyser shall be of the paramagnetic type or equivalent in performance and capable of measuring a range of at least 0 Vol % to 21 Vol % oxygen ($\mathit{Volume}_{O2}/\mathit{Volume}_{\text{air}}$). The uncertainty of measurement shall be ≤ 0,1 Vol % O_2 or better. The stability of the analyser shall be within 0,01 Vol % O_2 over a period of 30 min (measured as recommended in accordance with D.3.2). The output from the analyser and also the data acquisition system shall have a resolution of 0,01 Vol % O_2 or better.

8.3.3 Carbon dioxide

The CO_2 analyser shall be of the IR type or equivalent in performance and capable of measuring a range of at least 0 Vol % to 10 Vol % carbon dioxide. The uncertainty of measurement shall be ≤ 0,1 Vol % CO_2 up to 5 Vol % CO_2 and ≤ 0,2 Vol % CO_2 from 5 to 10 Vol % CO_2. The linearity of the analyser shall be 1 % of full scale or better. The output from the analyser and also the data acquisition system shall have a resolution of 0,01 Vol % CO_2 or better.

8.4 Optical density

8.4.1 General

The optical density of the smoke is determined by measuring the light obscuration with a system consisting of a lamp, lenses, an aperture and a photocell (see Figure 2) or with a laser system as given in Annex H.

8.4.2 Lamp

The lamp shall be of the incandescent filament type and shall operate at a colour temperature of (2 900 ± 100) K. The lamp shall be supplied with stabilized direct current, stable within ±0,5 % (including temperature, short-term and long-term stability).

8.4.3 Lenses

The lens system shall align the light to a parallel beam with a diameter, D, of at least 20 mm.

8.4.4 Aperture

The aperture shall be placed at the focus of the lens L_2 as shown in Figure 2 and it shall have a diameter, d, chosen with regard to the focal length, f, of L_2 so that d/f is less than 0,04. Other solutions to avoid light scattering are allowed.

8.4.5 Detector

The detector shall have a spectrally distributed response agreeing with the CIE[1], V(λ)-function (the CIE photopic curves) to an accuracy of at least ±5 %.

The detector output shall be linear within 5 % or 0,01 of the measured optical density value, over an output range of at least two decades. A routine to check this requirement is given in D.4.2.3.

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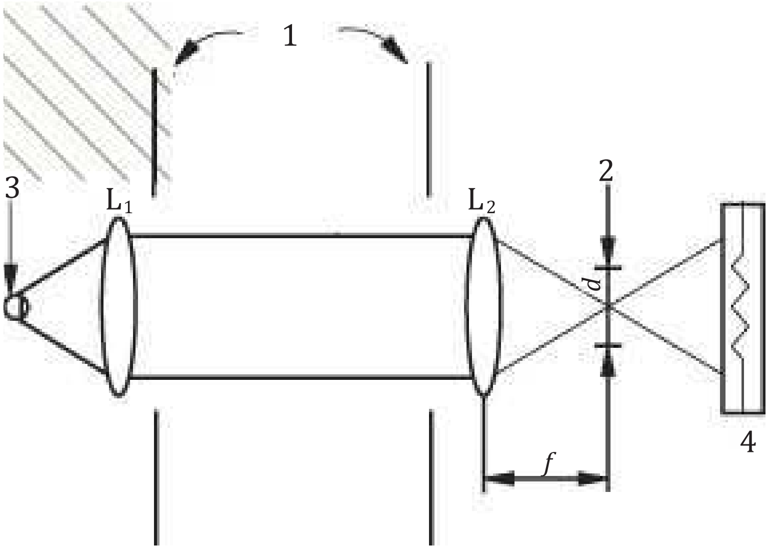
[1] Commission Internationale d'Eclairage.

8.4.6 Location

The light beam shall cross the exhaust duct along its diameter at a position where the smoke is homogenous.



Key

1 wall of exhaust duct

2 aperture

3 lamp

4 detector

Figure 2 — Optical system

9 System performance

9.1 System response

9.1.1 Procedure

The delay times and response times of the gas analysis system shall be checked for a stepwise change of the heat output from the burner according to Table 1. The burner shall be placed centrally 3,5 m below the centre line of the duct. Measurements shall be taken every 3 s. The volume flow rate of the exhaust system shall be set to (2,5 ± 0,5) m^3s^{-1}.

Table 1 — Burner heat output profile

Step Number	Time min	Heat output kW
1	0 to 2	0
2	2 to 7	100
3	7 to 12	300
4	12 to 17	100
5	17 to 19	0

9.1.2 Delay times

The delay time of the oxygen analyser is found as the time difference between a 3 K change in the duct temperature and a 0,05 % change in the oxygen concentration. The delay time of the carbon dioxide analyser is found as the time difference between a 3 K change in the duct temperature and a 0,02 % change in the carbon dioxide concentration. Neither delay time shall exceed 30 s. The data shall be corrected on the basis of these delay times before calculating the heat release rate.

9.1.3 Response times

The response times are found as the time between a 10 % and 90 % change in the measured oxygen or carbon dioxide level. The response times shall not exceed 18 s.

9.1.4 Calculations

Based on the unshifted data, calculate:

a) for each step:

  1) t_{gas}, the start time of the step as the time of the first data point at which the propane flow has changed by 100 mg/s in comparison with the mean value in the last 2 min of the previous step;

  2) t_{T}, the time of the first data point at which the temperature T_{s} has changed 3,0 K in comparison with the mean value in the last 2 min of the previous step;

  3) t_{O2}, the time of the first data point at which the oxygen concentration has changed 0,05 % in comparison with the mean value in the last 2 min of the previous step;

  4) t_{CO2}, the time of the first data point at which the carbon dioxide concentration has changed 0,02 % in comparison with the mean value in the last 2 min of the previous step;

  5) $t_{\mathrm{O2,10\,\%}}$, the time of the first data point at which the oxygen concentration has reached 10 % of its deflection using the mean values in the last 2 min of the previous and the current step;

  6) $t_{\mathrm{O2,90\,\%}}$, analogous to $t_{\mathrm{O2,10\,\%}}$, however for 90 % instead of 10 % deflection;

  7) $t_{\mathrm{CO2,10\,\%}}$, the time of the first data point at which the carbon dioxide concentration has reached 10 % of its deflection using the mean values in the last 2 min of the previous and the current step;

  8) $t_{\mathrm{CO2,90\,\%}}$, analogous to $t_{\mathrm{CO2,10\,\%}}$, however for 90 % instead of 10 % deflection;

b) the delay time of the oxygen analyser as the mean of $t_{\mathrm{O2}} - t_{\mathrm{T}}$ found for steps 2, 3, 4 and 5;

c) the delay time of the carbon dioxide analyser as the mean of $t_{\mathrm{CO2}} - t_{\mathrm{T}}$ found for steps 2, 3, 4 and 5;

d) the response time of the oxygen analyser as the mean of $t_{\mathrm{O2,90\,\%}} - t_{\mathrm{O2,10\,\%}}$ found for steps 2, 3, 4 and 5;

e) the response time of the carbon dioxide analyser as the mean of $t_{\mathrm{CO2,90\,\%}} - t_{\mathrm{CO2,10\,\%}}$ found for steps 2, 3, 4 and 5;

9.2 Daily Check

A calibration test shall be performed prior to each test or continuous test series.

NOTE Formulae for calculations are given in Annex E.

The calibration shall be performed with the burner heat outputs given in Table 1, with the burner placed centrally 3,5 m below the centre line of the duct . Measurements shall be taken every 3 s and shall be started 2 min prior to ignition of the burner. At steady-state conditions, the difference between the mean heat release rate (HRR_{total}) over 1 min (during the time interval between 180 s and 240 s after the start of steps 2, 3 and 4) calculated from the measured oxygen consumption and that calculated from the metered gas input ($\dot{q}_b$) shall not exceed 5 % for each level of heat output in steps 2, 3 and 4.

9.3 Precision

The precision of the system at various volume flow rates shall be checked by increasing the volume flow in the exhaust duct in four equal steps, starting from 2 m^3s^{-1} (at 0,1 MPa and 25 °C) up to the maximum. The heat output from the burner shall be 300 kW. The error in the mean heat release rate, calculated over 1 min shall be not more than 10 % of the actual heat output from the burner.

9.4 Methanol calibration

9.4.1 Frequency of calibration

At least once a year, or more often if needed, a calibration check using methanol shall be performed.

9.4.2 Container

The container for burning the methanol shall be of circular geometry and made of steel. The diameter of the container shall be (720 ± 10) mm and the height shall be (150 ± 10) mm. The thickness of the steel sheets shall be 2,0 mm. This gives a fuel area of (0,41 ± 0,01) m^2.

9.4.3 Methanol

The methanol shall have a purity of at least 98 %. The volume of methanol should be 10 l (approximately 7 920 g). The fire from the pool will release about 140 kW. One litre of methanol may be collected and stored in a separate container, so in case any doubt should arise about the purity of the liquid it can be chemically analysed at a later stage.

9.4.4 Procedure for methanol calibration

9.4.4.1 Initial conditions

The fuel container shall be placed on a weighing platform consisting of a slab placed on top of a weight measuring device. The slab shall have the dimensions 1,2 m × 1,2 m and be of calcium silicate boards according to EN 13238.

The weight measuring device, e.g. load cells, shall measure the specimen mass with an accuracy of at least ±100 g up to at least 90 kg of specimen mass. It shall be installed in such a way that the heat from the burning sample and any eccentricity of the load does not affect the accuracy. Care should be taken to avoid range shifts during measurements. All parts of the weight-measuring device, e.g. load cells, shall be below the top level of the slab.

The distance from the upper surface of the slab to floor level shall not exceed 0,5 m. The area between the slab and the floor level shall be shielded in order to avoid lifting forces due to fire induced air flow that could influence the measurement.

The container shall be centred under the hood and be in the horizontal plane.

The temperature of the fuel, the container and ambient shall be (20 ± 5) °C. The fuel container shall be allowed to cool between tests. The amount of fuel dispensed into the container shall be weighed with an accuracy of ±10 g.

The horizontal wind draught measured at a distance of 0,5 m from the boundary of the weighing platform in level with the slab shall not exceed 0,5 m/s.

9.4.4.2 Volume flow

The volume flow rate of the exhaust system shall be set to (2,5 ± 0,5) m^3s^{-1}.

9.4.4.3 Base line recording

A baseline of at least 2 min shall be recorded prior to the ignition of the fuel.

9.4.4.4 Ignition sequence

The fuel shall be ignited in such way that the weighing of the sample is not disturbed, for instance a burning match thrown into the fuel.

9.4.4.5 End of calibration test

After the fuel has burnt out, the measurements shall continue for another 2 min.

9.4.5 Requirements for methanol calibration

The effective heat of combustion, $\Delta H_{c,eff}$, calculated as the total heat released/total mass lost shall not deviate from the theoretical value of 19,83 kJ/g by more than 10 %. The value 17,3 MJ/m^3 at 25 °C for E (see E.2.2) shall be used.

NOTE Precision of calibration from an exercise amongst International laboratories is given in Annex G.

10 Preparation of test specimens

10.1 Specimen configuration

The product to be tested shall, as far as possible, be mounted in the same way as in the end use application. Configurations for mounting the specimen in the test room are given in Annex F.

10.2 Boards

In cases where the product to be tested is in board form, the normal width, length and thickness of the boards shall be used as far as possible.

10.3 Mounting

The product shall be attached either to a substrate or directly to the interior of the fire room. The mounting technique (for example, nailing, gluing, using a support system) shall, as far as possible, conform to that used for the product in its end use application. The thickness of the specimen including air gap shall be a maximum of 100 mm. The mounting technique shall be clearly stated in the report (see Clause 12), particularly if the mounting technique used improves the physical behaviour of the specimen during the test.

10.4 Substrates

Products shall be applied to a substrate according to EN 13238.

10.5 Paints and varnishes

Paints and varnishes shall be applied to the substrates at the application rate specified by the sponsor.

10.6 Conditioning

Specimens shall be conditioned according to EN 13238. Any weighing operation shall be performed on a representative piece of the specimen.

NOTE For wood-based products and products where vaporization of solvents can occur, a conditioning time of at least four weeks can be required.

11 Testing

11.1 Initial conditions

11.1.1 Ambient temperature

From the start of the installation of specimens until the start of the test, the temperature in the fire test room and the surrounding area shall be (20 ± 10) °C.

NOTE The time between the removal of the specimens from conditioning and the start of the test is to be kept to a minimum to ensure that the conditioning of the test specimen is not lost. Registration of temperature and humidity is recommended.

11.1.2 Ambient wind speed

The horizontal wind speed measured at a horizontal distance of 1 m from the centre of the doorway shall not exceed 0,5 m s^{-1}.

11.1.3 Burner

The burner shall be in contact with the test specimen in the corner wall. The surface area of the burner opening shall be clean.

11.1.4 Photographs

The product shall be photographed or video filmed before testing.

11.2 Procedure

11.2.1 Automated recording of data

The following data shall be measured and recorded automatically every 3 s. The recording shall begin at least 2 min before the ignition of the burner and continue to at least 22 min after the ignition or 2 min after flashover, whichever occurs first.

a) Time (t), in s. The start of recording of data, $t = -120$ s equates to 2 min before the ignition of the burner.

b) Mass flow of propane gas to the burner ($\dot{m}_b$) in mg/s. If a rotameter is used, the data should be added manually.

c) Pressure difference between the two chambers of the bi-directional probe (Δp), at the general measuring section in the exhaust duct, in Pa.

d) Signal from the light receiver (I), of the white light system at the general measuring section in the exhaust duct, in %.

e) O_2 percentage in exhaust flow sampled at the gas sampling probe at the general measuring section in the exhaust duct.

f) CO_2 percentage in exhaust flow sampled at the gas sampling probe at the general measuring section in the exhaust duct.

g) The duct temperature (T_S) at the general measuring section in the exhaust duct, in K.

11.2.2 Adjustment of burner and exhaust flow

Adjust the burner to the output level given in 6.4 within 10 s of ignition of the burner. Continuously adjust the exhaust capacity so that all of the combustion products are collected.

11.2.3 Photographs

A photographic and video recording shall be made of the test. A timer depicting "elapsed time" shall appear in all photographic records, giving time to the nearest 1 s. The timer shall be permitted to be integral to the camera. The timer shall be clearly viewed throughout the test period. Prior to ignition of the burner, the date and laboratory test report identification number shall be filmed. Colour slides, photographs, or digital images shall preferably be taken at intervals not exceeding 15 s for the first 3 min of the test and at intervals not exceeding 30 s thereafter for the duration of the test. A video camera with a manually adjustable iris, adjusted to prevent automatic closing of the iris opening due to brightness of the fire (at least 50 % open), shall be used. A video monitor shall be used to determine when adjustments and compensation for the brightness of the ignition flames are needed. The camera mount shall be adjusted so that the camera lens is approximately 900 mm from the floor. The camera angle and magnification shall be adjusted until the top of the doorway and the top of the burner are visible and the ceiling area directly above the fire is in full view.

The video shall be started at least 30 s prior to ignition of the burner, and the video recording shall be continuous for the duration of the test period.

11.2.4 Observations

During the test, record the following observations, including the time when they occur:

a) ignition of the ceiling;

b) whether flames spread any further down the walls of the test room than 0,5 m from the floor excluding the area which is within 1,2 m from the corner where the ignition source is located;

c) change of the heat output from the burner;

d) flames emerging through the doorway;

e) occurrence and location of burning droplets.

Burning droplets shall be recorded only when occurring outside a distance of 1,2 m from the specimen corner where the burner is placed.

11.2.5 Termination of test

Stop the test 20 min after ignition of the burner or earlier if flashover occurs.

NOTE Safety considerations may dictate an earlier termination.

11.2.6 Damage of tested sample

Note the extent of damage of the product after the test.

11.2.7 Unusual behaviour

Record any other unusual behaviour such as deformation, delamination, etc.

11.2.8 Additional measurements

Additional measurements, such as gas and surface temperatures, etc. may be performed as given in Annex B.

12 Test report

The test report shall contain the following information as a minimum. A clear distinction shall be made between the data provided by the sponsor and data determined by the test:

a) reference that the test was carried out in accordance with this part of ISO 9705, i.e. ISO 9705–1;

b) any deviations from the test method;

c) name and address of the testing laboratory;

d) date and identification number of the report;

e) name and address of the sponsor;

f) name and address of the manufacturer/supplier, if known;

g) date of sample arrival;

h) identification of the product;

i) description of the sampling procedure, where relevant;

j) a general description of the product tested including density, weight per unit area and thickness, together with the form of construction of the test specimen;

k) description of substrate and fixing to the substrate (if used);

l) details of conditioning;

m) date of test;

n) test results (see Annex E):

   1) time to flashover;

   2) time/heat release rate (HRR); and if the burner is included, time/heat release from the burner;

   3) ambient temperature;

   4) time/smoke production rate (SPR) at actual duct flow temperature;

   5) description of the fire development (photographs);

   6) FIGRA calculated according to Annex E;

   7) SMOGRA calculated according to Annex E;

   8) Total Smoke Production (TSP) calculated according to Annex E and specifying the time of integration;

   9) Total heat released (THR) calculated according to Annex E and specifying the time of integration.

o) on request of the contractor: data file with data recorded automatically according to 9.4. and/or latest calibration reports, including details of the calibration procedure if anything other than methanol calibration was used;

p) the statement: “The test results relate only to the behaviour of the test specimens of a material under the particular conditions of the test; they are not intended to be the sole criterion for assessing the potential fire hazard of the material in use.”;

q) visual observations of flame spread and droplets/particles;

r) additional test results, if measured (see Annex B).

Annex A
(normative)

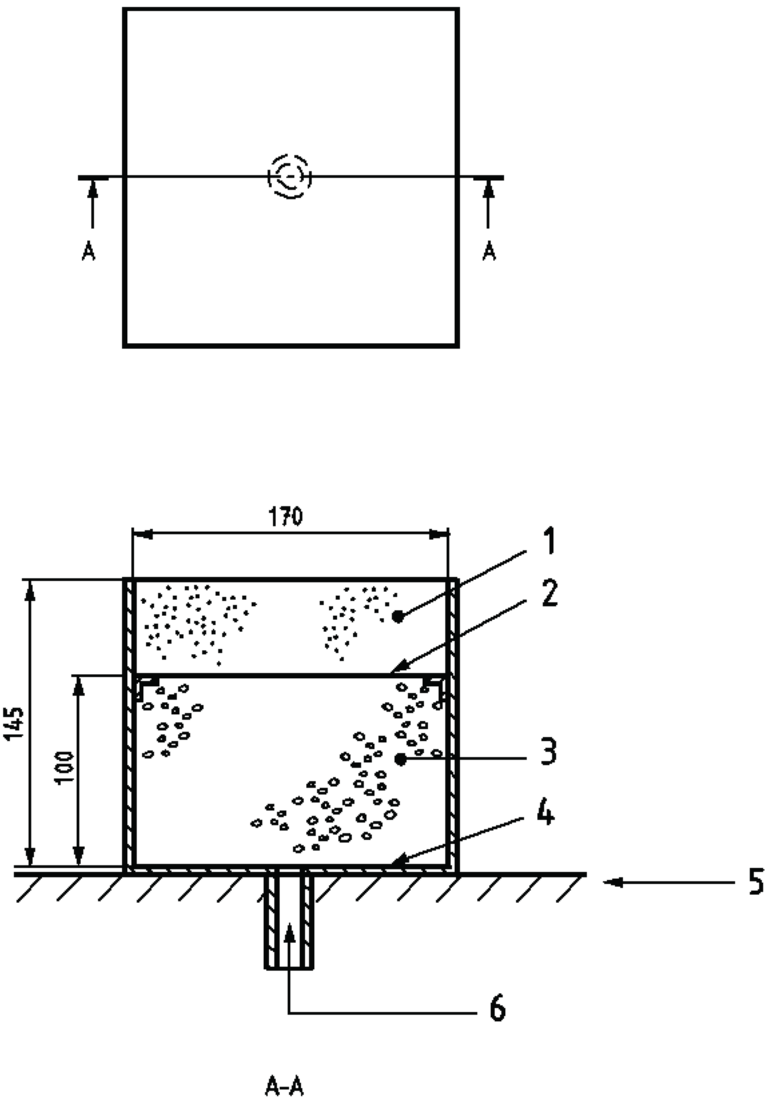
Ignition source

A.1 Standard ignition source — Burner

The burner shall be as shown in Figure A.1. The burner shall be made of steel plates with maximum thickness of 2 mm. The burner is filled with gravel of size 4 mm to 8 mm and sand of size 2 mm to 3 mm. Metal gauzes stabilize the two layers, the top gauze being of size 1,4 mm and the bottom gauze being of size 2,8 mm. The upper layer of sand is to be level with the upper edge of the burner.

NOTE Ceramic beads of nominal diameter up to 10 mm has been found to work as an alternative to sand and gravel layers.

Dimensions in millimetres



Key

A-A side view

1	sand
2	metal wire gauze
3	gravel
4	metal wire gauze
5	floor of test room
6	gas inlet

Figure A.1 — Standard ignition source

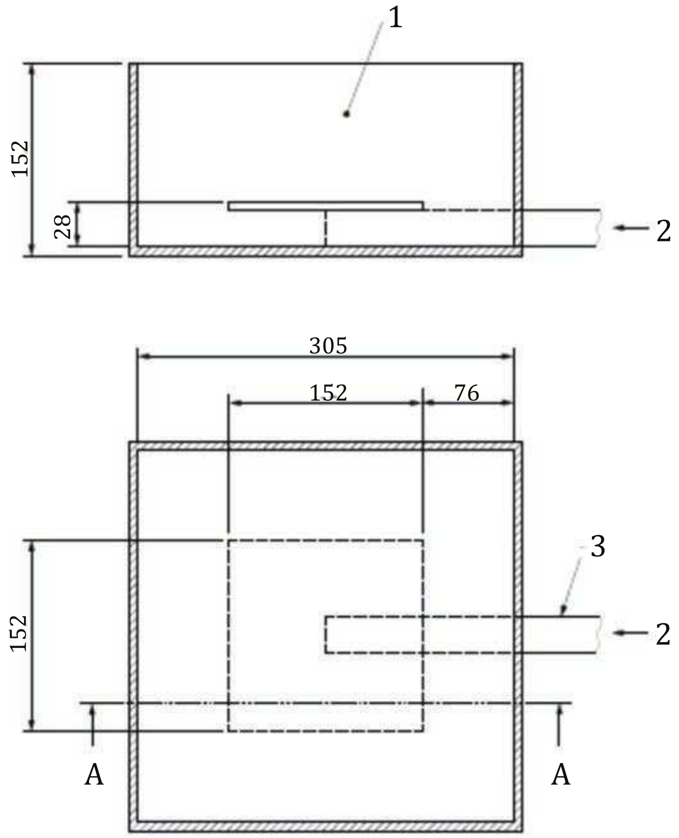
A.2 Alternative ignition source — Burner

The burner shall have a nominal 0,31 m × 0,31 m porous top surface of a refractory material. The top surface of the burner shall be located 0,3 m off the floor and shall be horizontal. The gas supply to the burner shall produce a maximum net heat output of (162 ± 4) kW (gross heat output 176 kW). The flow rate shall be measured throughout the test.

The burner shall be constructed with a minimum 100 mm layer of Ottawa sand, to provide the horizontal surface through which the gas is supplied (see Figure A.2). The use of a sand burner is preferable to the use of a burner with fibreboard, particularly for dripping materials.

After ignition, the net heat output shall be 25 % of its maximum value and after 30 s it shall be increased to 50 % of its maximum value. After a further 30 s it shall be increased to 75 % of its maximum value and after a further 30 s it shall be increased to its maximum value.

Dimensions in millimetres



Key

1 burner filled with Ottawa sand

2 gas inlet

3 19 mm nom. pipe

Figure A.2 — Alternative ignition source

Annex B
(informative)

Instrumentation of test room

B.1 Total heat flux

NOTE The main component of heat transfer to the heat flux meter is irradiance. However, convection transfer to or from the instrument cannot be ignored and therefore the term “total heat flux” is used instead of “irradiance.”

A total heat flux meter should be mounted at a height of 26 mm ± 5 mm above the floor surface, facing upward, in the geometric centre of the fire test room. The heat flux meter should be of the Schmidt–Boelter (thermopile) type, with a full-scale design range of 50 kW/m^2.

The meter target should be a circular flat surface that is not more than 15 mm in diameter and is coated with a durable matte black finish, having a view angle of 180 degrees. The target should be contained within a water-cooled body in which the front face is of highly polished metal, flat, coinciding with the plane of the target, and circular, with a diameter of not more than 50 mm ± 2 mm.

In operation, the heat flux meter should be maintained at a constant temperature at 25 °C ± 1 °C or at least 3 °C above the dew point, whichever is the highest.

The heat flux meter should be calibrated whenever required according to ISO 14934-3.

Radiation targets may be placed on the floor of the test room. The radiation targets should consist of a single piece of newsprint crumpled into a ball approximately 150 mm in diameter.

B.2 Gas temperatures

If the vertical gas temperature profile inside the test room is known, expressions are available to compute ingoing and outgoing gas flows through the room opening. To minimize gas temperature measurement errors, measurements should preferably be made with suction pyrometers or very thin thermocouples (50 μm).

Suitable locations for suction pyrometers or thermocouples are given in Figure B.1.

B.3 Surface temperatures

B.3.1 General

If it is desired to follow the growth of flame spread below the ceiling, surface thermocouples may be mounted on the product. Measurement of surface temperatures can also be useful in making a heat balance study of the test process.

B.3.2 Thermocouples

The diameter of the thermocouple wires should not exceed 0,25 mm. Estimates of measurement errors are hard to obtain and the errors may be variable in time and location due to changes in the convection and radiation environment in the test room. Practical experience shows that consistent and reliable results are obtained if the thermocouple is adhered to the specimen surface by a thin, heat resistant glass-fibre tape with a surface area of approximately 100 mm^2. Good contact between the tape and specimen should be maintained up to at least 500 °C. Suitable locations for surface thermocouples are suggested in Figure B.2.

B.4 Flow through opening

B.4.1 Bi-directional probes

Mass flow through the opening can be measured by bi-directional probes as specified in D.1. The gas temperature in the vicinity of the probe should be measured by a suction pyrometer. The pressure differential over the two taps of the probe should be measured by a pressure transducer able to resolve pressure differences of 0,05 Pa. It is recommended that the transducer is of the capacitance type. A suitable range of measurement is 0 Pa to 25 Pa.

B.4.2 Mass flow rate per unit area

Mass flow per unit time and area, $\dot{m}''$, expressed in kilograms per square metre second, is calculated using Formulae (B.1) and (B.2):

$$\dot{m}'' = \rho_s v = \rho_s / k_p (2\Delta P / \rho_s)^{1/2} \tag{B.1}$$

$$= 1 / k_p (2\Delta P \rho_o T_o / T_s)^{1/2} \tag{B.2}$$

where

ρ_s is the density of gas at point of measurement, in kg m^{-3};

v is the gas velocity, in m s^{-1};

k_p is the Reynolds number correction for the bi-directional probe;

ΔP is the measured pressure differential, in Pa;

ρ_o is the air density at 0 °C and 0,1 MPa, in kg m^{-3};

T_o = 273,15 K;

T_s is the gas temperature at point of measurement.

If k_p is equal to 1,08, the maximum error will be approximately 7 % down to velocities of 0,3 m s^{-1}. For lower velocities, the relative error will increase.

Total mass flow, $\dot{m}_{out}$ out of the room is obtained by integrating $\dot{m}''$ over the width of the opening and that part of the opening above the neutral plane (boundary between the warm smoke gases and the ambient air). It is essential that the position of the neutral plane is either measured or calculated as a function of time.

B.4.3 Convective heat flow rate per unit area

Convective heat flow rate per unit area, $\dot{Q}''$, expressed in kilowatts per square metre, out of the opening is calculated using Formula (B.3):

$$\dot{Q}'' = \dot{m}'' c_p (T_s - T_i) \tag{B.3}$$

where

$\dot{m}''$ is the rate of mass flow per unit area, in kg m^{-2} s^{-1};

c_p is the specific heat of combustion gases (~1,0), in kJ kg^{-1} K^{-1}

T_s is the temperature of gas flow, in K;

T_i is the ambient temperature, in K.

Total rate of convective energy outflow is obtained by integration as specified in B.4.2.

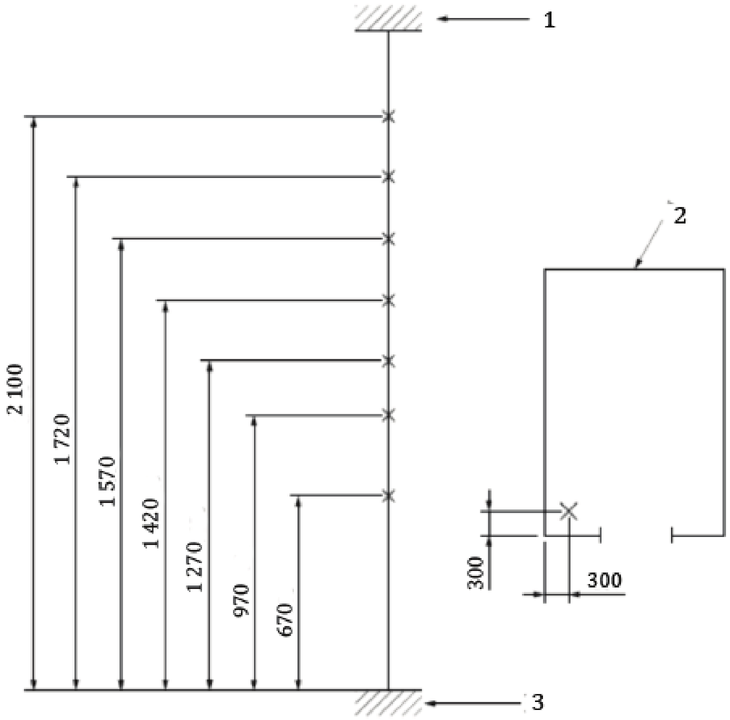
B.4.4 Location of probes

To map the gas flow pattern in the room door opening adequately requires at least 10 probes. The accuracy shall then be ±20 %. A rough estimate of the rate of gas flow can be obtained with three probes located 1 300 mm, 1 800 mm and 1 900 mm from the floor. All probes should be centrally located in a vertical plane through the middle of the doorframe, where the flow is essentially horizontal.

B.5 Radiation through opening

A heat flux meter as specified in B.1 can be located in the geometrical centre of the opening to measure the radiation through the opening.

Dimensions in millimetres



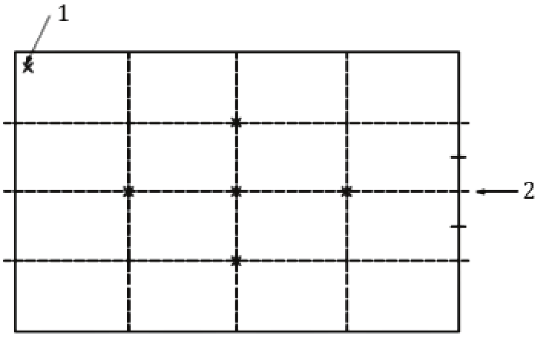
Key

1 ceiling

2 position of fire room

3 floor dimension

Figure B.1 — Measurement of gas temperatures inside test room



Key

1 specimen surface thermocouples in the ceiling above the burner

2 doorway

NOTE The thermocouple hot junctions are fixed to the specimen surface with approximately 100 mm^2 of glass fibre tape

Figure B.2 — Locations of specimen surface thermocouples in the ceiling

Annex C

(informative)

Design of exhaust system

C.1 General

During the fire growth process, the mass flow rate of combustion gases out of the test room can have a magnitude of 1 kg s^{-1} and the velocity of the gas, which varies with gas temperature, can be up to 4 m s^{-1}. The gases are collected by a hood. The following system has been tested in practice and has proved to comply with the requirements of this part of ISO 9705.

C.2 Hood

The hood is located centrally above the opening of the test room with the lower edge aligned to the roof of the room. The bottom dimensions of the hood are 3 m × 3 m and the height 1,0 m (see Figure C.1). On three sides, steel sheets are extended 1,0 m downwards (the fourth side is connected with the test room). The effective height of the hood will thus be 2 m (see Figure C.2). The hood feeds into a plenum having a 0,9 m × 0,9 m cross-sectional area. The plenum has a minimum height of 0,9 m.

In the plenum chambers, two plates approximately 0,5 m × 0,9 m are located to increase mixing of the combustion gases (see Figure C.2).

The hood should be designed and manufactured so that no leakage exists.

C.3 Duct

An exhaust duct is connected with the plenum chamber. The inner diameter of the exhaust duct should be 400 mm. The rectilinear duct should have a minimum length of 4,8 m.

To facilitate flow measurement, guide vanes are located at both ends of the exhaust duct (see Figure C.1 and Figure C.2), or the rectilinear part of the exhaust ducts should have such a length that a uniform flow profile is established at point of measurement.

The exhaust duct is connected to an evacuation system.

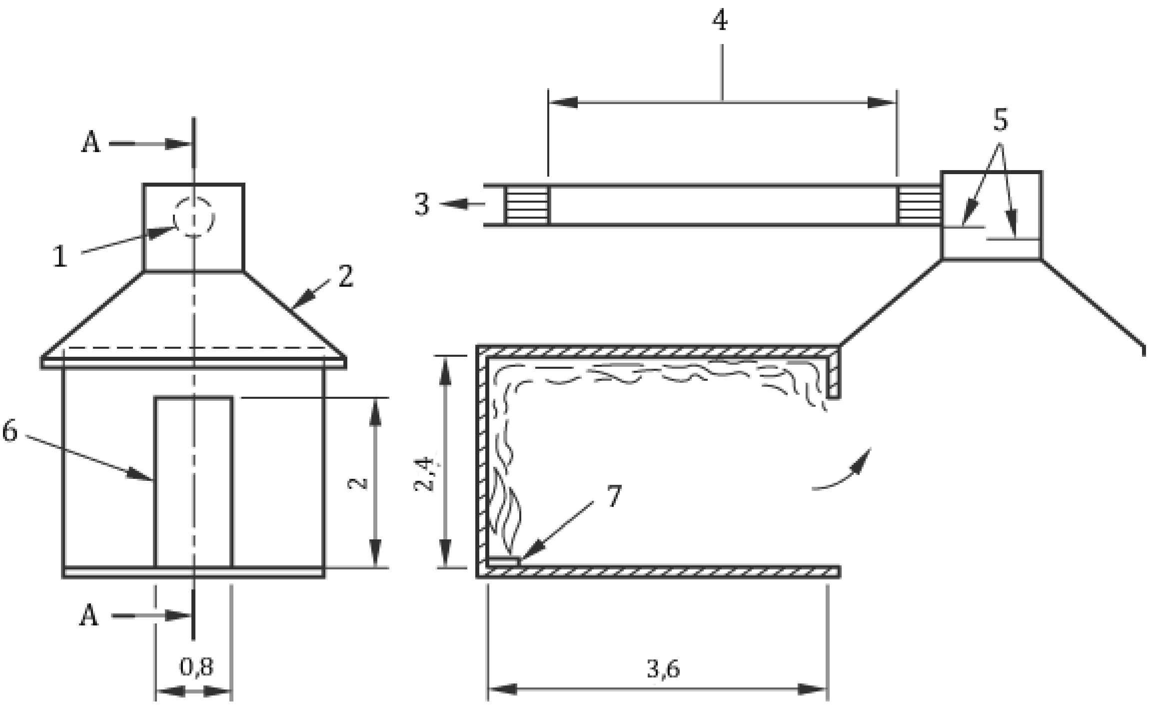
C.4 Capacity

The capacity of the extraction system should be designed to exhaust minimally all combustion gases leaving the test room. This requires an exhaust capacity of at least 4 kg s^{-1} (about 12 000 m^3 h^{-1} at standard atmospheric conditions) corresponding to a driving under pressure of about 2 kPa at the end of the duct. It should be possible to control the exhaust flow between 0,5 kg s^{-1} to 4 kg s^{-1} during the test process. If the airflow is not decreased during the initial part of the test, measurement precision will be too low.

C.5 Alternative systems

An alternative exhaust system may be used if it has been shown to produce equivalent results. Equivalence is demonstrated by complying with the requirements specified in Clause 9. Exhaust systems based on natural convection should not be used.

Dimensions in metres



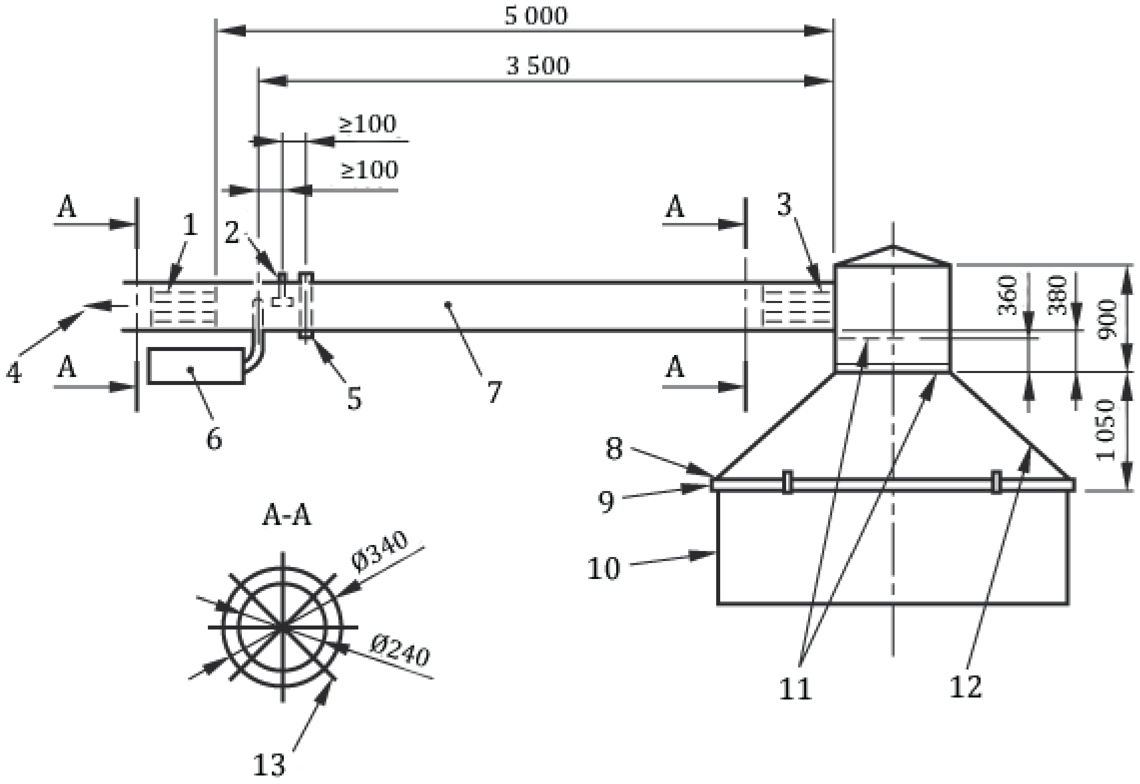
Key

A-A side view

1	exhaust duct (Ø 0,4)
2	hood (3 m × 3 m)
3	to exhaust gas cleaning
4	length 5 m
5	baffles
6	doorway
7	gas burner

Figure C.1 — Principal design (without steel sheet extensions)

Dimensions in millimetres



Key

A-A section of exhaust duct

1	guide vanes
2	pitot tube
3	guide vanes
4	to exhaust gas cleaning
5	lamp, photocell system
6	gas analysis
7	exhaust duct (Ø 400 mm)
8	opening (3 000 mm × 3 000 mm)
9	frame of steel profile (50 mm × 100 mm × 3,2 mm)
10	steel plates(1 000 mm × 3 000 mm)
11	steel plates (2 mm × 500 mm × 900 mm)
12	hood (2 mm-thick steel plates)
13	four steel plates (395 mm × 400 mm)

Figure C.2 — Details of exhaust system and location of sampling probes

Annex D
(informative)

Instrumentation in exhaust duct

NOTE Suitable locations for the probes described in D.1 to D.4 are shown in Figure C.2.

D.1 Volume flow

D.1.1 Bi-directional probe

The flow may be measured by a bi-directional probe located at the centre line of the duct. The probe shown in Figure D.1 consists of a stainless steel cylinder, 32 mm long and with an inner diameter of 14 mm. The cylinder is divided into two equal chambers. The pressure difference between the two chambers is measured by a pressure transducer. The plot of the probe response versus the Reynolds number is shown in Figure D.2.

D.1.2 Pressure transducer

The pressure transducer should have a measuring precision better than ±5 Pa and be of the capacitance type. A suitable range of measurement is 0 Pa to 2 000 Pa.

D.1.3 Thermocouple

Gas temperature in the immediate vicinity of the probe is measured by a sheathed thermocouple with a maximum sheath diameter of 1,6 mm. The thermocouple should not be allowed to disturb the flow pattern around the bi-directional probe.

D.2 Sampling line

D.2.1 Sampling probe

The sampling probe should be located where the exhaust duct flow is well mixed. The probe should have a cylindrical form so that disturbance of flow is minimized. The gas samples should be taken along the whole diameter of the exhaust duct.

D.2.2 Sampling line

The sampling line (see Figure D.3) should be manufactured from non-corrosive material, e.g. PTFE (Polytetrafluoroethylene). The combustion gases should be filtered with inert filters to the degree of particle concentration required by the gas analysis equipment. The filtering procedure should be carried out in more than one step. The gas mixture should be cooled to a maximum of 10 °C.

For gases other than CO, CO_2 and O_2, heated sampling lines (150 °C to 175 °C) should be used. The sampling lines should be as short as possible and the gases should not be filtered (see also D.2.3 and D.2.4).

D.2.3 Pump

The combustion gas should be transported by a pump that does not emit oil, grease or similar products which can contaminate the gas mixture. A membrane pump is suitable.

D.2.4 Sampling line end

The sampling line should end in an open container at atmospheric pressure. The volume of the container should not be so large that concentration gradients or time lags are generated. Transport time to the sampling line end should not exceed 2 s.

D.2.5 Specifications

A suitable sampling probe is shown in Figure D.4. The sampling line is shown Figure D.3. A suitable pump should have the capacity of 15 I min^{-1} to 50 I min^{-1}, as each gas analysis instrument requires about 1 I min^{-1} to 3 I min^{-1}. The pump should generate a pressure differential of at least 10 kPa to reduce the risk of smoke clogging of the filters. The intake of the sampling probe is turned downstream in order to avoid soot clogging in the probe.

D.3 Combustion gas analysis

D.3.1 General

The analysis of oxides of carbon and oxygen requires that any water vapour in the combustion gases is trapped out by means of a suitable drying agent.

D.3.2 Oxygen concentration

The oxygen analyser shall preferably comply with the requirements specified in 8.3.2.

The stability of the oxygen analyser output using the data acquisition system shall be checked after set up, maintenance, repair or replacement of the oxygen analyser or other major components of the gas analysis system and at least every six months.

The procedure for checking the stability of the oxygen analyser output shall be as follows.

a) Feed the oxygen analyser with oxygen-free nitrogen gas, until the analyser reaches equilibrium.

b) After at least 60 min in oxygen-free conditions, adjust the volume flow in the exhaust duct to (2,5 ± 0,5) $\text{m}^3\ \text{s}^{-1}$ and switch to air from the exhaust duct with the same flow rate, pressure and drying procedure as for sample gases. When the analyser reaches equilibrium, adjust the analyser output to (20,95 ± 0,01) %.

c) Within 1 min, start recording the oxygen analyser output at intervals ≤3 s for a period of 30 min.

d) Determine the drift by use of the least squares fitting procedure to fit a straight line through the data points. The absolute value of the difference between the readings at 0 min and at 30 min of this linear trend line represents the drift.

e) Determine the noise by computing the root-mean-square (rms) deviation around the linear trend line.

The sum of drift and noise (both taken as positive values) shall not be more than 0,01 % ($V_{\text{O2}}/V_{\text{air}}$).

D.3.3 Carbon dioxide concentration

The carbon dioxide analyser shall preferably comply with the requirements specified in 8.3.3.

D.4 Optical density

D.4.1 General

Typical components of a suitable light measuring system are as follows:

Lenses:	Plane convex; diameter 40 mm, focal length 50 mm.

Lamp: Halogen lamp; 6 V, 10 W.

Photocell: Silicon photodiode with a coloured glass subtractive filter that produces a spectral response equivalent to that of the human eye.

The photocell is connected to an appropriate resistance or amplifier that gives a minimum resolution of two decades. Lenses, lamp and photocell are mounted inside two housings, located on the exhaust duct diametrically opposite each other.

The system should be self-cleansing with respect to soot deposits, which may be achieved by having holes in the periphery of the two housings with the system being under pressure in the exhaust duct.

A suitable light measuring system is given in ISO/TR 5924.

D.4.2 Calibration

D.4.2.1 General

The light system calibration shall be performed before tests, after set up, maintenance, repair or replacement of the smoke measurement system holder or other major components of the exhaust system and at least every six months. The calibration consists of two parts: an output stability check and an optical filter check.

D.4.2.2 Stability check

Perform the following steps with the measuring equipment operating.

a) Set the volume flow of the exhaust to: $\dot{V}_{298} = (2{,}5 \pm 0{,}5)\ \text{m}^3\ \text{s}^{-1}$.

b) Start the time measurement and record the signal from the light receiver for a period of 30 min.

c) Determine the drift by use of a least squares method fitting procedure to fit a straight line through the data points. The absolute value of the difference between reading at 0 min and at 30 min of this linear trend line represents the drift.

d) Determine the noise by computing the root-mean-square (rms) deviation around the linear trend line.

NOTE Criterion: Both noise and drift shall be less than 0,5 % of the start value.

D.4.2.3 Optical filter check

The light system performance shall be checked with at least five neutral density filters in the optical density range of 0, 05 to 2,0. The optical density calculated with the measured light receiver signal shall be within ±5 % or ±0,01 of the theoretical value of the filters.

A suitable procedure is as follows.

a) Set the volume flow of the exhaust to: $\dot{V}_{298} = (2{,}5 \pm 0{,}5)\ \text{m}^3\ \text{s}^{-1}$.

b) Place a light blocking insert into the filter holder and adjust to zero.

c) Remove the light blocking insert and adjust the signal from the light receiver to 100 %.

d) Start the time measurement and record the signal from the light receiver for a period of 2 min.

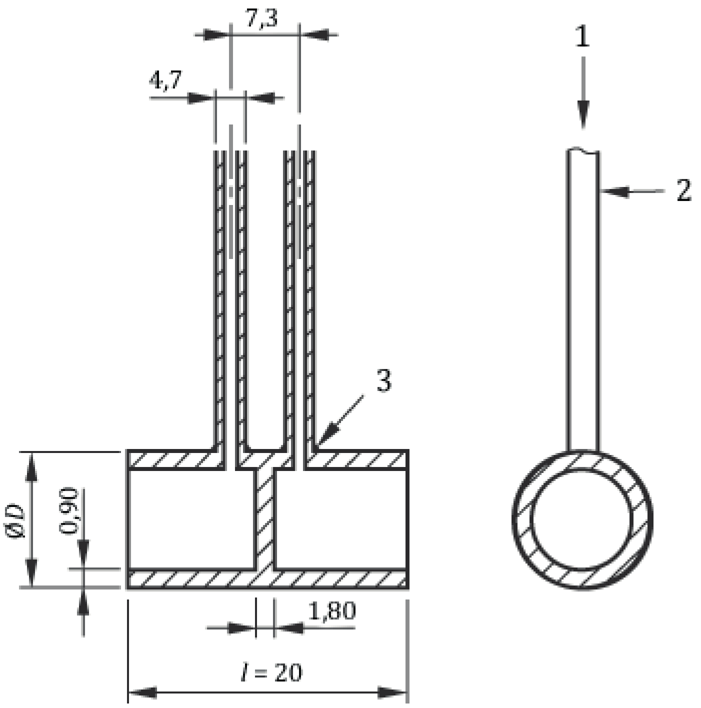
e) Introduce one of the optical filters and record the corresponding signal for at least 1 min.

f) Repeat step e) for the other filters.

g) Stop the data acquisition and calculate the mean transmission values for all filters.

NOTE Criterion: Each *d* value calculated from the mean transmission value [$d = -\log(I)$] shall be within 5 % or within 0,01 of the theoretical *d* value of the filter.

Dimensions in millimetres



Key

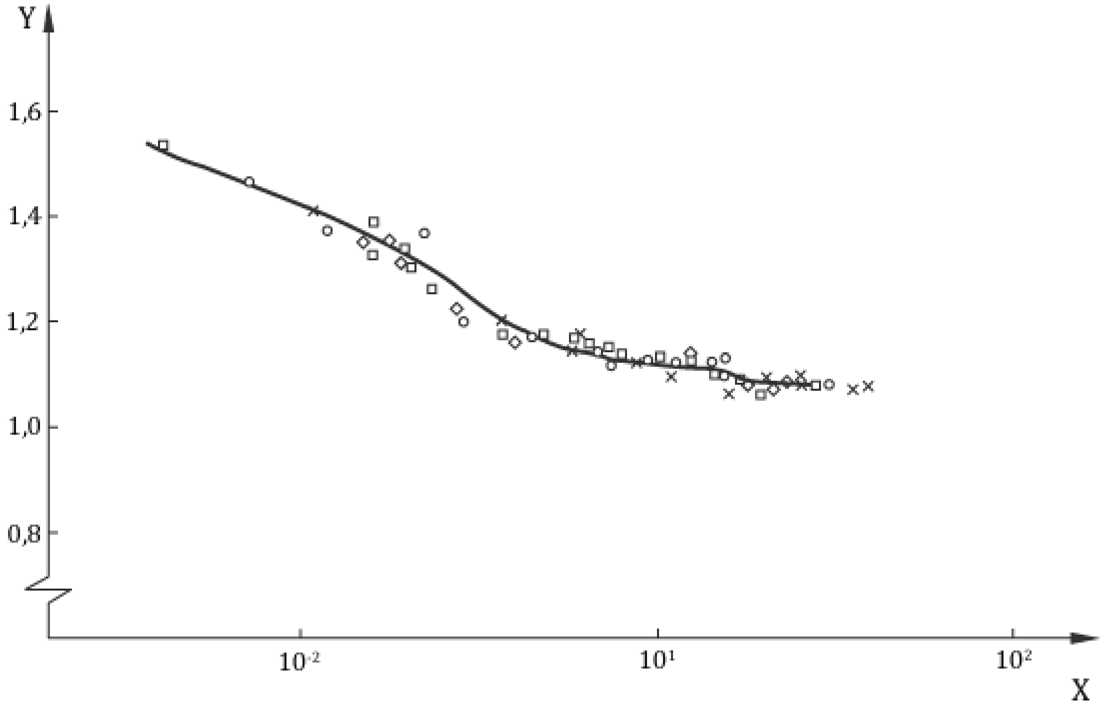
1 to Δp instrument

2 variable length support tubes

3 weld

NOTE Source: Reference [8].

Figure D.1 — Bi-directional probe



X $\mathrm{Re} = \dfrac{\rho V D}{\mu}$

Y $\dfrac{\left(\dfrac{2\Delta p}{\rho}\right)^{1/2}}{V}\sqrt{2}$

Key

Symbol	*D* (mm)
○	12,7
□	15,9 ref 2
◇	25,4
×	22,2 ref 1

Figure D.2 — Probe response versus Reynolds number

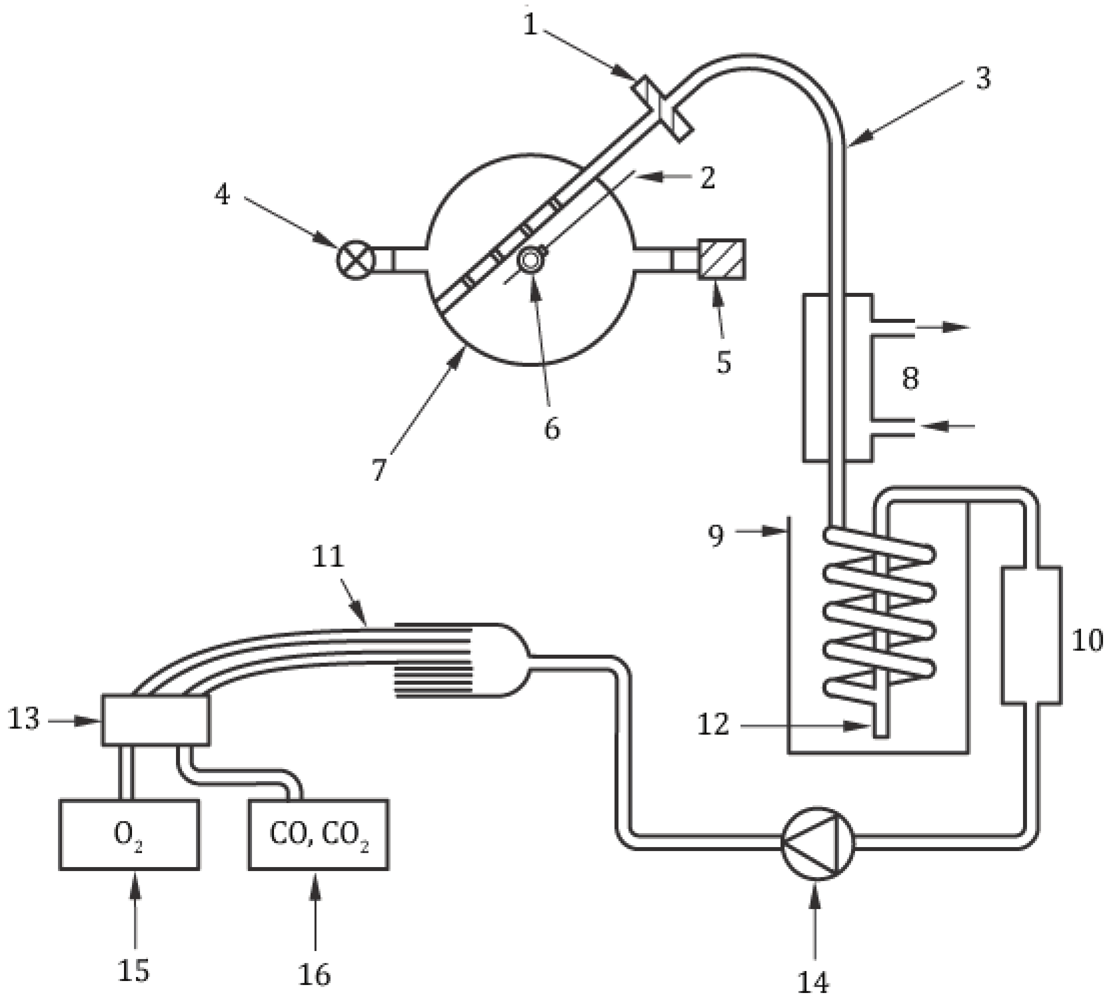
NOTE 1 Source: Reference [8].

NOTE 2 The pressure differences were measured with a sensitive electronic manometer; the uniform low velocity flows were provided by two independent facilities described in Reference [8]. Basically, a hot wire anemometer and pilot-static tube, where appropriate, were used to determine the stream velocity. For data reduction via computer, the polynomial curve fit obtained for the points shown in Figure D.2 is

$$\begin{aligned}\frac{(2\Delta p/\rho)^{1/2}}{V} &= 1{,}533 - 1{,}366\times10^{-3}\,\mathrm{Re}\\ &+1{,}688\times10^{-6}\,\mathrm{Re}^{2} - 9{,}706\times10^{-10}\,\mathrm{Re}^{3}\\ &+2{,}555\times10^{-13}\,\mathrm{Re}^{4} - 2{,}484\times10^{-17}\,\mathrm{Re}^{5}\end{aligned}$$

This representation is valid for 40 < Re < 3 800 and is accurate to about 5 %.

NOTE 3 A suitable value of *D* is 16 mm.

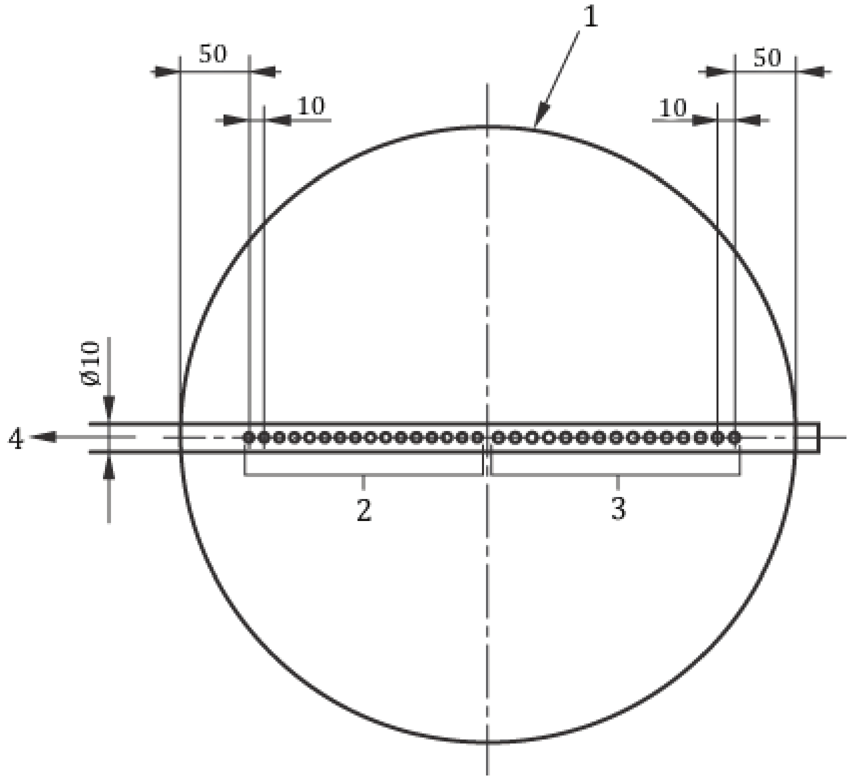


Key

1	glass filters (150 µm to 200 µm)
2	thermocouple
3	non-corrosive (i.e. PTFE) sampling line (Ø10 mm)
4	lamp
5	photocell
6	bi-directional probe
7	exhaust duct
8	water cooler
9	ice box
10	membrane filter (3 µm)
11	surplus gas
12	water drainage
13	filter for water absorption
14	membrane pump
15	paramagnetic oxygen analyser (O_2)
16	infrared spectrophotometer (CO, CO_2)

Figure D.3 — Principle of sampling line with gas analysis

Dimensions in millimetres



Key

1 exhaust duct
2 16 Ø2 mm holes on downstream side of flow
3 15 Ø3 mm holes on downstream side of flow

Figure D.4 — Sampling probe

Annex E
(normative)

Calculation

E.1 Volume flow

For the instrumentation described in D.1, the volume flow in the exhaust duct, $\dot{V}_{298}$, expressed in cubic metres per second, related to atmospheric pressure and an ambient temperature of 25 °C, is given in Formulae (E.1) and (E.2):

$$\dot{V}_{298} = (Ak_t / k_p) \times \frac{1}{\rho_{298}} \times (2\Delta p T_o \rho_o / T_s)^{1/2} \tag{E.1}$$

$$= 22{,}4(Ak_t / k_p)(\Delta p / T_s)^{1/2} \tag{E.2}$$

where

T_s is the gas temperature in the exhaust duct, in K;

T_o = 273,15 K;

Δp is the pressure difference measured by the bi-directional probe, in Pa;

ρ_{298} is the air density at *25* °C and atmospheric pressure, in kg m^{-3};

ρ_o is the air density at 0 °C and 0,1 MPa, in kg m^{-3};

A is the cross-sectional area of exhaust duct, in m^2;

k_t is the ratio of the average mass flow per unit area to mass flow per unit area in the centre of the exhaust duct;

k_p is the Reynolds number correction for the bi-directional probe suggested by McCaffrey and Heskestad. In the exhaust, duct conditions are such that Re is usually larger than 3 800 hence k_p can be taken as constant and equal to 1,08.

Formula (E.1) assumes that density changes in the combustion gases (related to air) are caused solely by the temperature increase. Corrections due to a changed chemical composition or humidity content may be ignored except in studies of the extinguishment process with water. The calibration constant k_t is determined by measuring the temperature and flow profile inside the exhaust duct along a cross-sectional diameter. Several series of measurements should be made with representative mass flows and with both warm and cold gas flows. The error when determining the k_t factor should not exceed ±3 %.

E.2 Heat release rate and total heat release

Before performing the calculations below the oxygen and carbon dioxide data are time-shifted in accordance with the analyser delay times.

E.2.1 Heat release rate from the ignition source

During the calibration and test process, the heat release rate from the ignition source, $\dot{q}_b$, expressed in kilowatts, is calculated from the consumption of propane gas using Formula (E.3):

$$\dot{q}_b = \dot{m}_b \, \Delta H_{c,eff} \tag{E.3}$$

where

$\dot{m}_b$ is the mass flow rate of propane to the burner, in g s^{-1};

$\Delta H_{c,eff}$ is the effective lower heat combustion of propane, in kJ g^{-1}.

Assuming a combustion efficiency of 100 %, $\Delta H_{c,eff}$ can be set equal to 46,4 kJ g^{-1}.

E.2.2 Heat release rate from the product

In the baseline period, prior to ignition of the burner (11.2.1) the following parameters are calculated.

a) The ambient temperature (T_a). This is taken as the average duct temperature T_s measured over 1 min from the time t = −90 s to t = −30 s.

b) The initial value for the oxygen ($x^0_{O_2}$) shall be measured as the average over 1 minute from the time t = −90 s to t = −30 s.

c) The initial value for the carbon dioxide ($x^0_{CO_2}$) shall be measured as the average over 1 min from the time t = −90 s to t = −30 s.

d) The initial value for the light intensity (I_0) shall be measured as the average over 1 min from the time t = −90 s to t = −30 s.

The heat release rate from the product and ignition burner, $\dot{q}_{\text{total}}$, is calculated using Formula (E.4):

$$\dot{q}_{\text{total}} = HRR_{\text{total}} = E^1 \dot{V}_{298} x^a_{O_2} \left(\frac{\phi}{\phi(\alpha - 1) + 1} \right) \tag{E.4}$$

with ϕ, the oxygen depletion factor, given by

$$\phi = \frac{x^0_{O_2}(1 - x_{CO_2}) - x_{O_2}(1 - x^0_{CO_2})}{x^0_{O_2}(1 - x_{CO_2} - x_{O_2})} \tag{E.5}$$

and the ambient mole fraction of oxygen ($x^a_{O_2}$), given by

$$x^a_{O_2} = x^0_{O_2} \left[1 - \frac{H}{100p} \exp\left\{ 23,2 - \frac{3\,816}{T_{\text{a}} - 46} \right\} \right] \tag{E.6}$$

Heat release rate from a tested product, $\dot{q}$, expressed in kilowatts, is calculated using Formula (E.7):

$$\dot{q} = HRR = E^1 \dot{V}_{298} x^a_{O_2} \left(\frac{\phi}{\phi(\alpha - 1) + 1} \right) - \frac{E^1}{E_{C_3H_8}} \dot{q}_b \tag{E.7}$$

where

E is the heat release per volume of oxygen consumed, in kJ m^{-3};

E^1 = 17,2 × 10^3 kJ m^{-3} (25 °C) for combustion of tested product; if another value of E is used, that should be reported and justified;

$E_{C_3H_8}$ = 16,8 × 10^3 kJ m^{-3} (25 °C) for combustion of propane;

E_{CH_3OH} = 17,3 × 10^3 kJm^{-3} for combustion of methanol;

$\dot{V}_{298}$ is the volume flow rate of gas in the exhaust duct at atmospheric pressure and 25 °C calculated as specified in E.1, in m^3 s^{-1};

α is the expansion factor due to chemical reaction of the air that is depleted of its oxygen (α = 1,105 for combustion of tested product);

$x_{O_2}^{a}$ is the ambient mole fraction of oxygen including water vapour;

$x_{O_2}^{0}$ is the initial value of oxygen analyser reading, expressed as a mole fraction;

x_{O_2} is the oxygen analyser reading during the test, expressed as a mole fraction;

$x_{CO_2}^{0}$ is the initial value of carbon dioxide analyser reading during the test, expressed as a mole fraction;

x_{CO_2} is the carbon dioxide analyser reading during the test, expressed as a mole fraction;

H is the relative humidity, in %;

p is the ambient pressure, in Pa;

$\dot{q}_b$ is the heat release rate from the burner.

NOTE Subtracting the heat release from the burner at the very beginning of a test will produce negative values of $\dot{q}$. This is due to combustion gas fill-up times in the room, transportation times to the hood, etc. All negative values of $\dot{q}$ should be set to zero.

E.2.3 Calculation of total heat release

The total heat release from a tested product, THR, is calculated as:

$$THR(t) = \frac{1}{1\,000}\sum_{0s}^{t} HRR(t)\cdot 3\,\mathrm{s} \qquad \text{(E.8)}$$

where

$THR(t)$ is the total heat release during 0 s – t s, in MJ;

$HRR(t)$ is the heat release rate, in kW.

The time, t, is selected according to requirements. The maximum value of time t is either the time at the end of test or one record before the time to flashover as defined in E.5.1

E.2.4 Calculation of HRR_{smooth}

HRR_{smooth} (t) is the average of $HRR_{\text{total}}(t)$ over 30 s, calculated as in Formula (E.9). HRR_{smooth} is used to define time to flashover as defined in E.5.1.

$$HRR_{\text{smooth}}(t) = \frac{HRR_{\text{total}}(t-15\,\text{s}) + HRR_{\text{total}}(t-12\,\text{s}) + \ldots + HRR_{\text{total}}(t+12\,\text{s}) + HRR_{\text{total}}(t+15\,\text{s})}{11}$$

(E.9)

During flashover, the first 30 s and the last 30 s of a test the calculation of HRR_{smooth} according to Formula (E.9) does not apply as the required 11 records are not available. For those cases, the procedures given below apply.

Beginning of test:

For t = 0 s: HRR_{smooth} = 0 kW;

For t = 3 s: HRR_{smooth} = HRR_{total} average over the period (0 s…6 s);

For t = 6 s: HRR_{smooth} = HRR_{total} average over the period (0 s…12 s);

For t = 9 s: HRR_{smooth} = HRR_{total} average over the period (0 s…18 s);

For t = 12 s: HRR_{smooth} = HRR_{total} average over the period (0 s…24 s);

For $t \geq 15$ s: HRR_{smooth} is calculated according to Formula (E.9);

End of test.

HRR_{smooth} is calculated according to Formula (E.9) until the data point $HRR_{\text{total}}(t + 15\text{ s})$ is one record before the flashover point or, if there is no flashover, until (t + 15 s) = 1 200 s. This means that there are no values of HRR_{smooth} given for the last five records, 15 s, of a test.

Flashover faster than 30 s.

In cases where flashover occurs before 30 s, HRR_{smooth} is calculated as the time average over the entire actual time interval. The corresponding value of t is taken at the middle of the time interval.

E.2.5 Limitations

Formulae (E.3) to (E.7) are based on certain approximations leading to the following limitations.

a) The amount of CO generated is not taken into consideration. Normally, the error is negligible. As the concentration of CO is measured, corrections can be calculated for those cases where the influence of incomplete combustion may have to be quantified.

b) The influence of water vapour on measurement of flow and gas analysis is only partially taken into consideration. A correction for this error can be obtained only by continuous measurement of the partial water vapour pressure.

c) The value of 17,2 MJ m^{-3} for the factor E, is an average value for a large number of products and gives an acceptable accuracy in most cases. It should be used unless a more accurate value is known, in which case the used E-value should be reported.

These accumulated errors should normally be less than 10 %.

E.3 Combustion gases

By measuring the mole fraction of a specified gas, it is possible to calculate the instantaneous rate of gas production, $\dot{V}_{\text{gas}}$, expressed in cubic metres per second at 0,1 MPa and 25 °C ($\text{m}^3\ \text{s}^{-1}$) and the total amount of gas production V_{gas}, expressed in cubic metres at 0,1 MPa and 25 °C (m^3), following Formulae (E.10) and (E.11):

$$\dot{V}_{\mathrm{gas}} = \dot{V}_{298}\, x_i \tag{E.10}$$

$$V_{\mathrm{gas}} = \int_0^t \dot{V}_{\mathrm{gas}} dt \tag{E.11}$$

where

$\dot{V}_{298}$	is the rate of volume flow in exhaust duct, in m^3 s^{-1} at 0,1 MPa and 25 °C;
x_i	is the mole fraction of specified gas in the analyser;
t	is the time from ignition, in seconds (s).

NOTE See E.2.2 regarding correction of water vapour.

E.4 Light obscuration

The optical density is represented by the extinction coefficient, k, expressed in reciprocal metres (m^{-1}), and is defined in Formula (E.12):

$$k = \frac{1}{L} \ln \left[\frac{I_0}{I} \right] \tag{E.12}$$

where

l_0	is the light intensity for a beam of parallel light rays measured in a smoke free environment with a detector having the same spectral sensitivity as the human eye;
l	is the light intensity for a parallel light beam having traversed a certain length of smoky environment;
L	is the length of beam through smoky environment, in metres (m).

The instantaneous smoke production rate, SPR, expressed in square metres per second (m^2 s^{-1}), and the total amount of smoke, TSP, expressed in square metres (m^2) are then calculated from Formula (E.13):

$$SPR\,(t) = k\,\dot{V}_s \tag{E.13}$$

where

$\dot{V}_s$	is the volume flow rate in the exhaust duct at actual duct gas temperature, in m^3 s^{-1};
t	is the time from ignition of the burner, in seconds (s).

E.4.1 Calculation of SPR_{smooth}

$SPR_{\text{smooth}}(t)$ is the average of $SPR(t)$ over 60 s, calculated as in Formula (E.14). SPR_{smooth} is used in Formula (E.17).

$$SPR_{\text{smooth}}(t) = \frac{SPR(t - 30\,\text{s}) + SPR(t - 27\,\text{s}) + \ldots + SPR(t + 27\,\text{s}) + SPR(t + 30\,\text{s})}{21} \tag{E.14}$$

During flashover, the first and the last minute of a test the calculation of SPR_{smooth} according to Formula (E.14) does not apply as the required 21 records are not available. For those cases, the procedures given below apply.

Beginning of test:

For $t = 0$ s: $SPR_{\text{smooth}} = 0$ m^2/s;

For $t = 3$ s: SPR_{smooth} = SPR average over the period (0 s...6 s);

For $t = 6$ s: SPR_{smooth} = SPR average over the period (0 s...12 s);

For $t = 27$ s: SPR_{smooth} = SPR average over the period (0 s...54 s);

For $t \geq 30$ s: SPR_{smooth} is calculated according to Formula (E.14);

End of test.

SPR_{smooth} is calculated according to Formula (E.14) until the data point $SPR(t + 30\text{ s})$ is one record before the flashover point or, if there is no flashover, until $(t + 30\text{ s}) = 1\,200$ s. This means that there are no values of SPR_{smooth} given for the last 10 records, 30 s, of a test.

Flashover faster than 60 s.

In cases where flashover occurs before 60 s, SPR_{smooth} is calculated as the time average over the entire actual time interval. The corresponding value of t is taken at the middle of the time interval.

E.4.2 Calculation of TSP

The total smoke production $TSP(t)$ is calculated as:

$$TSP(t) = \sum_{0s}^{t} SPR(t) \cdot 3\,\text{s} \tag{E.15}$$

where

$TSP(t)$ is the total smoke production during 0 s – t s (m^2);

$SPR(t)$ is the smoke production rate (m^2/s).

The time, t, is selected according to requirements. The maximum value of time, t, is either the time at the end of the test or one record before the time to flashover as defined in E.5.1.

E.5 Calculation of FIGRA and SMOGRA

E.5.1 Time to flashover

Time to flashover is the time when the sum of the heat release rate from the ignition source and the product reaches 1 000 kW. The heat release rate for determining the time to flashover is calculated as a 30-second sliding average as given in E.2.4. It is found by linear interpolation between the nearest two measured data points.

E.5.2 Calculation of FIGRA

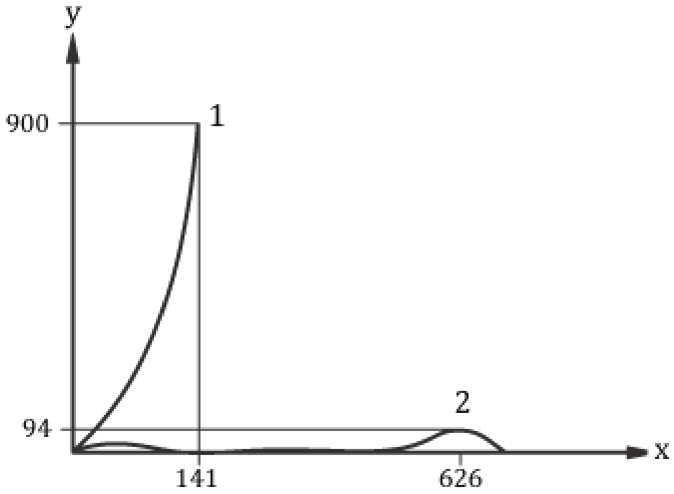
$$\text{FIGRA} = \text{Peak}HRR_{\text{product}}/t \tag{E.16}$$

where

PeakHRR_{product}	is the maximum *HRR* (kW) from the product [contribution from ignition source is excluded, calculated using Formula (E.7)] during test;
t	is the test time in s corresponding to the PeakHRR_{product}.

At the time of flashover, the total HRR is 1 000 kW, see definition. This means that peak HRR from the product can be either 900 kW or 700 kW depending on whether flashover occurs when the HRR of the ignition source is 100 kW or 300 kW, see Figure E.1. If flashover occurs, the time used to calculate FIGRA is the interpolated time to flashover. The units of FIGRA are kW/s.

For very small fires, i.e. a HRR less than or equal to 50 kW, the index may become uncertain and include noise. Therefore if the maximum HRR is less than 50 kW FIGRA is set to zero.



Key

x time, s

y HRR from product, kW

1 FIGRA = 900/141 = 6,4 kW/s

2 FIGRA = 94/626 = 0,15 kW/s

NOTE Two typical products are shown.

Figure E.1 — Calculation of the FIGRA index

E.5.3 Calculation of SMOGRA

$$\text{SMOGRA} = 10\,000\ \text{Peak}SPR_{\text{smooth}}/t \tag{E17}$$

where

PeakSPR_{smooth}	is the maximum SPR_{smooth} during test, defined as in E.4.1;
t	is the test time in s corresponding to the PeakSPR_{smooth}.

When maximum SPR_{smooth} occurs at the end of a test (at flashover or at 20 min), then the test time, t, is taken as the time when the last calculation of SPR_{smooth} was performed. For a flashover time shorter than 60 s, there is only one value of SPR_{smooth} (and hence PeakSPR_{smooth}) and a corresponding t; these are used to calculate SMOGRA.

Optionally, SMOGRA data could also be reported as a graph from ignition to the point of flashover or end of test, calculated as $\mathrm{SMOGRA}(t) = 10\,000\ SPR_{\mathrm{smooth}}(t)/t$.

Correction for smoke produced by the ignition burner is small and can be neglected.

If the smoke production from the product is very small, the index may become uncertain and be influenced by the smoke production from the burner. Therefore, if the maximum SPR_{smooth} is less than 0,3 $\mathrm{m}^2\ \mathrm{s}^{-1}$, SMOGRA is set to zero.

Annex F
(informative)

Specimen configurations

NOTE Different specimen configurations are possible depending on the practical use of the product under test and the specific situation that is to be studied.

F.1 Standard specimen configuration

In order to achieve comparable test data between laboratories, it is recommended that the walls (excluding the wall containing the doorway) and the ceiling are covered with the product. This is designated as the standard specimen test configuration.

F.2 Alternative specimen configuration

Other possibilities are to test the product covering only the walls and having standard ceiling materials, or to test the product covering only the ceiling and having standard wall materials.

The standard materials should then be chosen in accordance with 10.4.

It is also possible to test combinations of different wall and ceiling products in order to evaluate specific scenarios.

Annex G
(informative)

Precision

G.1 Precision of calibration

The International Commission in the work of developing the SBI test initiated a programme of large scale testing. These included calibration exercises amongst international laboratories. A summary from this work is given in Table G.1.

Table G.1 — Summary sheet for the calibration tests

Quantity	Average value measured lab no			
	1	2	3	4
***Methanol*: Measured effective heat of combustion, $\Delta H_{c,eff}$. Calculated as Total heat released/Total mass lost. (kJ/g)	19,25	18,74	19,43	20,60
***Propane under hood*: Deviation from true value at 100 kW and 300 kW level. Calculated as: (1 - Average measured HRR/ actual burner output) in per cent.	100 kW:	100 kW:	100 kW:	100 kW:
	1 %	1 %	1 %	0 %
	300 kW:	300 kW:	300 kW:	300 kW:
	1 %	1 %	0 %	2 %
***Propane in room*: Deviation from true value at 100 kW and 300 kW level. Calculated as: (1 - Average measured HRR/ actual burner output) in per cent.	100 kW:	100 kW:	100 kW:	100 kW:
	2 %	2 %	2 %	1 %
	300 kW:	300 kW:	300 kW:	300 kW:
	3 %	3 %	0 %	2 %

We see that methanol calibrations all are within 6 % of the theoretical value, which is considered as good. All data on propane calibration lies within 3 % which is considered as very good.

Annex H
(informative)

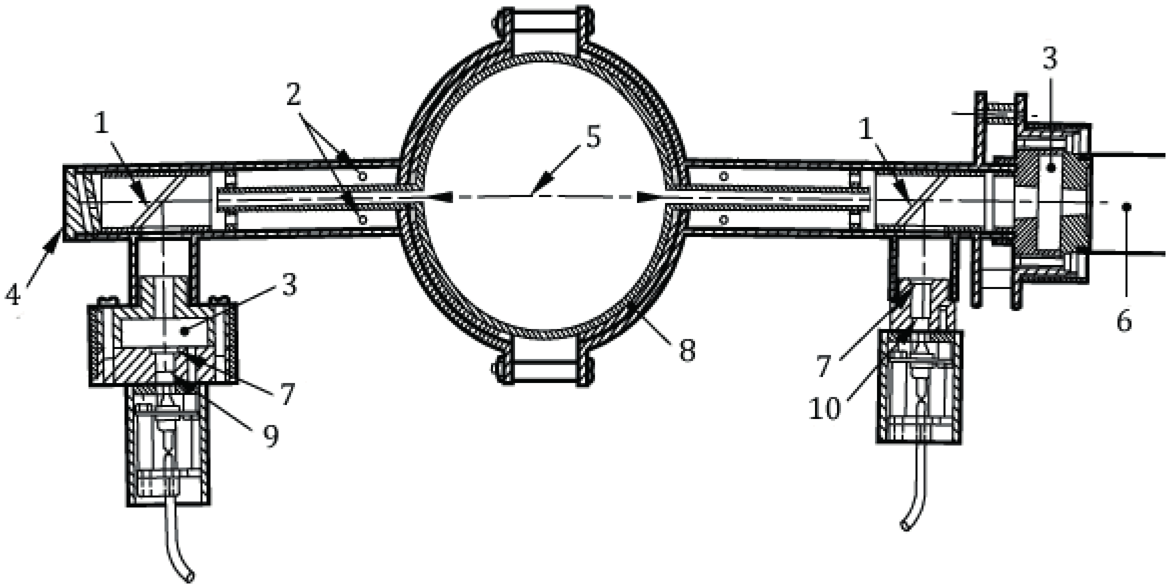
Laser smoke photometer

H.1 Photometer equipment

A laser smoke photometer shall use a helium-neon laser with a power output of 0,5 mW to 2,0 mW. The laser radiation shall be polarized. Figure H.1 shows the general arrangements of a laser smoke photometer. Two silicon photodiodes are provided: a main beam detector and a compensation detector. The electronics shall be arranged so as to provide a signal output, which is the ratio of the main beam detector to the compensation beam detector signals.

The system contains two holders for filters: one filter for checking the optical calibration and one filter (located directly after the laser) to check the proper functioning of the compensation. Calibration filters shall be of the type which is a uniform dispersion in glass; film-coated filters (“interference filters”) shall not be used.

The system should be designed for split yoke mounting in two pieces that are rigidly coupled together, or on an optical bench, resiliently attached to the exhaust duct by means of refractory gasketing.



Key

1	beam splitter	6	0,5 mW helium laser
2	purge air orifices	7	opal glass
3	opal glass	8	ceramic fibre packing
4	cap	9	main detector
5	optical path	10	compensation detector

Figure H.1 — Smoke obscuration measuring system

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[2] Withdrawn.

[3] For the use of a reference scenario for the SBI test (EN 13823) reference is made to Commission Decision 2000/147/EC, see also note below.

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