INTERNATIONAL STANDARD

ISO 13784-1

Second edition
2014-02-01

Reaction to fire test for sandwich panel building systems —

Part 1:
Small room test

Essais de réaction au feu des systèmes de fabrication de panneaux de type sandwich —

Partie 1: Essais pour des chambres de petite taille

Reference number
ISO 13784-1:2014(E)

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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 second edition cancels and replaces the first edition (ISO 13784-1:2002), which has been technically revised.

ISO 13784 consists of the following parts, under the general title *Reaction-to-fire tests for sandwich panel building systems*:

— *Part 1: Test method for small rooms*

— *Part 2: Test method for large rooms*

Introduction

Fire is a complex phenomenon; its behaviour and effects depend upon a number of interrelated factors. The behaviour of materials and products depends upon the characteristics of the fire, the method of use of the materials, and the environment in which they are exposed. The philosophy of reaction to fire tests is explained in ISO/TR 3814.

The need for improved insulation of buildings has led to the increased use of insulating sandwich panel systems in different parts of the building industry.

Sandwich panel systems are applied as external cladding of factory buildings, in internal envelopes with controlled atmospheres, and in cold stores which can vary from small rooms to large cool houses. Another application is the use for modular building rooms and sometimes for retail premises. They can also be used for roof applications in a traditional construction. Multi-layered panels with other facings (for example, plasterboard) or sandwich panel systems can be applied to walls as internal linings or insulation but this is not within the scope of this part of ISO 13784.

With free-standing or frame supported types of sandwich panel systems, there are three primary fire threats to the insulated walls and ceilings/roofs of the building:

a) an interior compartment fire impinging directly onto the joints of the wall (typical ignition sources are welding torches, burning items near the wall, fire in an adjacent room);

b) an external fire of combustibles accumulated near the wall, i.e. rubbish, vegetation, vehicles, etc.;

c) fire spread to outside spaces.

Fire can spread in several ways:

— over a combustible exterior surface;

— fire travelling vertically and horizontally through the combustible cores of cavities within the external wall or ceiling/roof;

— through combustible gases which have developed due to the pyrolysis of the combustible components and which will ignite on the surface;

— burning debris or flaming droplets.

This part of ISo 13784 deals with a simple representation of one fire scenario with this type of product, such as that typified by a local fire impinging directly on the internal face of a sandwich panel building construction.

This part of ISO 13784 provides a test method which should be used to provide a small-room scale, end-use evaluation of all aspects of sandwich panel systems, which include constructional techniques such as supporting frameworks, jointing detail etc.

This method is intended to evaluate products which, due to their nature, are not normally used as internal linings and are not suitable to be assessed using ISO 9705, which evaluates fire growth from a surface product. This part of ISO 13784, however, provides a method by which a free-standing or frame supported sandwich panel building construction may be built and evaluated within the room.

Tests of this type may be used for comparative purposes or to ensure the existence of a certain quality of performance considered to generally have a bearing on fire performance.

These tests do not rely on the use of asbestos-based materials.

Reaction to fire test for sandwich panel building systems —

Part 1:
Small room test

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 the combustion of test specimen. 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. Laboratory safety procedures shall be set up which ensure the safe termination of tests on sandwich panel products. Specimen with combustible content burning inside metallic facings may be difficult to extinguish with standard laboratory fire fighting equipment. Adequate means of extinguishing such a fire shall be provided. When tests are conducted using the free-standing room construction, specimens can emit combustion products from their back face, especially if joints open up. Specimen collapse can also occur into the laboratory space. Laboratory safety procedures shall be set up to ensure safety of personnel with due consideration to such situations.

1 Scope

This part of ISO 13784 specifies a method of test for determining the reaction to fire behaviour of sandwich panel building systems, and the resulting flame spread on or within the sandwich panel building construction, when exposed to heat from a simulated internal fire with flames impinging directly on the internal corner of the sandwich panel building construction.

The test method described is applicable to free-standing, self-supporting, and frame-supported sandwich panel systems. This part of ISO 13784 is not intended to apply to sandwich panel products which are glued, nailed, bonded, or similarly supported by an underlying wall or ceiling construction. For products used as internal linings, the ISO 9705 test method should be used.

This part of ISO 13784 provides for small room testing of sandwich panel building systems. For large-room testing of sandwich panel building systems, ISO 13784-2 should be used.

This method is not intended to evaluate the fire resistance of a product, which should be tested by other means.

NOTE Because of their design, some systems may be unsuitable for testing with this part of ISO 13784. These systems may be suitable for testing with ISO 13784-2 and the latter test method should be considered. In this case application area of the test report is restricted.

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 9705:1993, *Fire tests — Full-scale room test for surface products*

ISO 13943:2008, *Fire safety — Vocabulary*

ISO 14934-3:2012, *Fire tests — Calibration and use of heat flux meters — Part 3: Secondary calibration method*

IEC 60584-2:1982 + A1:1989, *Thermocouples — Part 2: Tolerances*

3 Terms and definitions

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

3.1
composite
combination of materials which are generally recognized in building construction as discrete entities, for example, coated or laminated materials

3.2
exposed surface
surface of the product subjected to the heating conditions of the test

3.3
product
material, composite, or assembly

3.4
constant mass
state of a test specimen when two successive weighing apparatus operations are carried out at an interval of 24 h, and do not differ by more than 0,1 % of the mass of the specimen or 0,1 g, whichever is greater

3.5
surface product
part of a building that constitutes an exposed surface on the walls and/or the ceiling/roof such as panels, boards, etc.

3.6
insulating sandwich panel
multi-layered product consisting of three or more layers bonded together

Note 1 to entry: One layer is an insulating material, such as mineral or glass wool, cellular plastics, or a natural material, e.g. corkboard protected by facings on both sides. The facing can be selected from a variety of materials and can be either flat or profiled.

Note 2 to entry: The most widely used facing is coated steel. The composite can vary from a simple construction to a complex composite system with specific fixing joints and supports depending on the application and on the performance requirements.

3.7
specimen
assembly representing the end-use construction

3.8
flashover
point in the fire history when the sum of the rate of heat release from the ignition source and the product reaches 1 000 kW for more than 10 s

4 Principle

The reaction to fire performance of a sandwich panel assembly is assessed when exposed to flames impinging directly on the internal corner of a small sandwich panel assembly. The different kinds of flame spread, for example within the internal core, on the surface or through joints, and through ignited combustible gases and falling debris or melting droplets of the sandwich panel assembly, are assessed to allow the following possible fire hazards to be determined:

a) the contribution of the system to fire development up to flashover;

b) the potential to transmit an interior fire to outside spaces or other compartments or adjacent buildings;

c) the possibility of collapse of the structure;

d) the development of smoke and fire gases inside the test room.

If for product development, quality control, or on special request by sponsor or regulatory body the heat release and/or smoke measurement is not included in the test procedure, this shall be clearly stated in the test report.

5 Types of systems

5.1 General

The test method applies to the following two types of structures which are representative of those used in practice, both in construction and materials.

5.1.1 Type A: frame-supported structures

For these types of structures, sandwich panel systems are mechanically fixed to the outside or the inside of a structural framework, normally steel, through the thickness of the panel. The ceiling/roof may be built traditionally or with sandwich panel systems. A widespread construction is an external cladding of industrial buildings. In most cases, this kind of sandwich panel systems is used for the exterior wall and/or the roof of a building.

When using a frame, the deformation of the frame can influence the fire behaviour of the sandwich panels. The test recommends that the frame is protected in practice using fire resistance requirements. Protection can be obtained by means of insulating boards or coatings.

5.1.2 Type B: free-standing structures

Sandwich panel systems are assembled together to provide a room or enclosure which does not depend for its stability on any other structural framework, e.g. cold stores, or food or clean rooms, constructed normally within a weatherproof shell. The ceiling of these constructions may be supported from above. These rooms are normally situated inside a building.

6 Test specimen

The test specimen used shall consist of the requisite number of panels required by the test method to be performed. In all cases, the test specimen shall be representative of that used in practice, both in construction and materials. All constructional details of joints, fixings, etc., shall be reproduced and positioned in the test specimen as in practice. If the investigated type of sandwich panel is used in practice with an inside or outside structural framework, this shall also be used in the test.

It is recommended that the test specimen is built by those suitably qualified in the construction of this type of structure.

NOTE 1 If in practice ceiling panels are different from wall panels, a test can be performed with the correct combination of wall and ceiling panels.

If the sandwich panel building system is intended to be used with decorative paint or film facings, these shall be present on the test specimen.

7 Test method

7.1 This method specifies a procedure by which sandwich panel assemblies may be assessed in their end-use scale and utilizing constructional details, which are incorporated in their end-use. Products are evaluated with end-use joints and fixings and where a supporting steel framework is part of the construction, with this framework also in place. Where the panels are self-supporting, it is recommended that an unconnected external framework be used for safety reasons.

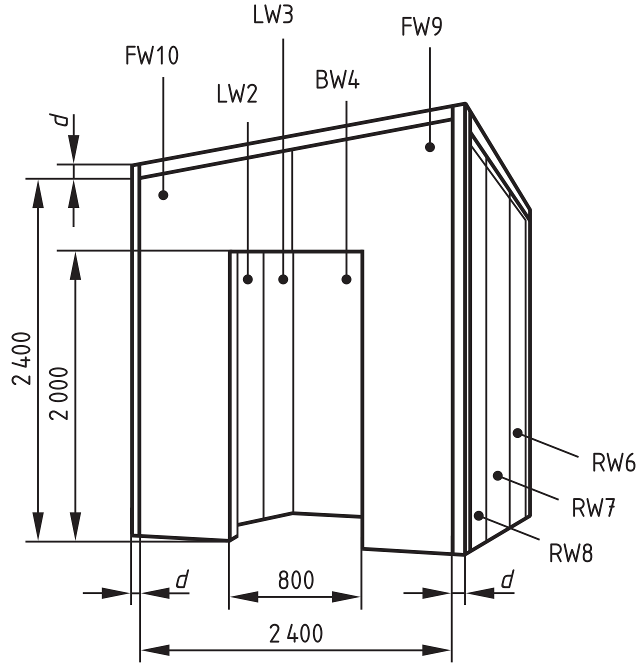
7.2 A room (see Figures 1 to 3) shall be constructed using the components of the sandwich panel systems to be tested. It shall consist of four walls at right angles and a ceiling, and shall be located on a rigid, non-combustible floor surface. The means of securing wall panels together and the means of attaching walls to floor and ceiling to walls shall be representative of end-use. The room shall have the following inner dimensions:

a) length: 3,6 m ± 0,05 m;

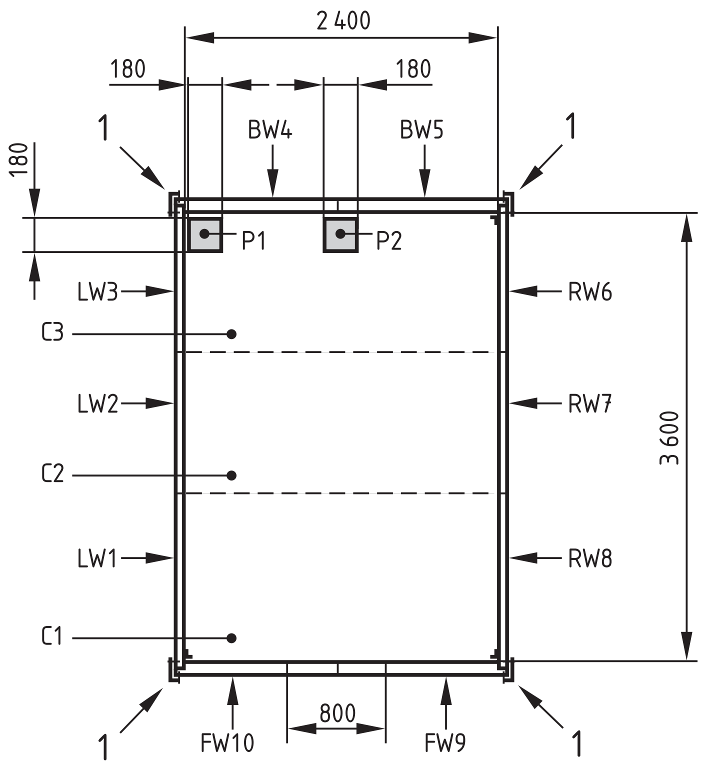
b) width: 2,4 m ± 0,05 m;

c) height: 2,4 m ± 0,05 m.

Dimensions in millimetres



a) Isometric elevation



b) Plan showing alternative burner position

Key

1 supporting frame (if applicable)

C ceiling panel

D thickness of panel

P1 burner position 1, at corner (in case of no frame)

P2 burner position 2, at joint (with frame) distance from corner should be ≤ 300 mm

LW left wall panel

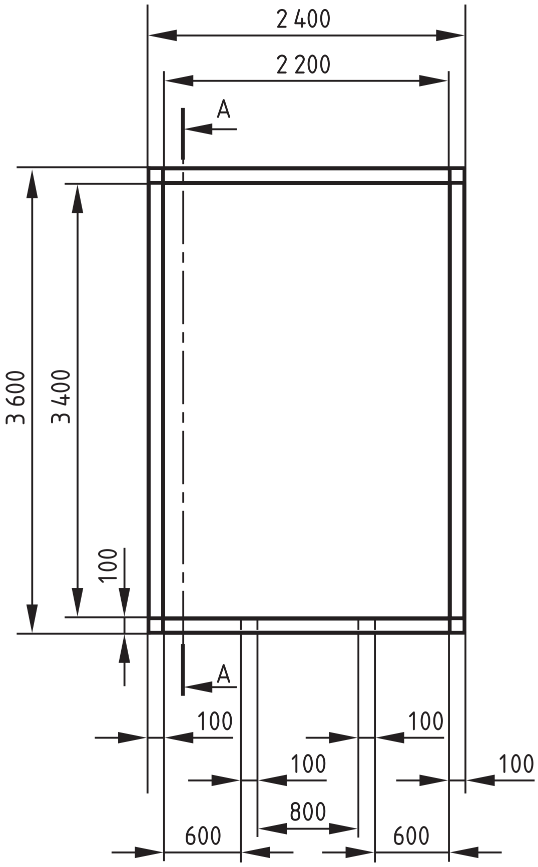
BW back wall panel

RW right wall panel

FW front wall panel

Figure 1 — Example of test specimen

Dimensions in millimetres



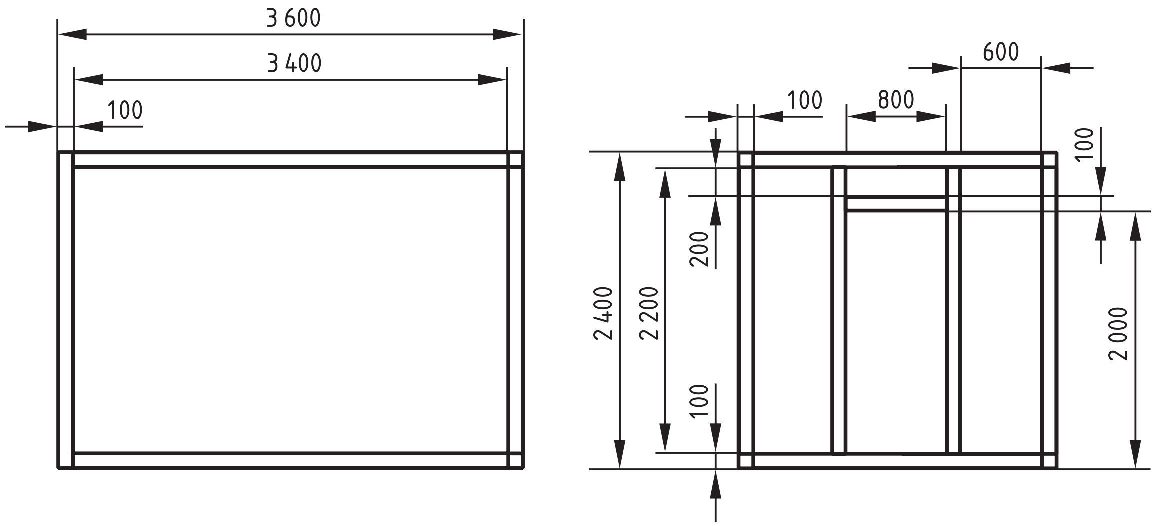


Figure 2 — Example of internal structural framework (plan, section A-A, front view)

Dimensions in millimetres

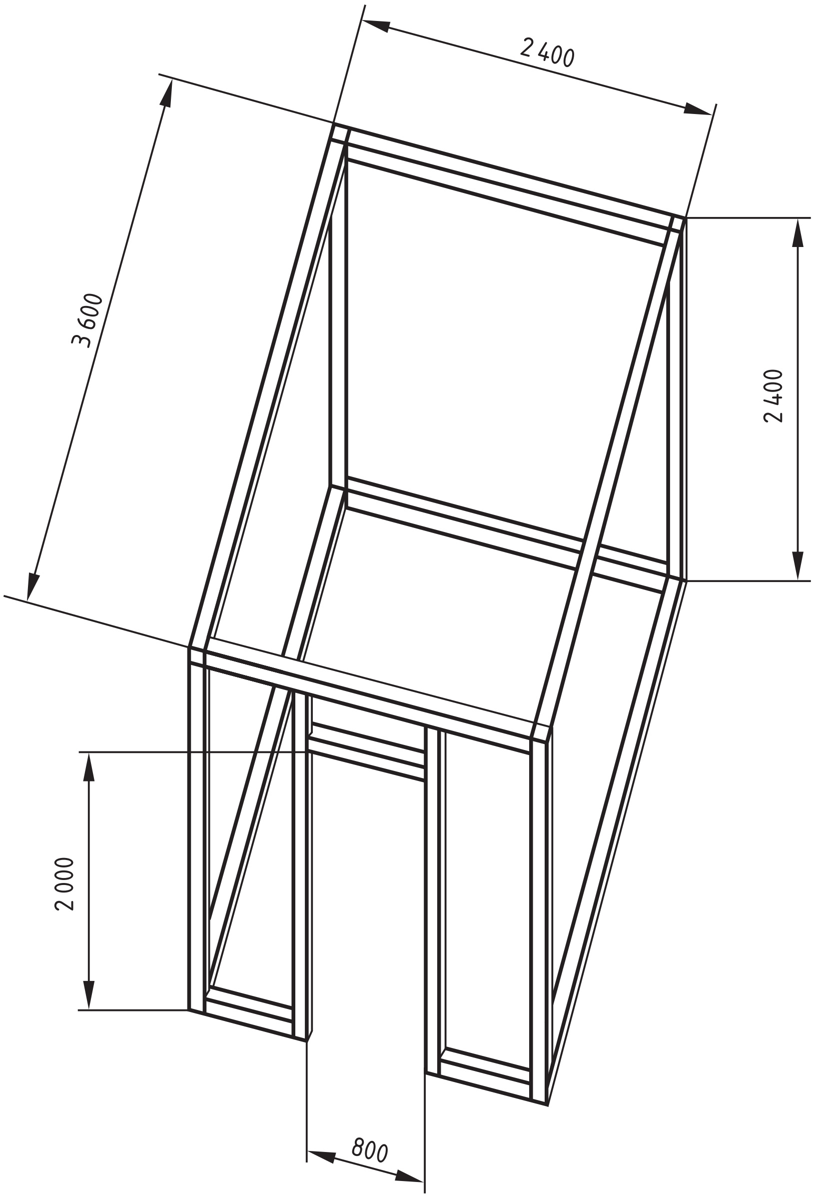


Figure 3 — Example of internal structural framework (isometric elevation)

7.3 A doorway shall be constructed in the centre of one of the 2,4 m x 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.

7.4 The room shall be located indoors. Tests shall not be conducted unless the temperature within the room is between 10 °C and 30 °C.

7.5 The connections between the panels and between the walls and the ceiling shall represent those in end-use application of the product being tested.

7.6 If the system includes any additional bracing, support members, etc., these shall also be installed in the test specimen construction. If the investigated type of sandwich panel systems is used in practice with an inside or outside structural frame work, these shall be used in the test. Examples are given in Figures 2 and 3.

NOTE Figures 1 to 3 give examples of the test room. The number of panels and their thickness will of course be different depending on the type of panels tested. Also, the type of supporting frame will depend on the practical end-use mounting. Only inner dimensions of room and door opening are mandatory.

7.7 The test room shall be positioned below the exhaust hood as described in Clause 9.

NOTE If for product development, quality control, or on special request by the sponsor or regulatory body the heat release and smoke production is not included in the test procedure, the test room does not need to be positioned under the hood.

8 Ignition source

8.1 The ignition source shall be a propane gas burner having a square top surface layer of a porous, inert material, e.g. sand. The burner shall have face dimensions of 170 mm × 170 mm and a height of 200 mm above the floor (see Figure 4). 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.

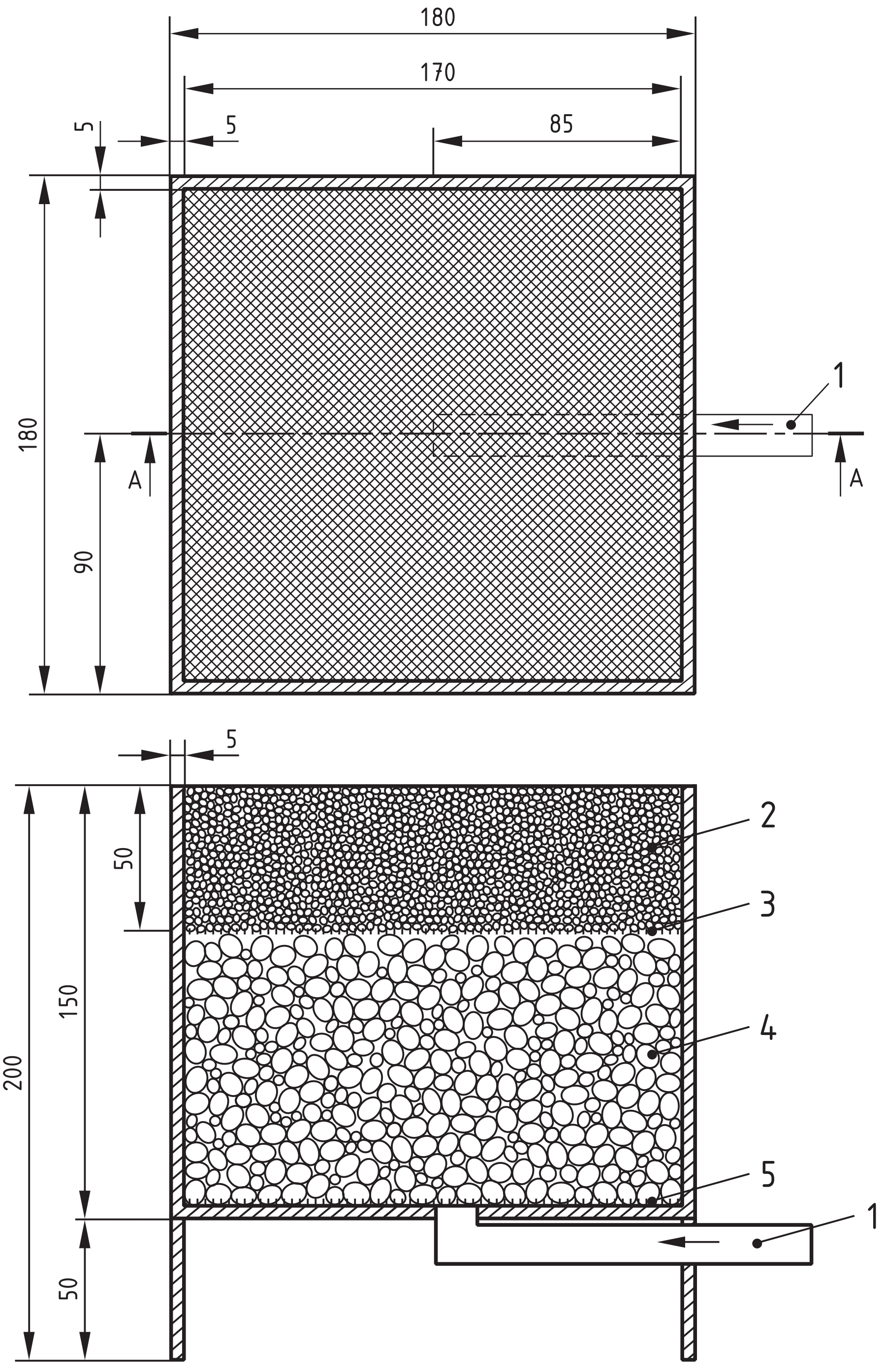
WARNING — All equipment such as tubes, couplings, flow meters, etc. shall be approved for propane. The installations shall be performed in accordance with existing regulations. For reasons of safety, the burner should be equipped with a remote-controlled ignition device, for example a pilot flame or 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.

8.2 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. If there is a structural framework member such as a column in the corner, the burner shall be placed at the nearest joint from the corner on the back wall. This joint shall be not less than 300 mm from the corner column (see Figure 1).

8.3 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.

8.4 The burner power output, based on the net (lower) calorific value of propane, shall be 100 kW during the first 10 min and then shall be increased to 300 kW for a further 10 min. After 20 min, another 10 min of observations shall be made with no power output to the burner.

Dimensions in millimetres



Key

1 gas inlet
2 sand (2 mm to 3 mm)
3 brass wire gauze (1,8 mm)
4 gravel (4 mm to 8 mm)
5 brass wire gauze (2,8 mm)

Figure 4 — Burner

9 Instrumentation

9.1 Thermocouples

Thermocouples shall be positioned on the external surface of each of the panels and within their core installed from the rear of the panel in such a way that flame spread within the core can be monitored. It is recommended that one thermocouple is installed on the external surface of each panel, sited on the centre line and one thermocouple within the core, one third of the distance from the top and bottom of the panel. Thermocouples shall also be positioned in the upper third of the door opening. The thermocouple distribution is shown in Figure 5. Only thermocouples O_2, O_6, and O_{10} in the door opening are mandatory. All the other thermocouples are optional.

The thermocouples shall be either sheathed thermocouples or welded thermocouples. In case of sheathed thermocouples, they shall by Type K Chromel/Alumel stainless steel sheathed thermocouples with a wire diameter of 0,3 mm and an outer diameter of (1,5 ± 0,1) mm. The hot junction shall be insulated and not earthed. In case of welded thermocouples they shall have a diameter of max 0,3 mm. The thermocouples on the external surface of the panels shall have their hot junctions in contact with the surface of the panel. The use of thermocouples with a copper disk is recommended for surface temperature measurements and welded non-sheathed thermocouple for gas temperature measurements. The thermocouples shall be of tolerance class 1 in accordance with IEC 60584-2.

9.2 Heat flux meter

A heat flux meter shall be placed at the centre of the floor of the room.

The heat flux meter shall be of the foil (Gardon) or thermopile (Schmidt-Boelter) type with a range of 0 kW/m^2 to 50 kW/m^2. The target receiving heat flux shall be flat, circular, not more than 10 mm in diameter and coated with a durable matt black finish. The target shall be contained within a water-cooled body, the front face shall be of slightly polished metal, flat, coinciding with the plane of the target and circular, with a diameter of about 25 mm.

Heat flux shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, insensitive to draughts, and stable in calibration. The instrument shall have an accuracy of within ±3 % and a repeatability within 0,5 %.

The heat flux meter shall be calibrated over its whole range in accordance with ISO 14934-3:2012.

9.3 Additional equipment

9.3.1 Data recorder

A chart recorder or data logger capable of recording and storing input data from the thermocouples at intervals not exceeding 10 s shall be provided. The data recorder shall be capable of providing a hard copy of the data.

9.3.2 Timing device

A clock with 1 s divisions or an equivalent timing device shall be provided.

9.4 Heat and smoke release measurement

Heat release measurement and smoke measurement procedures are given in Annexes A to C. Depending on the use of the test results, two options are available to perform the heat and smoke release measurements. The selected option shall be clearly stated in the test report.

9.4.1 Method 1

The sandwich panel building construction is connected to the hood system as described in ISO 9705. Using this option, only smoke and heat release coming out of the door opening will contribute to the measurements. Flaming and smoke coming out of the external joints of the structure are not included in this measurement. The measurement values give information about hazards a) and b) (see Clause 4). Any flaming observed for more than 10 s through the joints should be recorded.

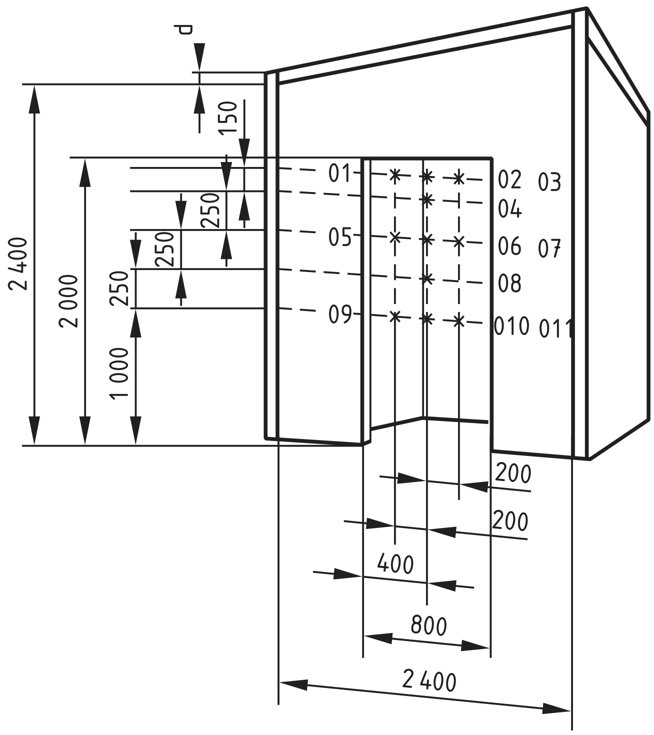
NOTE When smoke and flames escape through the joints, the heat and smoke release measurements are no longer accurate for the whole system as the smoke gases are not captured by the hood.

9.4.2 Method 2

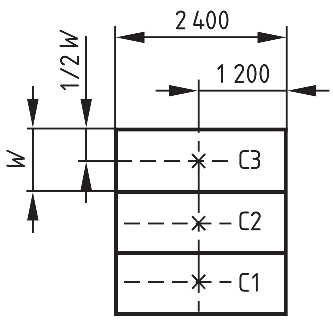
The sandwich panel building construction is placed under an enlarged hood and duct system (method 2a, see Figure 6). Alternatively, it should be placed in a ventilated enclosure (method 2b, see Figure 7) with an opening towards an enlarged hood and duct system. The walls and a ceiling of the enclosure should be at least 0,5 m from the outer surface of the sandwich panel building construction and built in such a way that feedback from these surfaces is not significant. In methods 2a and 2b, the enclosure should collect all the smoke and hot gases coming from the joints of the sandwich panel systems and the door opening of the construction. The enclosure shall be built in such a way that there is no feedback influence on the fire behaviour of the sandwich panel building construction, and an observation of the fire process, and also of flaming through joints, should be possible. In methods 2a and 2b, a calibration run shall be performed according to the procedure given in A.3.1; HRR calibration inside the enclosure shall be performed showing that at least 95 % of combustion products are captured by the enclosure and led into the hood (see Figure 6 and 7). Any flaming observed for more than 10 s through the joints should be recorded.

NOTE In both methods (1 and 2), the laboratory can end the test if dangerous conditions occur which can endanger the safety of the personnel and/or the laboratory.

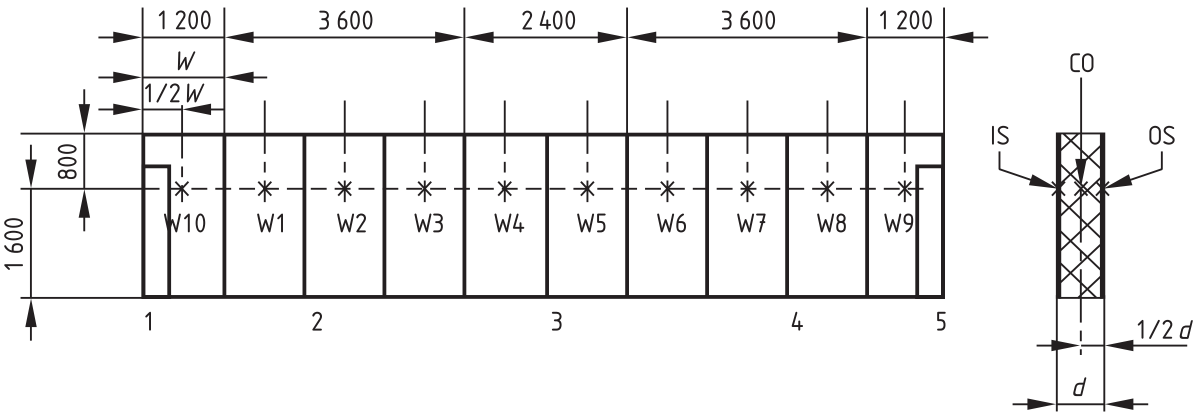
Dimensions in millimetres



a) Door opening



b) Ceiling



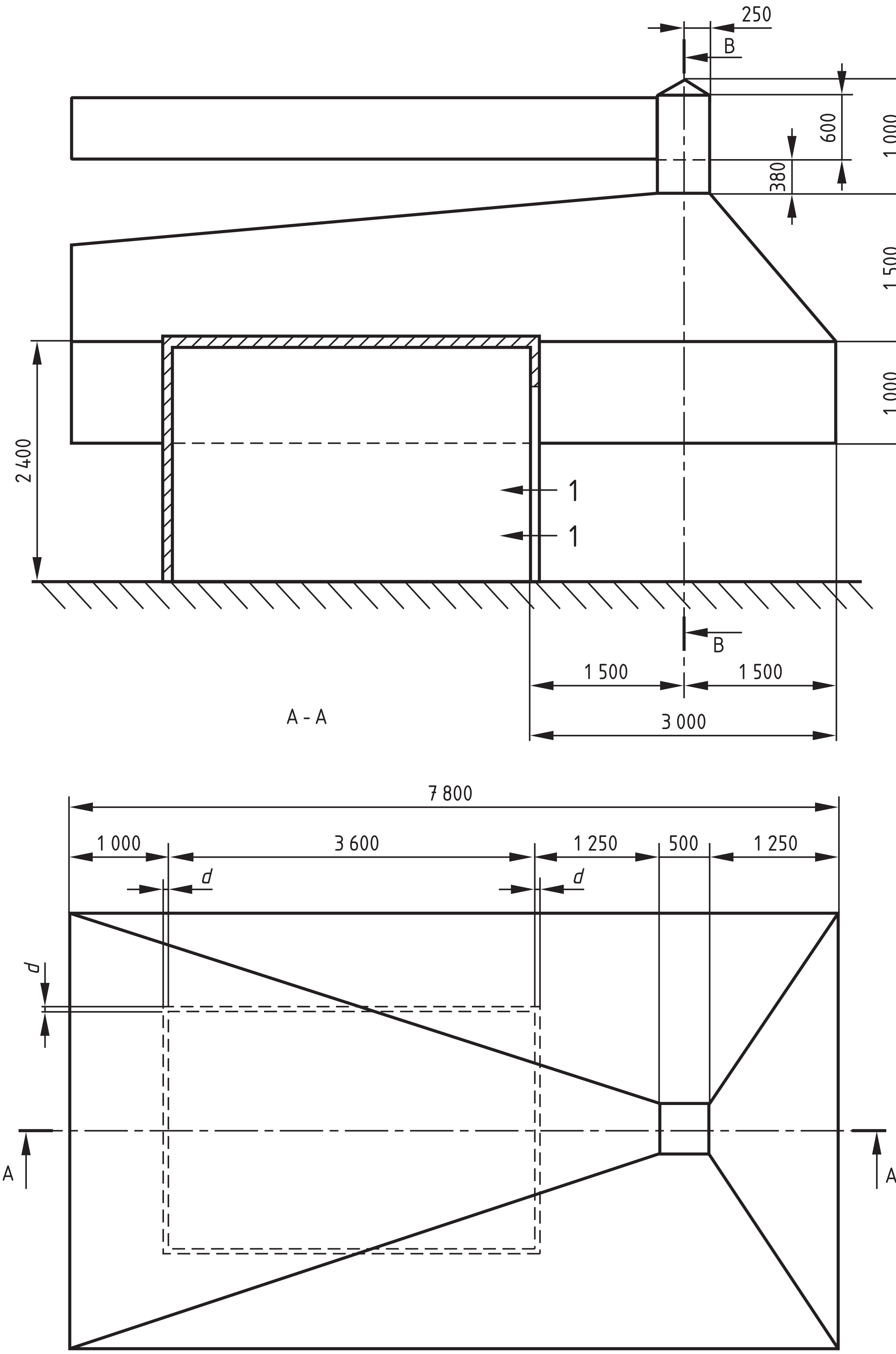
c) Walls

Key

1 wall with door
2 left wall
3 back wall
4 right wall
5 wall with door
O opening (1 to 11)
C ceiling panel (inside, core outside)
w width of the panel
W wall panel (inside, core outside)
IS surface at the inside of the room
CO core
OS surface at the outside of the room
d thickness of the panel

Figure 5 — Thermocouple distribution

Dimensions in millimetres



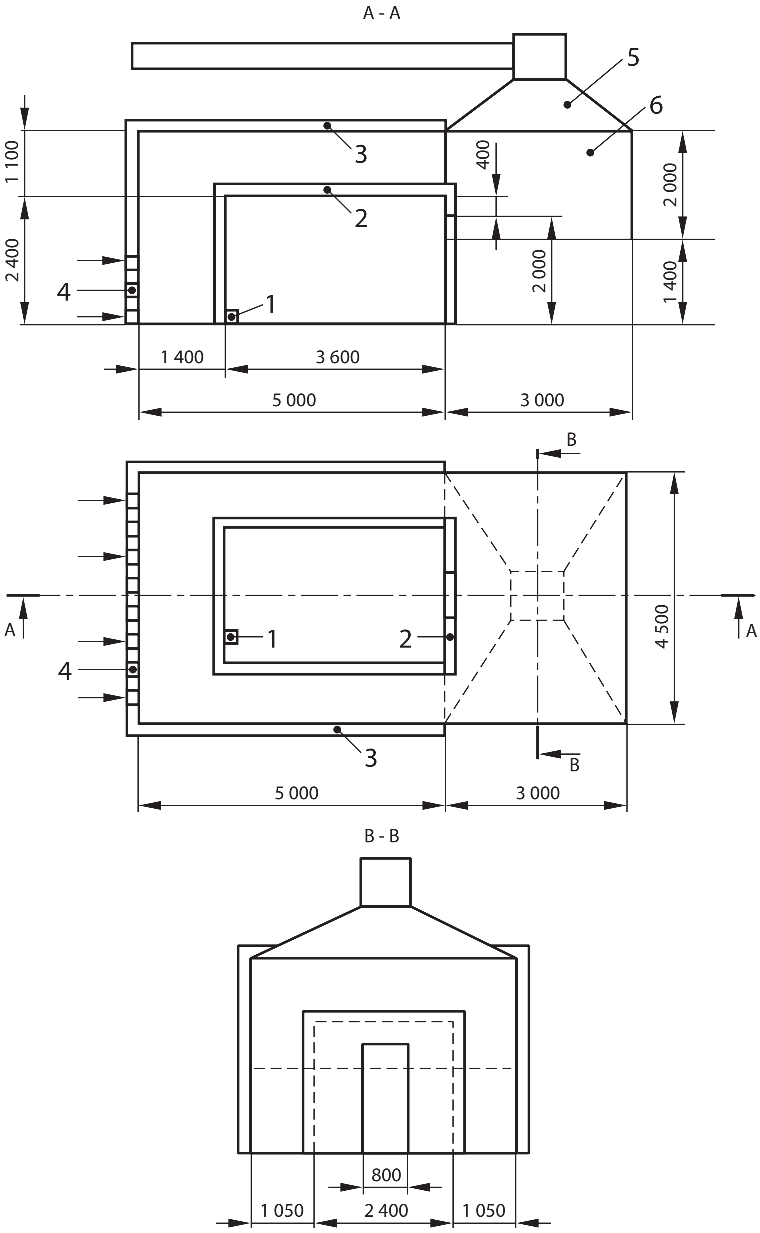
Key

d thickness of panel

1 air

Figure 6 — Example of an enlarged hood (method 2a)

Dimensions in millimetres



Key

1	burner	4	ventilation opening
2	test specimen	5	extract hood
3	enclosure	6	steel smoke curtains

Figure 7 — Example of a ventilated enclosure with an enlarged hood (method 2b)

10 Test procedure

10.1 Initial conditions

10.1.1 The temperature in the test facility at the start of the test shall be between 10 °C and 30 °C.

10.1.2 The horizontal wind speed measured at a horizontal distance of 1 m from the centre of the doorway shall not exceed 1,75 m·s−1.

10.1.3 The burner shall be in contact with the corner wall. The surface area of the burner opening shall be clean. If there is a structural framework member such as a column direct in the corner, then the burner has to be placed at the nearest joint from the corner on the back wall but not less than 300 mm.

10.1.4 The test setup shall be photographed or video recorded before testing.

10.2 Procedure

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

10.2.2 Adjust the burner to the required output levels within 10 s of ignition of the burner (see Figure 8). Adjust the exhaust capacity so that all combustion products are collected.

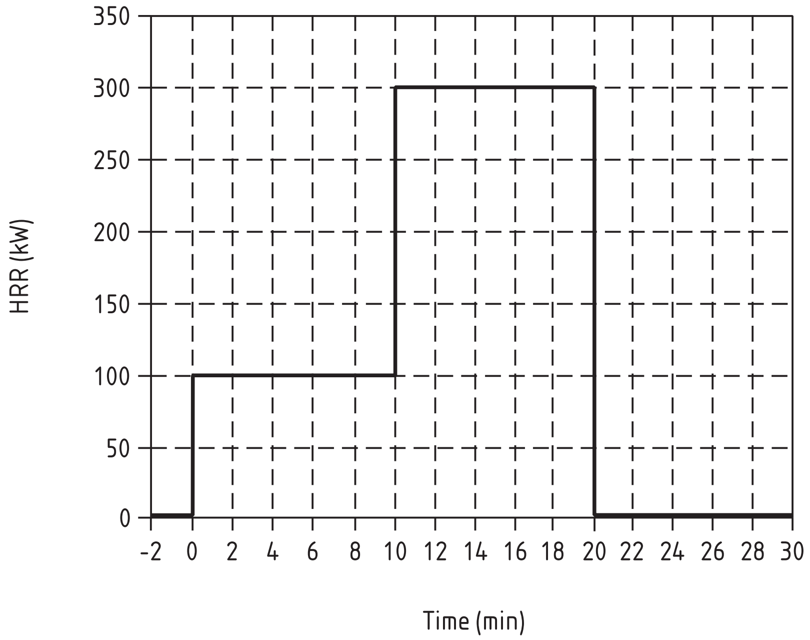


Figure 8 — Burner heat output programme

10.2.3 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.

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

a) ignition of the specimen;

b) the spread of flame on the surface, internal or external, of the panels (if any);

c) openings, cracks, damage or gaps appearing in the specimen;

d) opening joints and flaming from joints;

e) delamination, falling debris, flaming droplets;

f) smoke or flames outside of the room through joints;

g) smoke intensity and colour (visual);

h) indications of flame spread through core of specimen i.e. discoloration of facing panels;

i) flames emerging through the doorway;

j) flashover;

k) collapse of the structure.

10.2.5 End the test if flashover occurs, or after 30 min, whichever occurs first. The test may need to be terminated earlier if structural collapse or other conditions develop that are potentially dangerous to the laboratory staff. Continue observation until signs of visual combustion have ceased.

10.2.6 Note the extent of damage of the product after the test. Damage shall be clearly reported e.g. the extent of delaminations and/or joint openings, extent and depth of char (and possibly scorching), cracking, shrinkage, etc.

10.2.7 Record any other unusual behaviour.

11 Precision data

The first round robin was organized by FILK (KFPA), Korea and was performed at four laboratories in South Korea, Australia, and Sweden using this part of ISO 13784. Specimens were provided and distributed by FILK (KFPA) of South Korea. The specimen tested was a sandwich panel consisting of steel-cladded insulation material. The insulation material was a combination of a plastic foam and glass wool. The total thickness was 50 mm. The results are given in Tables 1 to 4 and focus on the maximum heat release rate (Max HRR) and total heat release rate (THR) as no flashover occurred in all tests.

According to ISO 5725-2 Grubbs variance test (Table 2) and Dixon's Q test (Table 3), there are no outliers. It should be taken into account that only one material was tested once in each lab.

Table 1 — Results for maximum HRR and THR

	Lab 1	Lab 2	Lab 3	Lab 4
THR (MJ) (0 min to approximately 20 min)	259	233	244.	279
Max HRR (kW) (0 min to approximately 20 min)	419	425	416	430
Time (s)	790	810	886	795
FIGRA (kW/s)	0,150	0,154	0,131	0,164

Table 2 — ISO 5725-2 Grubbs test for equal distribution

Min HRR	416	Min THR	233
Max HRR	430	Max THR	279
Average HRR	422	Average THR	254
Standard deviation	6,4	Standard deviation	20
G min	1,025	G min	1,048
G max	1,197	G max	1,260
G (*n* = 4, 0,05p)	1,481	G (*n* = 4, 0,05p)	1,481

Table 3 — Dixon's Q test for outlier detection

Qcrit (95 % C.L., *n* = 4)	0,829	Qcrit (95 % C.L., *n* = 4)	0,829
Qexp (HRR max = 430,0)	0,350	Qexp (THR max = 279,35)	0,427
Qexp (HRR min = 415,8)	0,197	Qexp (THR min = 232,81)	0,243
Outlier (if Qexp > Qcrit)	No outlier	Outlier (if Qexp > Qcrit)	No outlier

Table 4 — Results for 95 % confidence interval

Mean of HRR	422	Mean of THR	254
Standard deviation	6,4	Standard deviation	20
df (*n* = 4)	3	df (*n* = 4)	3
Confidence level	95 % (significance 0,05p)	Confidence level	95 % (significance 0,05p)
t distribution value	3,182	t distribution value	3,182
95 % Confidence Interval	±10,16	95 % Confidence Interval	±37,00

12 Test report

The test report shall contain the following information:

a) the name and the address of the testing laboratory;

b) the date and the identification number of the report;

c) the name and the address of the sponsor;

d) the purpose of the test;

e) the method of sampling;

f) the name and the address of the manufacturer or supplier of the product;

g) the name or other identification marks and description of the product;

h) construction and installation details of the product:

   1) drawings;

   2) descriptions;

   3) assembly instructions;

   4) specification of included materials;

   5) details of the joints and fixings;

i) the date of supply of the product;

j) the date of test;

k) the test method used (free-standing room or frame-supported room construction) and a reference to this part of ISO 13784 (i.e. ISO 13784-1:2014);

l) conditioning of the test specimen, environmental data during the test (temperature, atmospheric pressure, relative humidity, etc.);

m) deviations from the test method, if any;

n) test results:

   1) temperatures within the core of the sandwich panel as a function of time, in a graph;

   2) maximum temperatures;

   3) illustration (e.g. by pictures) and description of the fire damage;

   4) observations during and after the test;

   5) time/volume flow in the exhaust duct;

   6) time/rate of total heat release and time/heat release from the burner (mention type of method used, i.e. 1, 2a, or 2b);

   7) time/production of carbon monoxide at reference temperature and pressure;

   8) time/production of carbon dioxide at reference temperature and pressure;

   9) time/production of light-obscuring smoke at actual duct flow temperature;

o) the designation of the product according to criteria expressed in official standards or regulations, where appropriate.

Annex A
(normative)

Heat and smoke release measurement procedure according to ISO 9705

A.1 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 door opening during a test are collected. In accordance with Method 1, the sandwich panel building construction is connected to the ISO 9705 hood system. The system shall not disturb the fire-induced flow in the doorway. The exhaust capacity shall be at least 3,5 $m^3 \cdot s^{-1}$ at normal pressure and a temperature of 25 °C.

NOTE An example of the design of a hood and an exhaust duct is given in ISO 9705.

A.2 Instrumentation in the exhaust duct

This clause specifies minimum requirements for instrumentation in the exhaust duct.

A.2.1 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.

A.2.2 Gas analysis

A.2.2.1 Sampling line

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.

A.2.2.2 Oxygen

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

A.2.2.3 Carbon monoxide and carbon dioxide

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

A.2.3 Optical density

A.2.3.1 General

The optical density of the smoke is determined by measuring the light obscuration with an incandescent lamp photometer. An alternative smoke measuring system using a laser photometer is described in

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

A.2.3.2 Incandescent lamp photometer

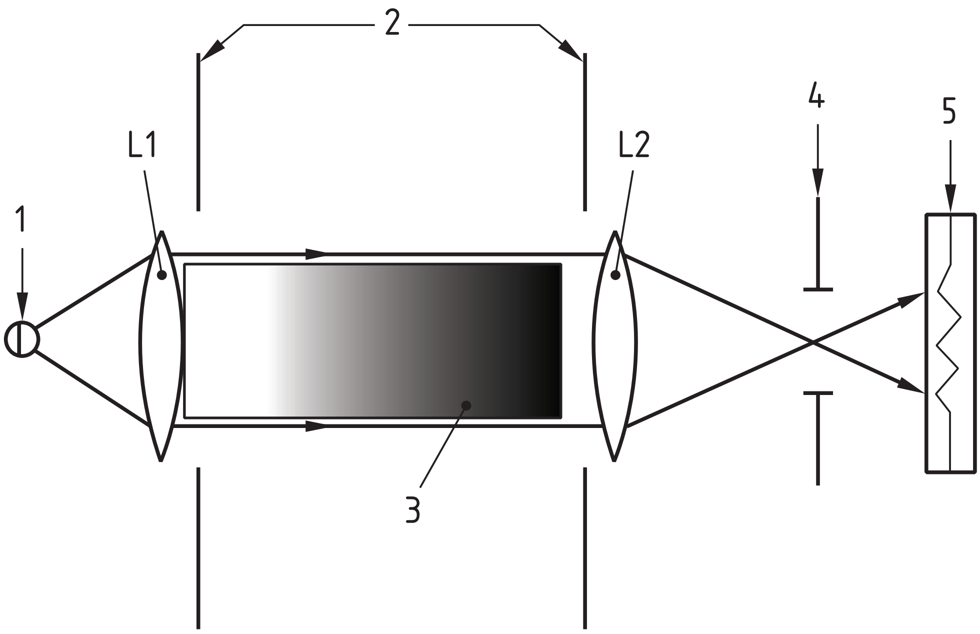
The lamp shall be of the incandescent filament type and shall operate at a colour temperature of (2 900 ± 100) K. The lamp shall be supplied with stabilized direct current, stable within ±0,2 % (including temperature, short-term and long-term stability). The lens system shall align the light to a parallel beam with a diameter D of at least 20 mm. The aperture shall be placed at the focus of the lens L_2 as shown in Figure A.1 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.

The detector shall have a spectrally distributed responsivity in agreement 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 % over an output range of at least 3,5 decades.

A.2.3.3 Location

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



Key

1	light source	4	aperture
2	path source	5	photo detector
3	smoke	L1, L2	lenses

Figure A.1 — White light optical system

1) Commission Internationale d'Éclairage.

A.3 System performance

A.3.1 Calibration

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

NOTE 1 Formulae for calculations are given in Annex C.

NOTE 2 HRR calibration at higher levels than 300 kW can be performed to decrease the measuring uncertainty. This can be performed by gas burners or by liquid pool fires.

The calibration shall be performed with the burner heat outputs given in Table A.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 heat release rate 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.

Table A.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

A.3.2 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 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.

The system shall be checked at various volume flow rates shall be checked by increasing the volume flow in the exhaust duct in four equal steps, starting from 2 $m^3 \cdot s^{-1}$ (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 heat release rate, calculated over 1 min, shall be not more than 10 % of the actual heat output from the burner.

Annex B
(normative)

Heat release and smoke release measurement procedure using method 2

B.1 Enclosure

The enclosure shall have a capacity and be designed in such a way that at least 95 % of all the combustion products which are leaving the fire room through the joints in the walls and the ceiling/roof and through the doorway during a test are collected. This “enlarged hood” or enclosure can be connected to an exhaust duct system in accordance with ISO 9705. The bottom part of the enclosure shall be open on all sides to have free access of fresh air into the enclosure. The minimal height of the opening is 1,5 m. The enclosure or enlarged hood shall be built with non-combustible material (e.g. lightweight construction with non-combustible boards). An example of a possible enclosure and enlarged hood is given in Figures 6 and 7.

B.2 Hood and exhaust duct

The hood and the exhaust duct shall be designed using the rules given in ISO 9705.

NOTE Either the example of hood and exhaust duct given in ISO 9705 can be used or a larger hood with large diameter can be used if not more than 95 % of the smoke gases are captured. Examples are given in Figures 6 and 7.

B.3 Instrumentation in the exhaust duct

The instrumentation in the exhaust duct shall also be in accordance with ISO 9705.

Annex C
(normative)

Calculations

C.1 Volume flow

C.1.1 Calculation of volume flow

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 by Formula (C.1).

$$\dot{V}_{298} = (Ak_t / k_p) \times \frac{1}{\rho_{298}} \times (2\Delta p T_o \rho_o / T_s)^{1/2} = 22{,}4(Ak_t / k_p)(\Delta p / T_s)^{1/2} \quad \text{(C.1)}$$

where

T_s is the gas temperature in the exhaust duct, expressed in kelvins (K);

T_o is equal to 273,15 K;

Δp is the pressure difference measured by the bi-directional probe, expressed in pascals (Pa);

ρ_{298} is the air density at 25 °C and atmospheric pressure, expressed in kilograms per cubic metre ($kg{\cdot}m^{-3}$);

ρ_o is the air density at 0 °C and 0,1 MPa, expressed in kilograms per cubic metre ($kg{\cdot}m^{-3}$);

A is the cross-sectional area of exhaust duct, expressed in square metres (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 bidirectional probe, taken as constant and equal to 1,08.

Formula (C.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 %. A procedure for determining k_t is given in ISO 3966:2008. For several flows and/or temperature the procedure shall be repeated and an overall average can be determined.

The k_t factor shall be measured after set up, maintenance, repair, or replacement of the bi-directional probe or other major components of the exhaust system and at least every year. The measurements are made using a pitot tube or a hot wire anemometer and both specifications as well as a procedure are given below.

C.1.2 Measurement specifications for the determination of k_t factor

a) The equipment shall be run on a damping setting that is sufficiently high to obtain a steady reading.

b) When inserted into the exhaust duct the measurement probe shall be mechanically fixed into position rather than held by hand. The horizontal or vertical positioning of the probe (whichever is required) and the right angles to the duct shall be checked.

c) The entry ports not used by the anemometer shall be closed.

d) The gas velocity shall be measured 20 times in every measurement position, 10 times when traversing outwards from the centre, and 10 times when traversing inwards to the centre.

e) The measurement positions on a single radius are at the following distances from the wall, expressed as a fraction of the radius (taken from ISO 3966:2008): 0,038; 0,153; 0,305; 0,434; 0,722; 1,000 (centre). The positions are indicated in Figure C.1 for a duct diameter of 600 mm.

NOTE For a duct diameter of 400 mm, these positions are (in millimetres from the centre): 0 mm; 55,6 mm; 113,2 mm; 139 mm; 169,4 mm; 192,4 mm.

Dimensions in millimetres

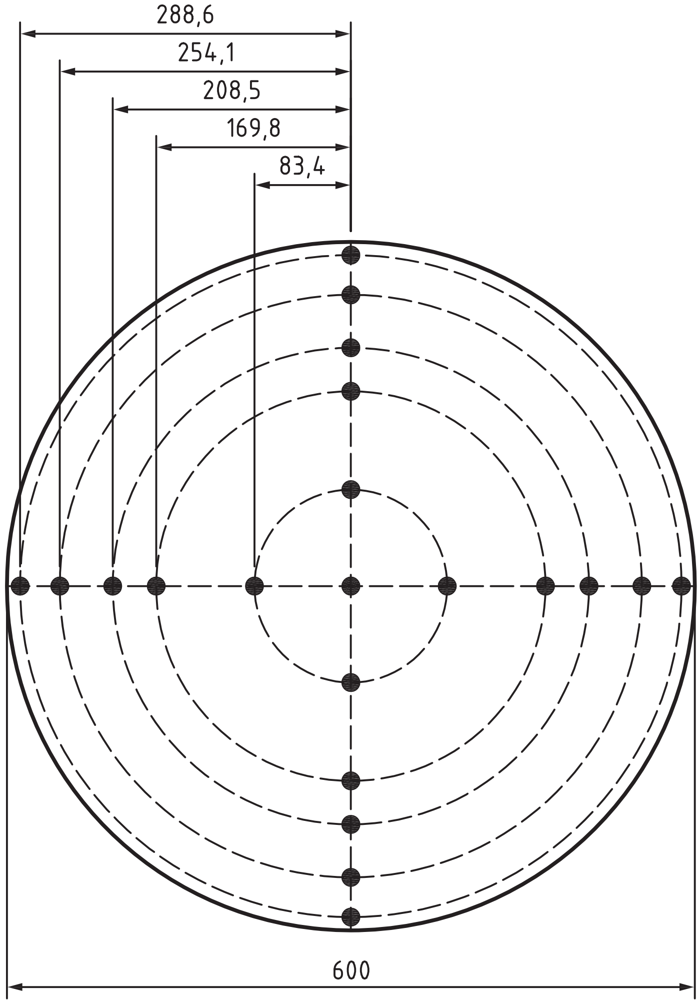


Figure C.1 — Section of the exhaust duct — Positions for measurement of the gas velocity

C.1.3 Actions

Perform the following steps.

a) Set the volume flow of the exhaust to the design value used during testing.

b) Record the temperatures in the exhaust duct and the ambient temperature for at least 300 s.

c) Measure the gas velocity in all measurement positions, six positions per entry port.

d) Calculate the gas velocity at all measurement positions as the mean of the 20 values measured, giving v_c for the centre position and five v_n values for the five other positions for each entry port.

NOTE As a result, the velocity profile is measured and calculated both horizontally and vertically over the full diameter.

C.1.4 Calculation of k_t

For a given radius, the mean velocity at a radius n is given by v_N, which is the mean of the four v_n values measured. The velocity at the centre position is given by v_C, which is the mean of the four v_c values measured. The profile factor k_t is then:

$$k_t = \frac{1}{5}\sum \frac{v_N}{v_C} \quad \text{(C.2)}$$

C.1.5 Measurement report

The measurement report shall include the following information:

a) the velocity profile based on the mean v_n at five radii and v_c, separately for each entry port (a vertical and a horizontal cross section);

b) the values of four v_n's, four v_c's, v_N, v_C, and the resulting k_t.

C.2 Heat release rate, calibration, and test process

C.2.1 During the calibration process, heat release rate from the ignition source, $\dot{q}_b$, expressed in kilowatts, is calculated from the consumption of propane gas from Formula (C.3).

$$\dot{q}_b = \dot{m}_b \, \Delta h_{c,eff} \quad \text{(C.3)}$$

where

$\dot{m}_b$ is the mass flow rate of propane to the burner, expressed in grams per second (g·s^{-1});

$\Delta h_{c,eff}$ is the effective lower heat combustion of propane, expressed in kilojoules per gram (kJ·g^{-1}).

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

C.2.2 Heat release rate from a tested product $\dot{q}$, expressed in kilowatts, is calculated from Formula (C.4).

$$\dot{q} = E^1 \dot{V}_{298} x^a_{O_2} \left(\frac{\phi}{\phi(\alpha - 1) + 1} \right) - \frac{E^1}{E_{C_3H_8}} \dot{q}_b \quad \text{(C.4)}$$

with ϕ , the oxygen depletion factor, given by

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

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

$$x^a_{O_2} = x^0_{O_2}(1 - x^a_{H_2O}) \quad \text{(C.6)}$$

where

E is the heat release per volume of oxygen consumed, expressed in kilojoules per cubic metre ($kJ \cdot m^{-3}$);

E^1 is equal to $17,2 \times 10^3$ $kJ \cdot m^{-3}$ (25 °C) for combustion of tested product;

$E_{C_3H_8}$ is equal to $16,8 \times 10^3$ $kJ \cdot m^{-3}$ (25 °C) for combustion of propane;

$\dot{V}_{298}$ is the volume flow rate of gas in the exhaust duct at atmospheric pressure and 25 °C calculated as specified in Formula (C.1), expressed in cubic metres per second ($m^3 \cdot s^{-1}$);

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);

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

NOTE $x^a_{O_2}$ can be measured prior to the test without trapping of water.

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

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

$x^0_{CO_2}$ is the carbon dioxide analyser reading during test, expressed as a mole fraction;

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

$x^a_{H_2O}$ is the ambient mole fraction of water vapour.

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., and can be corrected by making measurements of the burner only when placed in the room and then subtracting the time-dependent response that was measured.

C.2.3 Formulae (C.3) to (C.6) 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 $kW \cdot m^{-3}$ 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.

These accumulated errors should normally be less than 10 %.

C.3 Combustion gases

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

$$\dot{V}_{gas} = \dot{V}_{298}\, x_i \quad \text{(C.7)}$$

$$V_{gas} = \int_0^t \dot{V}_{gas} dt \quad \text{(C.8)}$$

where

$\dot{V}_{298}$ is the rate of volume flow in exhaust duct, expressed in cubic metres per second at 0,1 MPa and 25 °C ($m^3 \cdot s^{-1}$);

x_i is the mole fraction of specified gas in the analyser;

t is the time from ignition, expressed in seconds (s).

C.4 Light obscuration

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

$$k = \frac{1}{L} \ln\left[\frac{I_o}{I}\right] \quad \text{(C.9)}$$

where

I_o 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;

I 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, expressed in metres (m).

The instantaneous rate of light-obscuring smoke, R_{inst}, expressed in square metres per second ($m^2 \cdot s^{-1}$), and the total amount of smoke, R_{tot}, expressed in square metres (m^2) are then calculated from

$$R_{inst} = k\dot{V}_s \quad \text{(C.10)}$$

$$R_{\text{tot}} = \int_0^t k \dot{V}_s \, dt \tag{C.11}$$

where

$\dot{V}_s$ is the volume flow in the exhaust duct at actual duct gas temperature, expressed in cubic metres per second ($m^3 \cdot s^{-1}$);

t is the time from ignition, expressed in seconds (s).

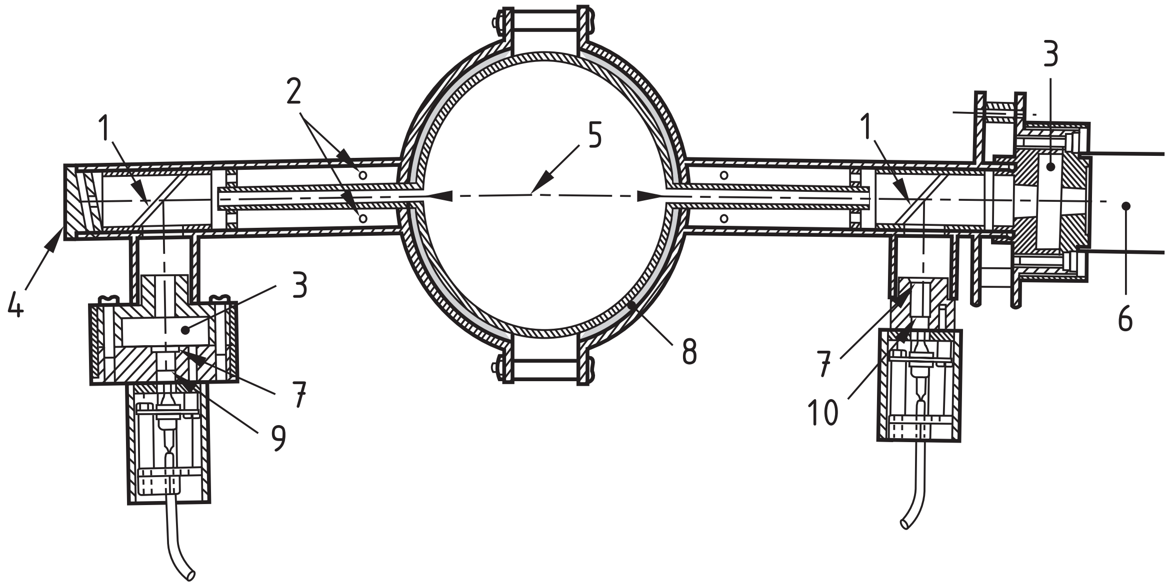
Annex D
(informative)

Laser smoke photometer

D.1 Photometer equipment

A laser 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 D.1 shows the general arrangements of a laser 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.



Key

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

Figure D.1 — Smoke obscuration measuring system

Bibliography

[1] ISO 3966:2008, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

[2] ISO 13784-2:2002, *Reaction-to-fire tests for sandwich panel building systems — Part 2: Test method for large rooms*

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