

INTERNATIONAL STANDARD

ISO
9705

First edition
1993-06-15

Corrected and reprinted
1996-03-01

Fire tests — Full-scale room test for surface products

*Essais au feu — Essai dans une pièce en vraie grandeur pour les produits
de surface*



Reference number
ISO 9705:1993(E)

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International Organization for Standardization

Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Foreword

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

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

International Standard ISO 9705 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Reaction to fire*.

Annex A forms an integral part of this International Standard. Annexes B, C, D, E, F, G and H are for information only.

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Introduction

This method 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.

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Fire tests — Full-scale room test for surface products

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 for extinguishing a fully developed fire should be available.

1 Scope

This International Standard specifies a test method that simulates a fire that under well ventilated conditions starts in a corner of a small room with a single open doorway.

The method is intended to evaluate the contribution to fire growth provided by a surface product using a specified ignition source.

A standard ignition source is specified, but other alternatives are allowed. It should, however, be noted that the type, position and heat output of the ignition source will considerably influence the fire growth.

The method is especially suitable for products that for some reason cannot be tested in a small laboratory scale, for example thermoplastic materials, the effect of an insulating substrate, joints, surfaces with great irregularity.

The method is not intended to evaluate the fire resistance of a product.

A test performed in accordance with the method specified in this International Standard provides data for the early stages of a fire from ignition up to flashover.

2 Normative reference

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

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

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 3261 and the following definitions apply.

3.1 assembly: Fabrication of materials and/or composites, for example, sandwich panels.

NOTE 1 An assembly may include an air gap.

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

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

3.4 material: Single substance or uniformly dispersed mixture, for example, metal, stone, timber, concrete, mineral fibre, polymers.

3.5 product: Material, composite or assembly about which information is required.

3.6 specimen: Representative piece of the product which is to be tested together with any substrate or treatment.

NOTE 2 The specimen may include an air gap.

3.7 surface product: Any part of a building that constitutes an exposed surface on the interior walls and/or the ceiling such as panels, tiles, boards, wall papers, sprayed or brushed coatings.

4 Principle

The potential for fire spread to other objects in the room, remote from the ignition source, is evaluated by measurements of the total heat flux incident on a heat flux meter located on the centre of the floor.

The potential for fire spread to objects outside the room of origin is evaluated by the measurement of the total rate of heat release of the fire.

An indication of the toxic hazard is provided by the measurement of certain toxic gases.

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

The fire growth is visually documented by photographic and/or video recording.

NOTE 3 If further information is required, measurements of the gas temperature in the room and the mass flow in and out the doorway may be performed.

5 Fire test room

5.1 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: $3,6 \text{ m} \pm 0,05 \text{ m}$;
- b) width: $2,4 \text{ m} \pm 0,05 \text{ m}$;
- c) height: $2,4 \text{ m} \pm 0,05 \text{ m}$.

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 and of the ignition source, the test room may be placed so that the floor can be reached from beneath.

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

- a) width: $0,8 \text{ m} \pm 0,01 \text{ m}$;
- b) height: $2,0 \text{ m} \pm 0,01 \text{ m}$.

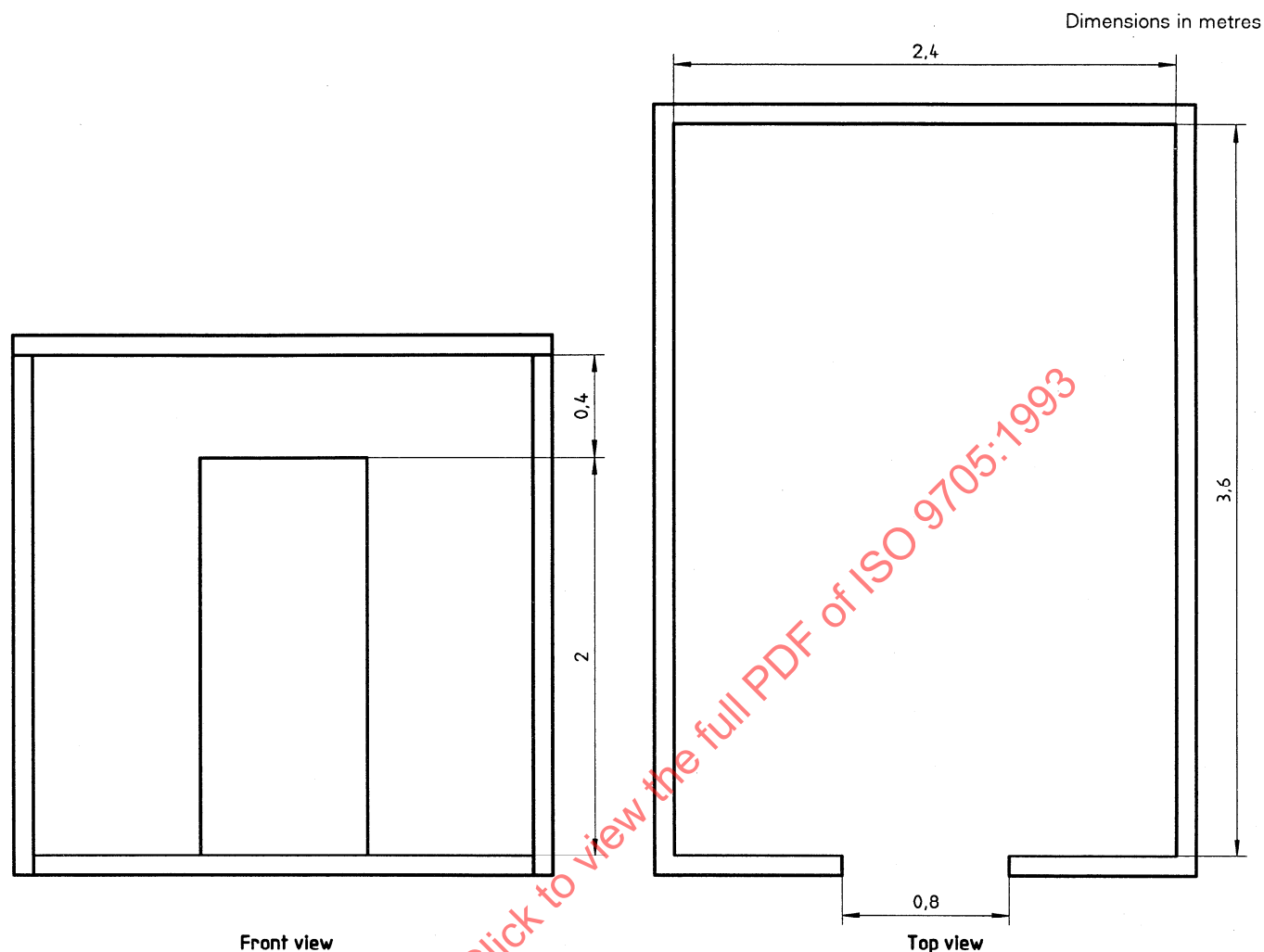


Figure 1 — Fire test room

5.3 The test room shall be constructed of non-combustible material with a density of 500 kg m^{-3} to 800 kg m^{-3} . The minimum thickness of the construction shall be 20 mm.

6 Ignition source

6.1 Recommended sources

It is recommended to use one of the ignition sources specified in annex A to which the following requirements apply.

6.1.1 The ignition source shall be a propane gas burner having a square top surface layer of a porous, inert material, e.g. sand. The construction shall be such that an even gas flow is achieved over the entire opening area.

The ignition source is a propane gas burner that 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.

The burner should, for reasons of safety, be equipped with a remote-controlled ignition device, for example a pilot flame or a glow wire. There should be a warning system for leaking gas and a valve for immediate and automatic cut-off of the gas supply in case of extinction of the ignition flame.

6.1.2 The burner shall be placed on the floor in a corner opposite to the doorway wall. The burner walls shall be in contact with the specimen.

6.1.3 The burner shall be supplied with natural grade propane (95 % purity). The gas flow to the burner shall be measured with an accuracy of at least ± 3 %. The heat output to the burner shall be controlled within ± 5 % of the prescribed value.

6.2 Alternative sources

Alternative sources as specified in annex B may also be used.

7 Heat flux instrumentation in the fire room

This clause specifies minimum requirements for heat flux instrumentation in the fire room. Additional information and designs can be found in annex C.

7.1 Specification

The heat flux meter shall be of the Gardon (foil) or the Schmidt-Boelter (thermopile) type with a design range of about 50 kW m^{-2} . The target area shall be a flat black surface having a view angle of 180° . The heat flux meter shall have an accuracy of at least ± 3 % and a repeatability within 0,5 %. In operation, the meter shall be maintained at a constant temperature (within $\pm 5^\circ\text{C}$) above the dew point.

7.2 Location

The heat flux meter shall be mounted at the geometric centre of the floor. The target area shall be 5 mm to 30 mm above the floor surface. Radiation shall not pass through any window before reaching the target.

7.3 Calibration

The calibration of the heat flux meter shall be checked whenever required, by comparison with two instruments held as reference standards and not used for any other purpose. One of the reference standards shall be fully calibrated at yearly intervals.

NOTE 4 An example procedure is given in BS 6809.

8 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 exhaust capacity shall be at least $3,5 \text{ m}^3 \text{ s}^{-1}$ at normal pressure and a temperature of 25°C .

NOTE 5 An example of one design of hood and an exhaust duct is given in annex D.

9 Instrumentation in the exhaust duct

This clause specifies minimum requirements for instrumentation in the exhaust duct. Additional information and designs can be found in annex E.

9.1 Volume flow rate

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

The response time to a stepwise change of the duct flow rate shall be a maximum of 1 s at 90 % of the final value.

9.2 Gas analysis

9.2.1 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 E.)

9.2.2 Oxygen

The oxygen consumption shall be measured with an accuracy of at least $\pm 0,05$ % (V/V) oxygen. The oxygen analyser shall have a time constant not exceeding 3 s. (See annex E.)

9.2.3 Carbon monoxide and carbon dioxide

The gas species shall be measured using analysers having an accuracy of at least $\pm 0,1$ % (V/V) for carbon dioxide and $\pm 0,02$ % (V/V) for carbon monoxide. The analysers shall have a time constant not exceeding 3 s. (See annex E.)

9.3 Optical density

9.3.1 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). The system shall be constructed in such a way as to ensure that soot deposits during the test do not reduce the light transmission by more than 5 %.

9.3.2 Lamp

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

9.3.3 Lenses

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

9.3.4 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.

9.3.5 Detector

The detector shall have a spectrally distributed responsivity agreeing with the CIE¹⁾ $V(\lambda)$ -function (the CIE photopic curve) to an accuracy of at least $\pm 5\%$.

The detector output shall be linear within 5 % over an output range of at least 3,5 decades.

9.3.6 Location

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

10 System performance

10.1 Calibration

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

NOTE 6 Equations for calculations are given in annex F.

The calibration shall be performed with the burner heat outputs given in table 1, with the burner positioned directly under the hood. Measurements shall be taken at least every 6 s and shall be started 1 min prior to ignition of the burner. At steady state conditions, the difference between the mean rate of heat release over 1 min calculated from the measured oxygen consumption and that calculated from the metered gas input shall not exceed 5 % for each level of heat output.

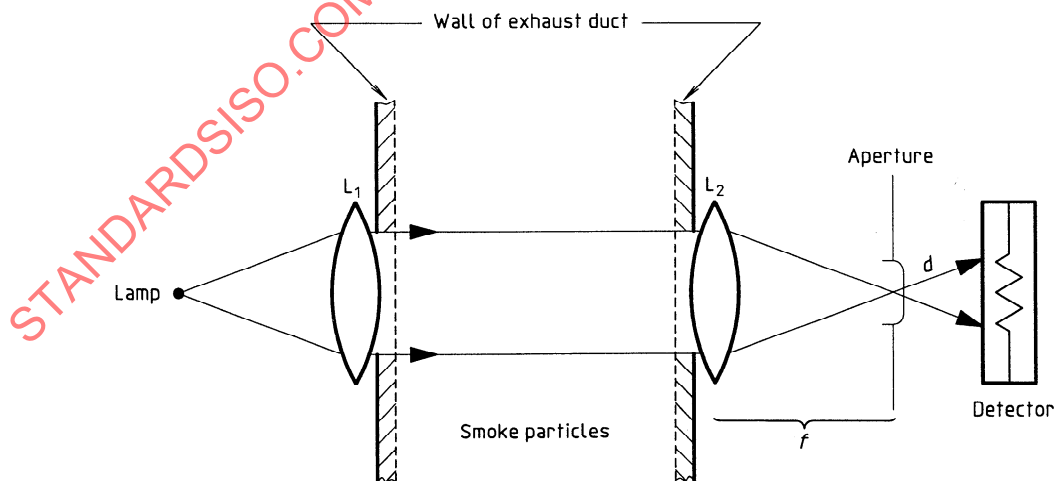


Figure 2 — Optical system

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10.2 System response

The time delay for a stepwise change of the heat output from the burner, when placed centrally 1 m below the hood, shall not exceed 20 s and shall be corrected for in test data. The time delay shall be determined by measuring the time taken to reach agreement to within 10 % of the final measured heat release value, when going through the stepwise procedure given in table 1, taking measurements at least every 6 s.

Table 1 — Burner heat output profile

Time min	Heat output kW
0 to 2	0
2 to 7	100
7 to 12	300
12 to 17	100
17 to 19	0

10.3 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 $2 \text{ m}^3 \text{ s}^{-1}$ (at 0,1 MPa and 25 °C) up to maximum. The heat output from the burner shall be 300 kW. The error in the mean rate of heat release, calculated over 1 min, shall be not more than 10 % of the actual heat output from the burner.

11 Preparation of test specimens

11.1 The product to be tested shall, as far as possible, be mounted in the same way as in practical use.

NOTE 7 In the standard specimen configuration, three walls and the ceiling are covered with the product. Alternative specimen configurations are given in annex G.

11.2 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.

2) Constant mass is considered to be 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 piece or 0,1 g, whichever is the greater.

11.3 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. The mounting technique shall be clearly stated in the report, particularly if the mounting technique used improves the physical behaviour of the specimen during the test.

11.4 Thin surface materials, thermoplastic products that melt, paints and varnishes shall, depending on their end use, be applied to one of the following substrates:

- non-combustible fibre-reinforced silicate board having a dry density of $680 \text{ kg m}^{-3} \pm 50 \text{ kg m}^{-3}$;
- non-combustible board having a dry density of $1\,650 \text{ kg m}^{-3} \pm 150 \text{ kg m}^{-3}$;
- chipboard (particle board) having a density of $680 \text{ kg m}^{-3} \pm 50 \text{ kg m}^{-3}$ after conditioning in an atmosphere of $(50 \pm 5) \%$ relative humidity at a temperature of $(23 \pm 2) \text{ °C}$;
- gypsum board having a density of $725 \text{ kg m}^{-3} \pm 50 \text{ kg m}^{-3}$ after conditioning in an atmosphere of $(50 \pm 5) \%$ relative humidity at a temperature of $(23 \pm 2) \text{ °C}$;
- the actual substrate if its thermal properties differ significantly from those of substrates a) to d), for example, steel, mineral wool.

NOTE 8 A suitable thickness for substrates a) to d) is 9 mm to 13 mm.

11.5 Paints and varnishes shall be applied to one of the substrates listed in 11.4 at the application rate specified by the client.

11.6 Unless non-hygroscopic, specimens shall be conditioned to equilibrium in an atmosphere of $(50 \pm 5) \%$ relative humidity at a temperature of $(23 \pm 2) \text{ °C}$. Equilibrium shall be deemed to be reached when a representative piece of the specimen has achieved constant mass.²⁾

NOTE 9 For wood-based products and products where vaporization of solvents can occur, a conditioning time of at least four weeks can be required.

12 Testing

12.1 Initial conditions

12.1.1 The temperature in the fire test room and the surrounding area from the start of the installation of specimens until the start of the test shall be $20\text{ °C} \pm 10\text{ °C}$.

NOTE 10 The time between the removal of the specimens from conditioning and the start of the test should be kept to a minimum.

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

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

NOTE 11 Marking the product with a grid of $0,3\text{ m} \times 0,3\text{ m}$ squares on those surfaces adjacent to the corner where the burner is located can help in determining the extent of flame spread.

12.1.4 The product shall be photographed or video-filmed before testing.

12.2 Procedure

12.2.1 Start all recording and measuring devices and record data for at least 2 min prior to the burner being ignited.

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

12.2.3 A photographic and/or video recording shall be made of the test. A clock shall appear in all photographic records, giving time to the nearest 1 s.

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

- a) ignition of the ceiling;
- b) flame spread on wall and ceiling surfaces;
- c) change of the heat output from the burner;
- d) flames emerging through the doorway.

12.2.5 End the test if flashover occurs or after 20 min (source A.1)/15 min (source A.2), whichever occurs first. Continue observation for 2 h, or until signs of visual combustion have ceased, whichever occurs first.

NOTE 12 Safety considerations can dictate an earlier termination.

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

12.2.7 Record any other unusual behaviour.

13 Test report

The test report shall contain the following information:

- a) name and address of the testing laboratory;
- b) date and identification number of the report;
- c) name and address of the client;
- d) purpose of the test;
- e) method of sampling;
- f) name of manufacturer or supplier of the product;
- g) name or other identification marks and description of the products;
- h) density or mass per square unit and thickness of the product;
- i) date of supply of the product;
- j) description of the specimens and mounting technique;
- k) conditioning of the specimens;
- l) date of test;
- m) test method;
- n) test results (see annex F):
 - 1) time/heat flux incident on the meter at the centre of the floor,
 - 2) time/volume flow in the exhaust duct,
 - 3) time/rate of heat release; and if the burner is included, time/heat release from the burner,

- 4) time/production of carbon monoxide at reference temperature and pressure,
 - 5) time/production of carbon dioxide at reference temperature and pressure,
 - 6) time/production of light-obscuring smoke at actual duct flow temperature,
 - 7) description of the fire development (photographs),
 - 8) calibration results according to 10.2;
- o) additional test results, if measured (see annex C):
- 1) time/surface temperature of the product,
 - 2) time/vertical temperature profile in the doorway,
 - 3) time/mass flow through the doorway,
 - 4) time/convective heat flow through the doorway,
 - 5) time/production of hydrocarbons (CH_n) at a reference temperature and pressure,
 - 6) time/production of nitrogen oxides (NO_x) at a reference temperature and pressure,
 - 7) time/production of hydrogen cyanide (HCN) at a reference temperature and pressure;
- p) designation of the product according to criteria expressed in official standards or regulations.

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Annex A

(normative)

Recommended ignition sources

A.1 Standard ignition source

A.1.1 Burner

The burner shall be as shown in figure A.1. 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.

A.1.2 Output level

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.

A.2 Alternative ignition source

A.2.1 Burner

The burner should 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 $162 \text{ kW} \pm 4 \text{ kW}$ (gross heat output 176 kW). The flow rate shall be metered throughout the test.

NOTE 13 The burner may be constructed with either a 25 mm thick porous ceramic fibreboard over a 200 mm plenum, or a minimum 100 mm layer of Ottawa sand, to provide the horizontal surface through which the gas is supplied (see figure A.2). The sand burner can be preferable for dripping materials.

A.2.2 Output level

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.

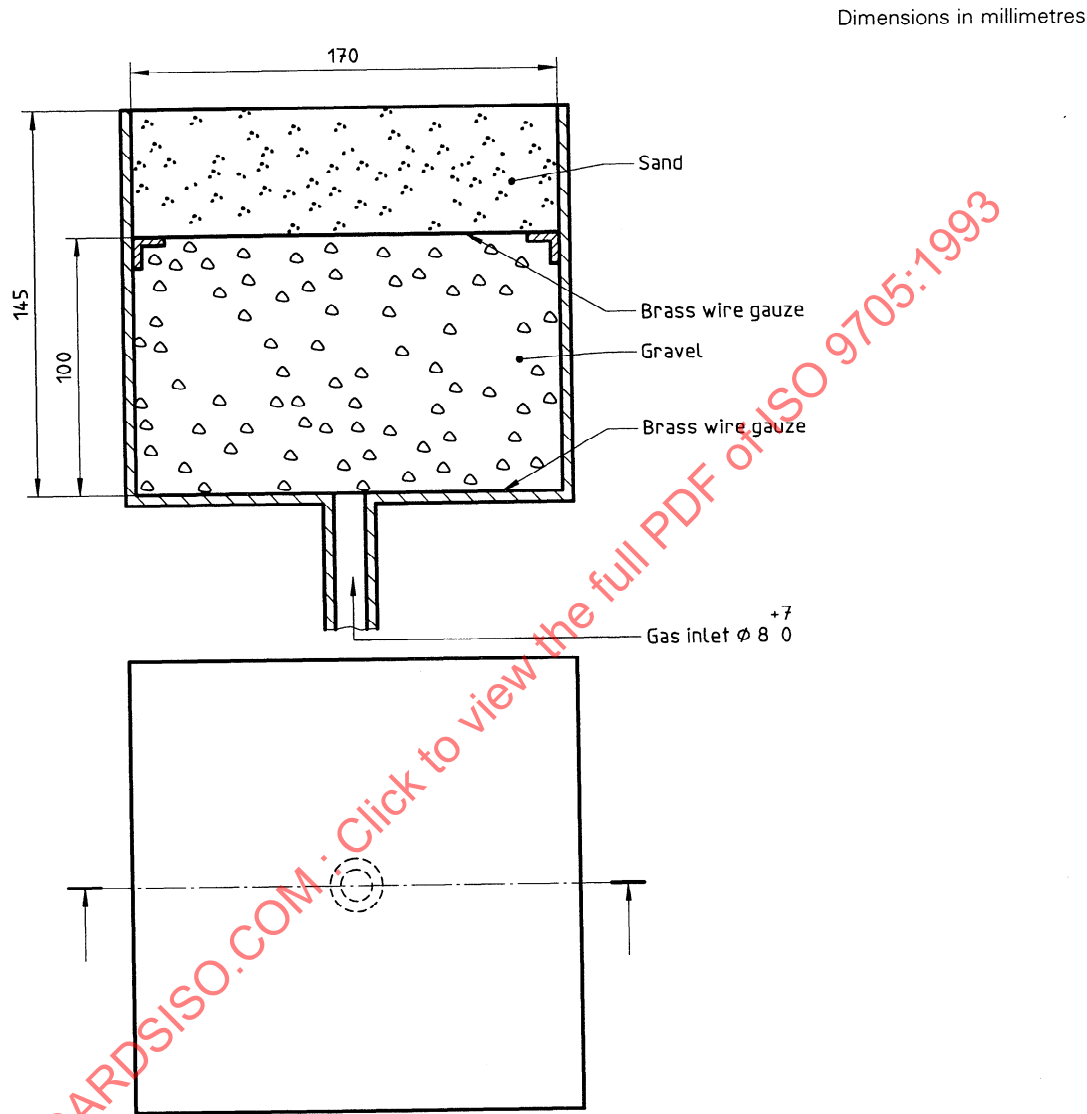


Figure A.1 — Standard ignition source

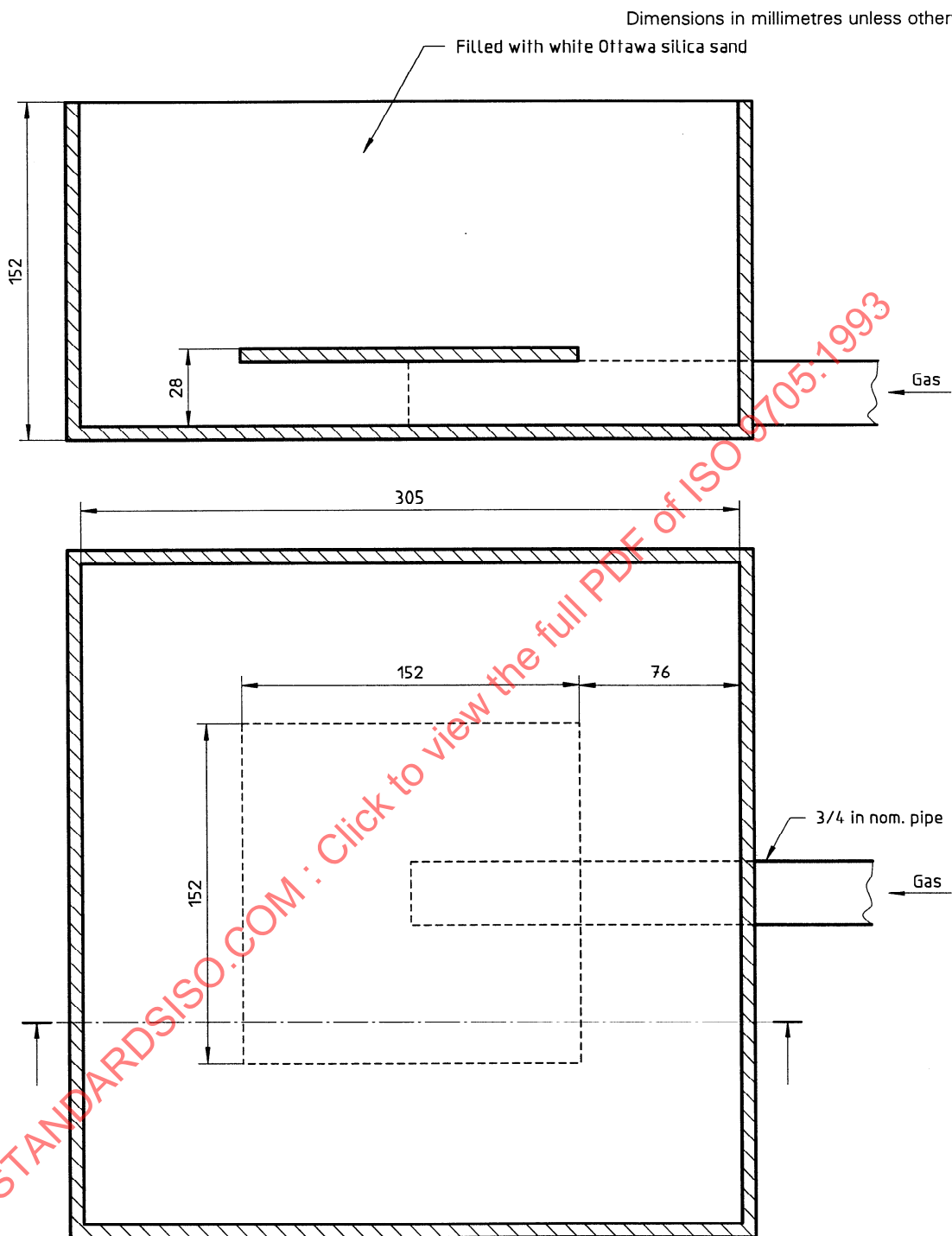


Figure A.2 — Alternative ignition source

Annex B

(informative)

Alternative ignition sources

NOTE 14 In order to achieve comparable test data between laboratories, it is essential that tests have been performed with similar and well defined ignition sources.

Other ignition sources may be used, for example:

- a) the alternative ignition source specified in A.2 with a net heat output of 40 kW during the first 5 min after ignition and at a net heat output of 160 kW for a further 10 min;
- b) primary ignition sources such as impinging flames;

- c) secondary ignition sources such as furniture or waste paper baskets that will act on the lining material in the room.

If other ignition sources are used, details should be given. Secondary ignition sources should be related to fire scenarios and proved to be repeatable and reproducible.

NOTE 15 Primary ignition sources are under consideration.

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Annex C (informative)

Instrumentation of test room

C.1 Heat flux

NOTE 16 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 "heat flux" is used instead of "irradiance".

The target receiving radiation, and possibly to a small extent convection, should be flat, circular, not more than 15 mm in diameter and coated with a durable matt-black finish. The target should be contained within a water-cooled body whose front face should be of highly polished metal, flat, coinciding with the plane of the target and circular, with a diameter of not more than 50 mm.

The instrument should be robust, simple to set up and use, insensitive to draughts and stable in calibration. The instrument should have an accuracy of $\pm 3\%$ and a repeatability of within 0,5 %.

C.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 be made with suction pyrometers or very thin thermocouples (50 μm).

Suitable locations for pyrometers or thermocouples are given in figure C.1.

C.3 Surface temperatures

C.3.1 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.

C.3.2 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 re-

sistant glass-fibre tape with a surface area of approximately 100 mm². 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 C.2.

C.4 Flow through opening

C.4.1 Mass flow through the opening can be measured by bidirectional probes as specified in E.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.

C.4.2 Mass flow per unit time and area, $\dot{m}''$, expressed in kilograms per square metre second, is calculated from the following equation:

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

$$= 1 / k_p (2\Delta P \rho_0 T_0 / T_s)^{1/2} \quad \dots (C.2)$$

where

ρ_s is the density of gas at point of measurement, expressed in kilograms per cubic metre (kg m⁻³);

v is the gas velocity, expressed in metres per second (m s⁻¹);

k_p is the Reynolds number correction for the bidirectional probe;

ΔP is the measured pressure differential, expressed in pascals (Pa);

ρ_0 is the air density at 0 °C and 0,1 MPa, expressed in kilograms per cubic metre (kg m⁻³);

$$T_0 = 273,15 \text{ K};$$

T_s is the gas temperature at point of measurement.

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

Total mass flow, $\dot{m}_{\text{out}}$, 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. It is essential that the position of the neutral plane is either measured or calculated as a function of time.

C.4.3 Convective heat flow rate per unit area, $\dot{Q}''$, expressed in kilowatts per square metre, out of the opening is calculated from the following equation:

$$\dot{Q}'' = \dot{m}'' c_p (T_s - T_i) \quad \dots (\text{C.3})$$

where

$\dot{m}''$ is the rate of mass flow per unit area, expressed in kilograms per square metre second ($\text{kg m}^{-2} \text{ s}^{-1}$);

c_p is the specific heat of combustion gases, expressed in kilojoules per kilogram kelvin ($\approx 1,0 \text{ kJ kg}^{-1} \text{ K}^{-1}$);

T_s is the temperature of gas flow, expressed in kelvins (K);

T_i is the ambient temperature, expressed in kelvins (K).

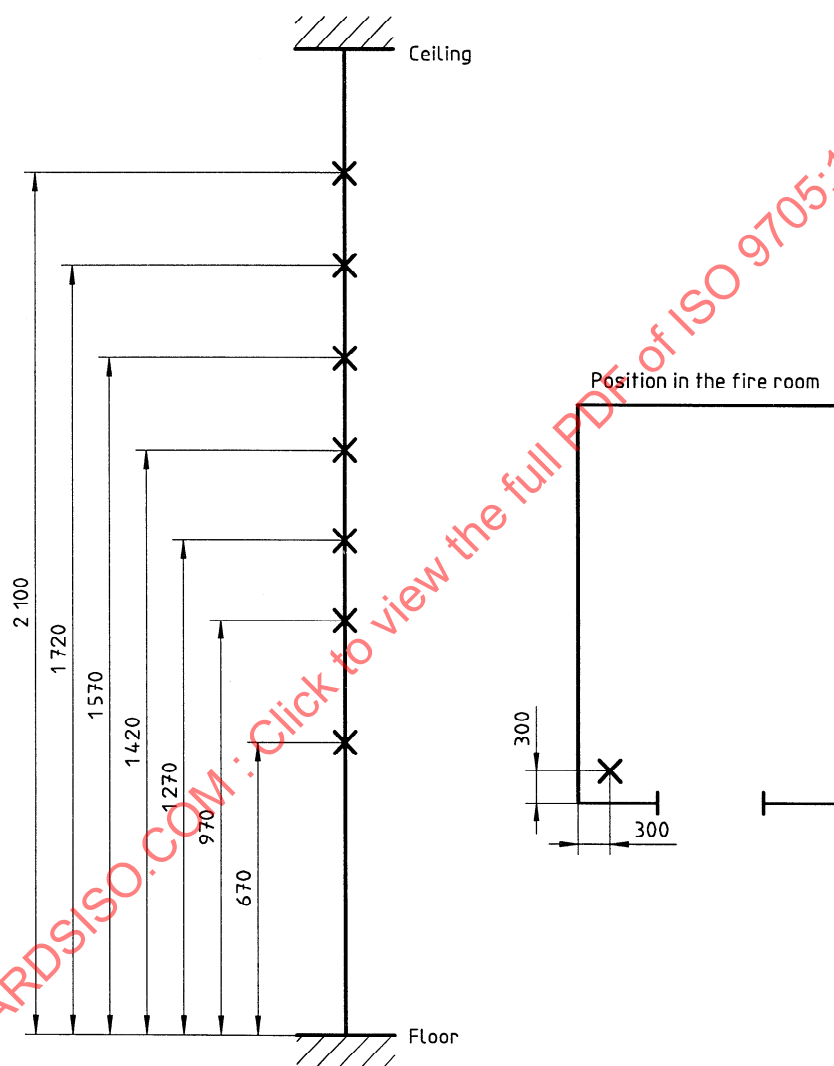
Total rate of convective energy outflow is obtained by integration as specified in C.4.2.

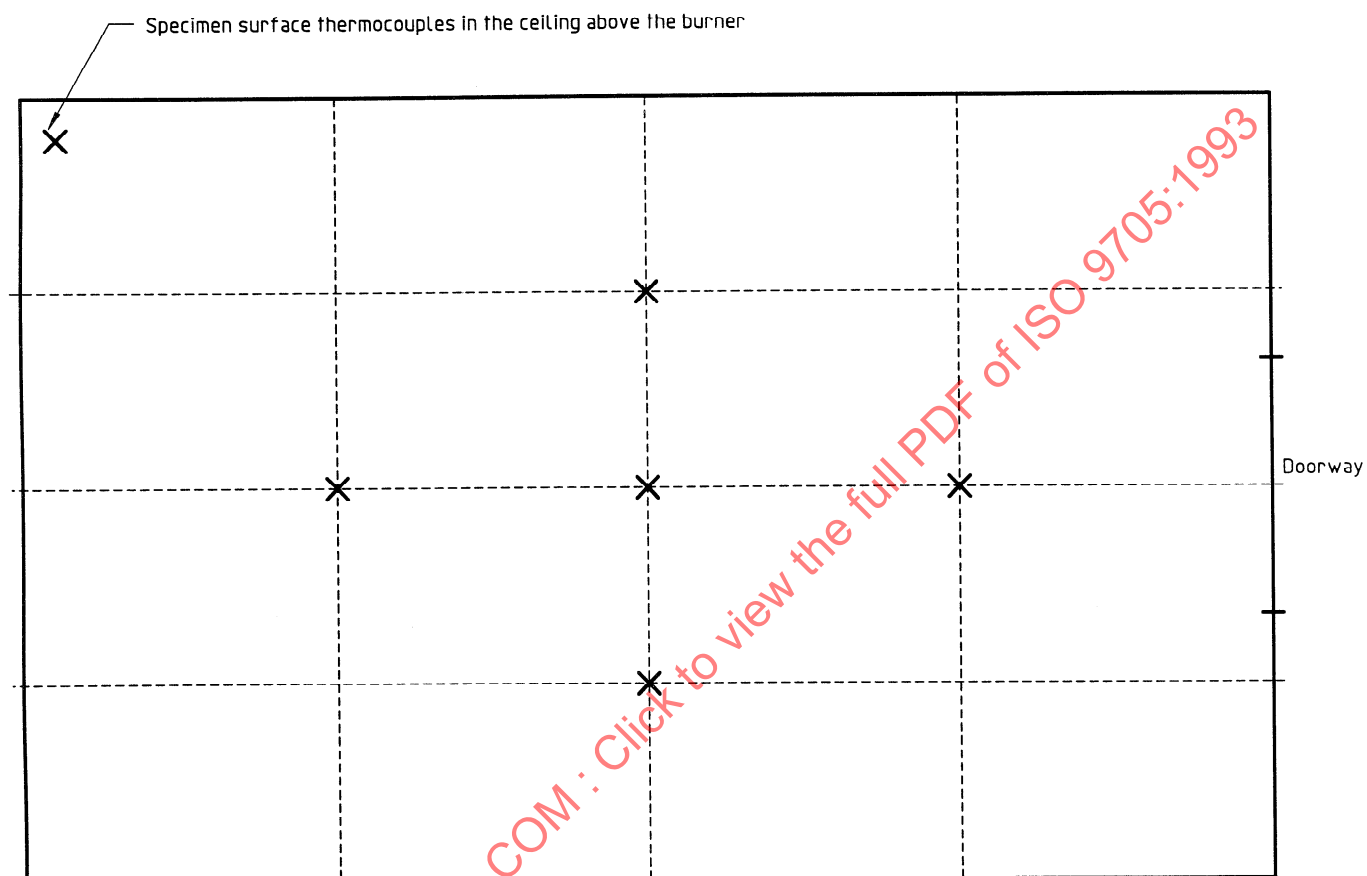
C.4.4 To map the gas flow pattern in the room door opening adequately requires at least 10 probes. The accuracy will then be $\pm 20 \%$. A rough estimate of the rate of gas flow can be obtained with three probes located 1 300 mm, 1 800 mm and 1 900 mm from the floor. All probes should be centrally located in a vertical plane through the middle of the door frame, where the flow is essentially horizontal.

C.5 Radiation through opening

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

Dimensions in millimetres

**Figure C.1 — Measurement of gas temperatures inside test room**



NOTE — The thermocouple hot junctions are fixed to the specimen surface with approximately 100 mm² of glass fibre tape.

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

Annex D (informative)

Design of exhaust system

D.1 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 International Standard.

D.2 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 $3 \text{ m} \times 3 \text{ m}$ and the height $1,0 \text{ m}$ (see figure D.1). On three sides, steel sheets are extended $1,0 \text{ m}$ downwards (the fourth side is connected with the test room). The effective height of the hood will thus be 2 m (see figure D.2). The hood feeds into a plenum having a $0,9 \text{ m} \times 0,9 \text{ m}$ cross-sectional area. The plenum has a minimum height of $0,9 \text{ m}$.

In the plenum chambers, two plates approximately $0,5 \text{ m} \times 0,9 \text{ m}$ are located to increase mixing of the combustion gases (see figure D.2).

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

D.3 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 $4,8 \text{ m}$.

To facilitate flow measurement, guide vanes are located at both ends of the exhaust duct (see figures D.1 and D.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.

D.4 The capacity of the evacuation 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 $12\,000 \text{ m}^3 \text{ h}^{-1}$ 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 $0,5 \text{ kg s}^{-1}$ to 4 kg s^{-1} during the test process. If the air flow is not decreased during the initial part of the test, measurement precision will be too low.

D.5 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 10. Exhaust systems based on natural convection should not be used.

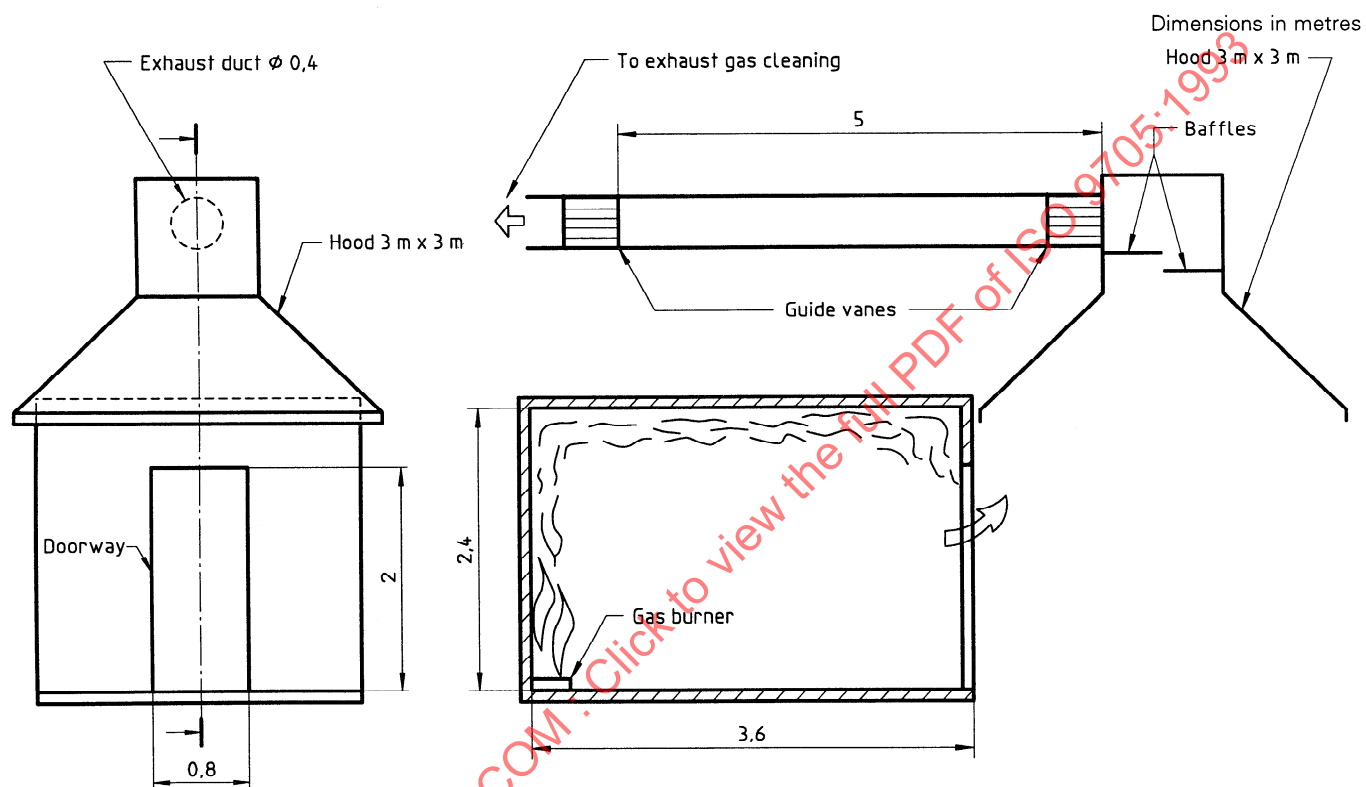


Figure D.1 — Principal design (without steel sheet extensions on the hood)

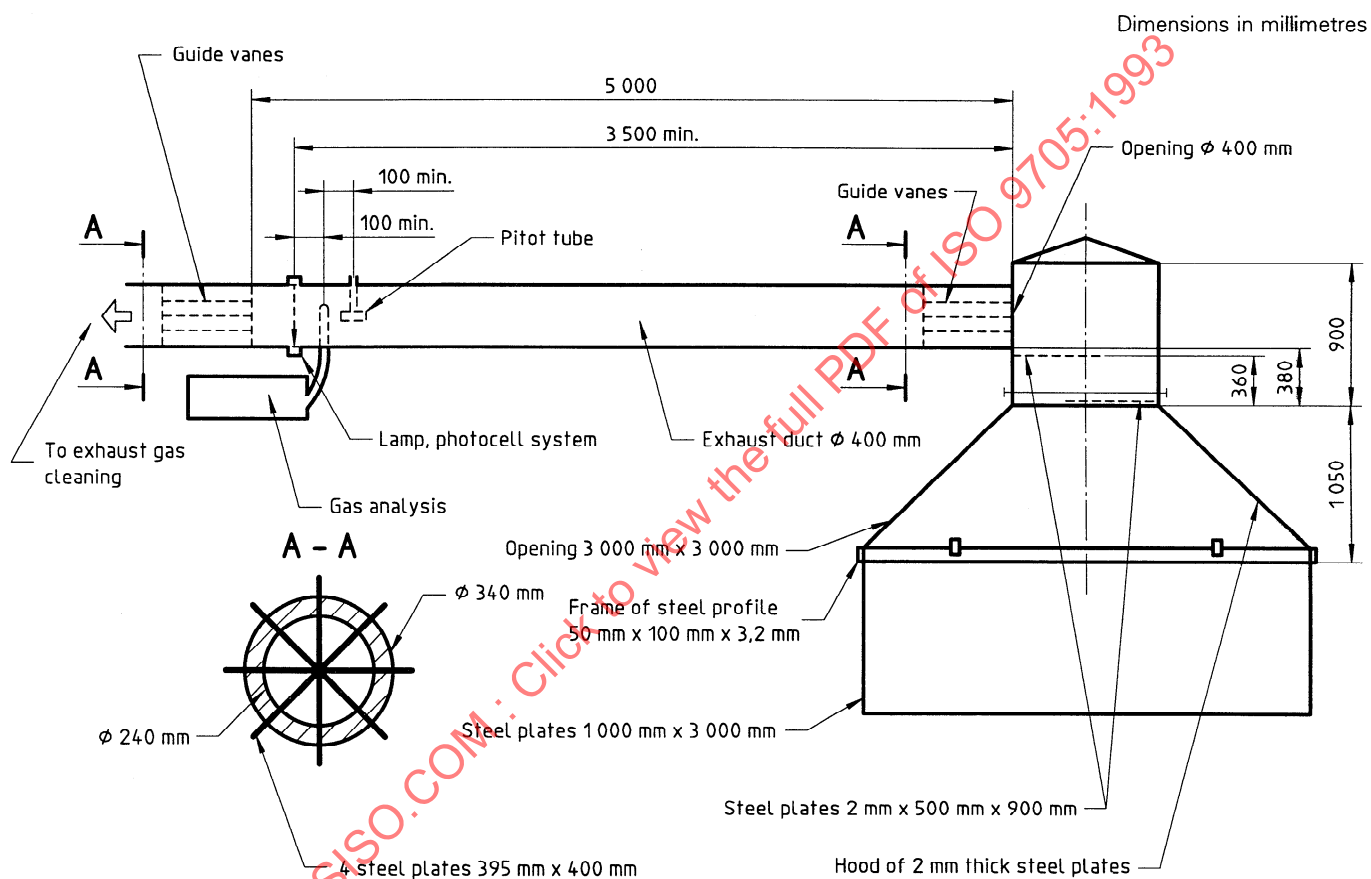


Figure D.2 — Details of exhaust system and location of sampling probes

Annex E

(informative)

Instrumentation in exhaust duct

NOTE 17 Suitable locations for the probes described in E.1 to E.4 are shown in figure D.2.

E.1 Volume flow

E.1.1 The flow may be measured by a bidirectional probe located at the centre line of the duct. The probe shown in figure E.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 E.2.

E.1.2 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.

E.1.3 Gas temperature in the immediate vicinity of the probe is measured by a thermocouple with a maximum diameter 0,25 mm. The thermocouple should not be allowed to disturb the flow pattern around the bidirectional probe.

E.2 Sampling line

E.2.1 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.

E.2.2 The sampling line (see figure E.3) should be manufactured from non-corrosive material, e.g. PTFE. 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, CO₂ and O₂, 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 E.3.3 and E.3.4).

E.2.3 The combustion gas should be transported by a pump which does not emit oil, grease or similar products, which can contaminate the gas mixture. A membrane pump is suitable.

E.2.4 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 in the sampling line should not exceed 1 s.

E.2.5 A suitable sampling probe is shown in figure E.4. The sampling line is shown in figure E.3. A suitable pump should have the capacity of 10 l min⁻¹ to 50 l min⁻¹, as each gas analysis instrument requires about 1 l 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.

E.3 Combustion gas analysis

NOTE 18 Further details of combustion gas analysis are given in ISO/TR 9122-3.

E.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.

E.3.2 Oxygen concentration

The oxygen analyser should comply with the requirements specified in 9.2.2 and should be of the paramagnetic type.

E.3.3 Carbon monoxide and dioxide concentration

Continuous analysis of the oxides of carbon can be achieved using IR spectrometers. A suitable range of measurement is 0 % to 1 % for carbon monoxide and 0 % to 6 % for carbon dioxide.

E.3.4 Hydrocarbons

Hydrocarbons are most conveniently measured by IR spectroscopy and expressed in total hydrocarbon content referred to equivalent amount of normal hexane. The maximum error of the instrument should be 2 %. A suitable range of measurement is 0 ppm to 2 000 ppm. The sample should be taken from the sampling line and the time lag, including the time constant of the analyser, should be less than 6 s. A heated sampling line should be used.

E.3.5 Nitrogen oxide concentration

The concentration of NO and NO₂ can be measured together in total and with an analyser of chemiluminescence type. The total maximum error of the analyser should be 2 % and a suitable range of measurement is 0 ppm to 250 ppm. Response times are specified in E.3.4. A heated sampling line should be used.

E.4 Optical density

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

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

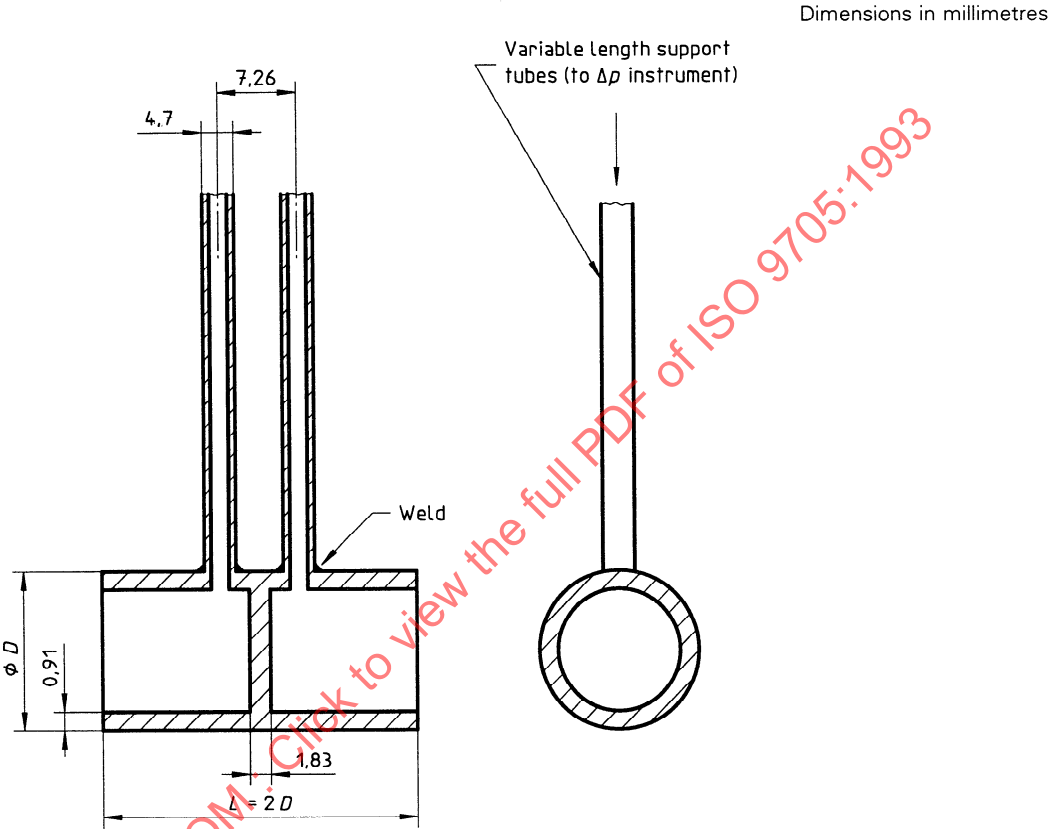
Lamp: Halogen lamp; 6 V, 10 W.

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 3,5 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.

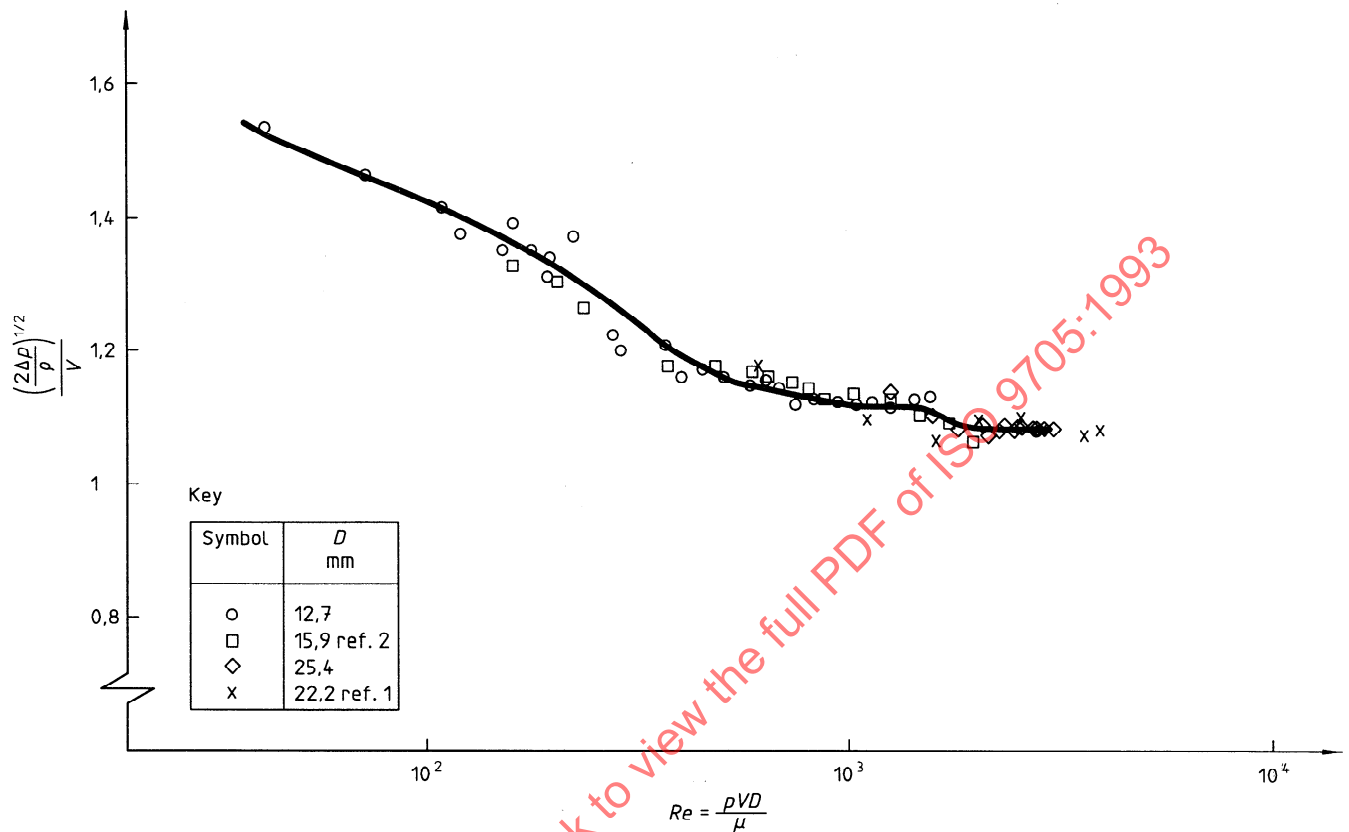
A suitable light measuring system is given in ISO/TR 5924.



NOTE — Taken from McCaffrey and Heskestad^[6].

Figure E.1 — Bidirectional probe

Dimensions in millimetres



NOTES

1 Source: McCaffrey and Heskestad^[6].

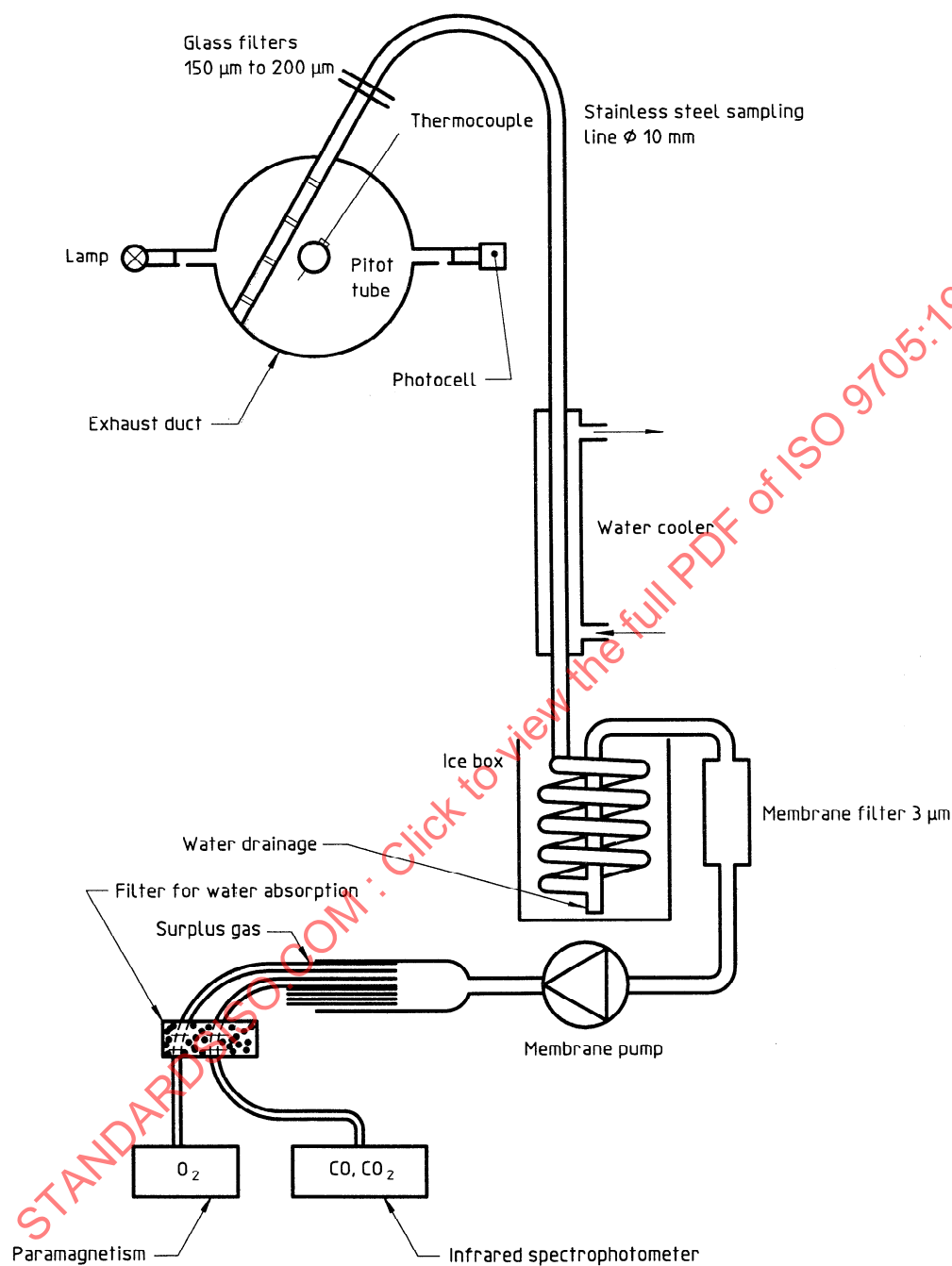
2 The pressure differences were measured with a sensitive electronic manometer; the uniform low velocity flows were provided by two independent facilities described in McCaffrey and Heskestad^[6]. Basically, a hot wire anemometer and pitot-static tube, where appropriate, were used to determine the stream velocity. For data reduction via computer, the polynomial curve fit obtained for the points shown in figure E.2 is

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

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

3 A suitable value of D is 16 mm.

Figure E.2 — Probe response versus Reynolds number



NOTE — Other gas cooling systems may be used. Cooling may be omitted if the water trap is sufficiently efficient.

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