Rwanda Standards Board

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1.2

Reaction to fire tests for building products — Building products excluding floorings exposed to the thermal attack by a single burning item

ICS 13.220.50; 91.060.01; 91.100.01

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Foreword

Rwanda Standardsarepreparedby Technical Committees and approved by Rwanda Standards Board (RSB) Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by members of RSB Board of Directors for publication and gazettment as Rwanda Standards.

DRS540 was prepared by Technical Committee RSB/TC 9, *Civil engineering and Building materials.*

In the preparation of this standard, reference was made to the following standard:

BS EN 13823:2020: Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item

The assistance derived from the above source is hereby acknowledged with thanks.

Committee membership

The following organizations were represented on the Technical Committee on *Civil engineering and Building materials*(RSB/TC 9) in the preparation of this standard.

A+Construction Group Ltd

Africeramics Ltd

Consultants Engineers Group (CEG) Ltd

D&D Resources Ltd

Dutureheza Ltd

Enabel Rwanda

Greenpack Africa Ltd

Integrated Polytechnic Regional Centre (IPRC) - Musanze

Mass Design Group

NP Construction Company (NPCC) Ltd

Road Transport Development Agency (RTDA)

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Rwanda Quarries Association (RQA)

SKAT Consult

St Joseph Engineering Company (SJEC) Ltd

Standards for Sustainability (SfS)

Stonecraft Industries Ltd

University of Rwanda - College of Science and Technology (UR - CST)

Rwanda Standards Board (RSB) – Secretariat

Introduction

The classification of the reaction to fire performance of construction products established by Delegated Regulation (EU) 2016/364 defines the reaction to fire classes for building products excluding floorings. The relevant test methods for determining the reaction to fire are being prepared by CEN/TC 127.

Safety warning

The attention of all persons concerned with managing and carrying out the tests described in this document is drawn to the fact that fire testing can be hazardous and that toxic and/or harmful smoke and gases can be produced during the test.

An assessment of all potential hazards and risks to health should be made and safety precautions should be identified and provided. Smoke and gases should be removed from the workplace. Written safety instructions should be issued. Appropriate training should be given to relevant personnel. Laboratory personnel should ensure that they follow written safety instructions at all times.

Special precautions are required for the propane gas supply system.

- The equipment, for example tubes, couplings, flow meters, should be approved for propane.

- 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. The pilot flames can be ignited directly by an operator in the test room; however, no one should be present in the test room during ignition of a burner.

- It should be possible to operate the switch between auxiliary and main (primary) burner and the preceding main valve (to open or stop the propane supply) from outside the test room.

Special precautions are required for the extinction of burning specimens.

When the extinction is carried out because of intensive combustion of the specimens, it is recommended that a second operator is ready to intervene. Means for extinguishing should be available (e.g. since the heat output during intensive combustion can damage the apparatus).

Reaction to fire tests for building products — Building products excluding floorings exposed to the thermal attack by a single burning item

2 Scope

This Draft Rwanda standard specifies a method of test for determining the reaction to fire performance of construction products excluding floorings when exposed to thermal attack by a single burning item (SBI).The calculation procedures are given in Annex A. Information on the precision of the test method is given in Annex B. The calibration procedures are given in Annexes C and D, of which Annex C is a normative annex.

Comment [SN1]: Cant we change this and remove this part since it refer to the other standard

NOTE This document has been developed to determine the reaction to fire performance of essentially flat products. The treatment of some families of products, e.g. linear products (pipes, ducts, cables etc.), can need special rules.

3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

DRS 547 , Fire classification of construction products and building elements - Classification using data from reaction to fire tests

Comment [SN2]: Was replaced by DRS 547

ISO 13943:2017, Fire safety — Vocabulary

4 Terms and definitions

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

3.1

backing board

calcium silicate panel used to back the specimen that can be placed directly against a freestanding test specimen or at a distance from it

3.2

specimen

piece of a product, which is to be tested

Note 1 to entry: This can include the mounting technique used in its end-use application. This also can include an air gap and/or a substrate where appropriate.

3.3

substrate

product which is used immediately beneath the product about which information is required

3.4

THR600s

total heat release from the specimen in the first 600 s of exposure to the main (primary) burner flames

3.5

LFS

lateral flame spread on the long specimen wing

Note 1 to entry: The LFS is defined in more detail in 8.3.3.

3.6

TSP_{600s}

total smoke production from the specimen in the first 600 s of exposure to the main (primary) burner flames

3.7

FIGRA0,2 MJ

fire growth rate index

maximum of the quotient of heat release rate from the specimen and the time of its occurrence using a THR-threshold of 0,2 MJ

Note 1 to entry: The FIGRA0,2 MJ is described in more detail in A.5.3.

3.8

FIGRA0,4 MJ

fire growth rate index

maximum of the quotient of heat release rate from the specimen and the time of its occurrence using a THR threshold of 0,4 MJ

Note 1 to entry: The FIGRA0,4 MJ is described in more detail in A.5.3.

3.9

SMOGRA

smoke growth rate index

maximum of the quotient of smoke production rate from the specimen and the time of its occurrence

Note 1 to entry: The SMOGRA is described in more detail in A.6.3.

3.10

sustained flaming

persistence of flame on or over a surface for a minimum period of time

[SOURCE: ISO 13943:2017]

5 Test facility

5.1 General

The SBI test facility shall consist of a test room, the test apparatus (trolley, frame, burners, hood, collector and ducting), the smoke exhaust system and general measuring equipment. These components are specified in 4.2 to 4.7. Design drawings are given in Annex G. Dimensions given in the drawings are nominal unless tolerances are given in the text.

The air supply to the test room entering below the trolley should be fresh, uncontaminated air.

5.2 Test room

4.2.1 The test room shall have an inner height of (2,4 ± 0,05) m and an inner floor area of (3,0 ± 0,05) m in both directions. The walls shall be made of stone type building blocks (e.g. cellular concrete), gypsum boards, calcium silicate boards or other boards classified as class A1 or A2.

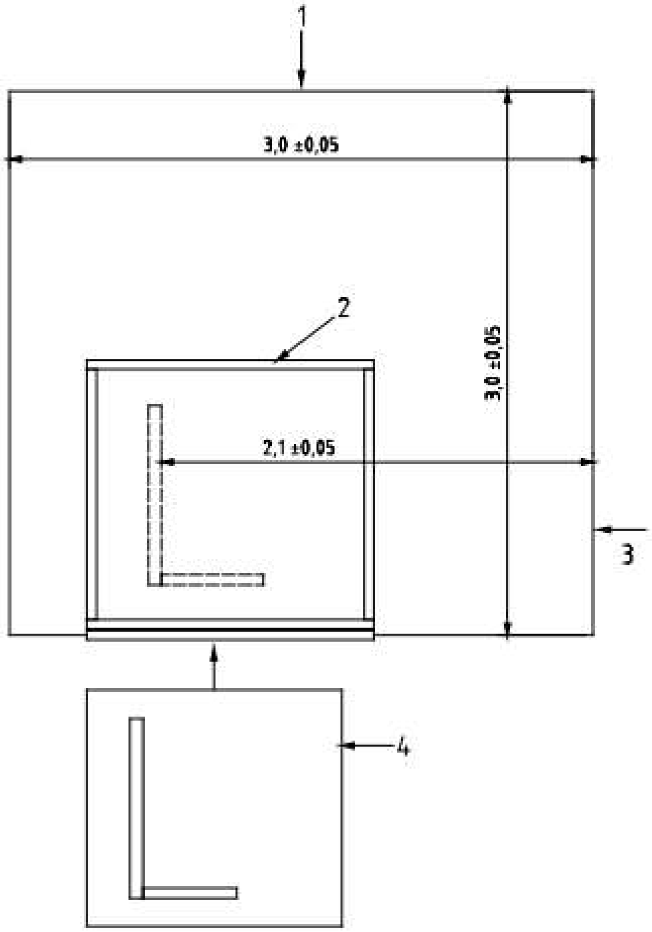
4.2.2 One wall of the test room shall have an opening to insert the trolley from the surrounding laboratory into the test room. The opening shall be at least 1 470 mm wide and 2 450 mm high (dimensions of the frame). Windows shall be placed in the two walls facing the front side of the two perpendicular specimen planes. To be able to handle the SBI apparatus and the specimen when the trolley is in place, an additional door is needed.

4.2.3 With the trolley in place in the test room, the distance between the long wing specimen surface touching the U-profile and the wall of the test room shall be (2,1 ± 0,05) m. This distance shall be measured perpendicularly to the wall facing the long wing. The areas of the openings in the test room, excluding the air inlet at the bottom of the trolley and the smoke exhaust opening in the hood, shall not exceed a total of 0,05 m2.

4.2.4 Both left-orientated arrangements, as shown in Figure 1, and right-orientated arrangements (the trolley shown in Figure 1 mirrored around a vertical line) are allowed. To be able to remove side plates of the hood without removing the collector, attention should be paid to the connection between the frame of the SBI apparatus and the ceiling of the room. It should be possible to move the side plate outwards at the bottom.

NOTE The relative position of the frame in the test room depends on the details of the connection between room and frame.

Dimensions in metres



Key

1 visual observation

2 fixed frame

3 visual observation (left orientated specimen)

4 trolley (with left orientated specimen)

NOTE Both left orientated and right oriented specimens are acceptable. For right orientated specimens the figure is mirrored around a vertical line.

Figure 1 — Top view of the SBI test room design (schematic drawing)

5.3 Materials

Commercial propane, of minimum purity 95 %.

5.4 Test apparatus

NOTE See Figures E.1 to E.35.

4.4.1Trolley, on which two perpendicular specimen parts are placed, with a sandbox burner at the bottom of the vertical corner.

The trolley is put in place with its back side closing the opening in the wall of the test room; the air inlet under the floor of the trolley is provided with perforated plates (open area to total area 40 % to 60 %; perforation diameter 8 mm to 12 mm) to produce an evenly distributed flow along the floor of the test room.

Using a spirit level placed in the gully, periodically check the level of the L profile (behind the burner) and the C profile (in front of the specimen) to ensure they are horizontal. This will ensure that any material which melts and flows from the specimen will remain in the gulley during the test.

In addition, periodically measure the level of the platform in front of the burner to ensure this is also horizontal.

4.4.2Fixed frame, in which the trolley is pushed and which supports the hood; a second burner is fixed to the frame.

4.4.3Hood, on top of the frame, which collects the combustion gases.

4.4.4Collector, on top of the hood with baffles and a horizontal outlet for the exhaust duct.

4.4.5Exhaust duct, circular tube of inner diameter (315 ± 5) mm, and insulated with 50 mm high temperature resistant mineral wool, with the following parts (in flow direction):

- connection to the collector;
- ducting, of length 500 mm with four thermocouple mountings (for optional temperature measurements) at adistance of at least 400 mm from the collector (drawing E25 part A; optional);
- ducting, of length 1 000 mm (drawing E25 part B; optional);
- two 90° bends, (radius of curvature of axis 400 mm) (drawing E25 part C and D; optional); connection to the collector with an optional J-shaped bend;
- ducting, of length 1 625 mm with guide vanes and an orifice; guide vane length 630 mm closest to the collector at a minimum distance of 50 mm; directly behind the guide vanes a (2,0 ± 0,5) mm thick circular orifice with inner opening diameter 265 mm and an outer diameter of 314 mm (drawing E25 part E; mandatory);

- ducting, of length 2 155 mm with mountings for pressure-probe, four thermocouples, gassampling probeand white light extinction system; this section is called the “general measurement section” (drawing E25 part F; mandatory);

- ducting, of length 500 mm (drawing E25 part G; mandatory);

- connection to exhaust.

Attention should be paid to the fixing of the measuring duct. The total mass excluding probes, etc. is about 250kg.

4.4.6 Two identical sandbox burners (see Figure E.9), one in the bottom plate of the trolley (the “main (primary) burner”), one fixed to a post of the frame (the “auxiliary (secondary) burner”), with the following specifications:

a) Shape: right angled triangle (top view) with two equal sides of 250 mm, height 80 mm, bottom closed except for a 12,5 mm pipe socket at the gravitational centre, top open. A rightangled triangular perforated plate shall be positioned in the burner at a height of 10 mm above the bottom. Metal gauze with a maximum mesh size of 2 mm shall be positioned at heights of 12 mm and 60 mm above the bottom. All dimensions shall be within ± 2 mm.

b) Material: box made of 1,5 mm stainless steel, filled from bottom to top with, successively, a 10 mm void, a layer of pebbles within a size distribution of 4 mm to 8 mm up to a height of 60 mm, and a top layer of sand within a size distribution of 2 mm to 4 mm up to a height of 80 mm. The metal gauze is used to stabilize the two layers and prevent the pebbles from entering the gas pipe socket. The pebbles and sand used shall be rounded (river) stones, not broken ones.

c) Position of main (primary) burner: mounted in the tray (see Figures E.9 and E.19) and connected to the U-profile at the bottom of the specimen position. The top edge of the main (primary) burner shall be (25 ± 2) mm above the top edge of the U-profile.

d) Position of auxiliary (secondary) burner: fixed to the post of the frame opposite to the specimen corner, with the top of the burner at a height of (1 450 ± 5) mm from the floor of the test room (1 000 mm vertical distance to the hood), its diagonal parallel and nearest to the hypotenuse of the main (primary) burner.

e) The main (primary) burner is connected to U-profiles at the long and the short wing specimen position (see Figure E.18, part 10). In both U-profiles a blanking plate (see Figure E.19) is placed with its top at the same height as the top of the U-profile and at 0,3 m from the corner line between the mounted specimen wings (at the border of the burner zone, see 8.3.4).

f) The main (primary) burner shall be protected with a tilted triangular grid when previous tests on the same type of product have led to an early termination to the test due to fallen material on the sand-bed in accordance with 8.5. The grid shall have a ratio of open area to total area of at least 90 %. One side of the grid shall be placed on the hypotenuse of the burner.

The tilt angle is (45 ± 5)° with the horizontal, measured along the line from the hypotenuse midpoint to the specimen corner. See Figure E.36.

4.4.7 Shield of rectangular shape, width (370 ± 5) mm, height (550 ± 5) mm, made of calcium silicate board (specification the same as the backing boards), to protect the specimens from the heat flux of the flames of the auxiliary (secondary) burner.

It shall be fixed to the hypotenuse side of the auxiliary (secondary) burner, centred in the horizontal plane (shielding the total width of the diagonal plus (8 ± 3) mm at both sides) with the top edge (470 ± 5) mm above the top level of the auxiliary (secondary) burner.

4.4.8 Mass flow controller with a range of at least 0 g/s to 2,3 g/s and an accuracy of 1 % of the reading for the range 0,6 g/s to 2,3 g/s. The mass flow controller shall be calibrated annually.

NOTE The propane flow of 2,3 g/s corresponds to a heat release of 107 kW using the effective lower heat of combustion of propane (46 360 kJ/kg). The accuracy of 1 % is when either using air, nitrogen or propane

4.4.9 Switch, used to supply propane to either of the burners.

The switch shall prevent propane being supplied to both burners at the same time, except during burner switching time (the short period of time in which the auxiliary (secondary) burner is decreasing and the main (primary) burner is increasing in output). This burner switch response time, calculated in accordance with C.2.1, shall be between 9 and 12 s.

It shall be possible to operate the switch and the preceding main valve from outside the testing room.

4.4.10 Backing boards, used to back the specimen wings in the trolley.

The backing boards shall be high density calcium silicate boards as defined in Annex B with a thickness of (12± 3) mm. The dimensions of the backing boards shall be:

a) for the short wing: (at least 570 + thickness of the specimen) mm × (1 500 ± 5) mm;

b) for the long wing: (1 000 ± 5) mm × (1 500 ± 5) mm.

On the short wing, the backing board is wider than the specimen. The additional width shall extend at one side only.

4.4.11 Removable panel parts, to allow for additional airflow behind both specimen wings panels 22 and 25 in Figure E.20 shall be replaced by half panels, covering only the upper half of the space covered by panels 22 and 25.

The panel shall only be removed under the conditions given in 5.2.2, a).

5.5 Smoke exhaust system

4.5.1 Under test conditions, the smoke exhaust shall be capable of continuously extracting a volume flow, normalized to 298 K, of 0,50 m3/s to 0,65 m3/s.

4.5.2 The exhaust duct shall have two side ducts (circular tubes of inner diameter 45 mm) horizontally perpendicular to and at the height of the longitudinal axis of the exhaust duct (see Figures E.32 and E.33).

4.5.3 The two possible configurations of the extraction duct are given in Figure E.1. The trolley opening in the test room is at the topside in the configuration drawings. The orientation of the duct may deviate from Figure E.1 if proof is provided that this does not change the airflow over the specimen. Removal of the 180° bend in the extraction duct and replacement of the hemispherical pressure probe are acceptable, provided that it is proved that the uncertainty in flow measurement is equal or better.

NOTE Due to changes in heat output, some exhaust systems (especially those provided with local fans) can need manual or automatic readjustment during tests, to meet the requirement given in 4.5.1.

The duct should be cleaned at intervals to avoid excessive accumulation of soot.

5.6 General measurement section equipment

NOTE See Figures E.28 to E.35.

4.6.1 Three thermocouples, all of the K-type in accordance with Annex C , diameter in the range 0,5 mm to 1 mm, sheathed and insulated.

The position of the tips shall be at a radius of (87 ± 5) mm from the axis and with 120° mutual angular distance.

4.6.2 Hemispherical probe, connected to a pressure transducer with a range of at least 0 Pa to 100 Pa, and an accuracy of ± 2 Pa. (see reference [4]).

The pressure transducer output shall have a 90 % response time of 1 s or better.

4.6.3 Gas sampling probe, connected to a gas conditioning unit and gas analysers for O2 and CO2.

a) The O2 analyser shall be of the paramagnetic type and capable of measuring at least a range of 16 % to 21 % oxygen (VO2/Vair). The response time of the analyser shall be not more than 12 s (as measured in accordance with C.2.2). The noise and drift of the analyser shall be not more than 100 ppm over a period of 30 min (both as measured in accordance with C.1.3).

   The output from the analyser to the data acquisition system shall have a resolution of maximum 100 ppm.

b) The CO2 analyser shall be of the IR type and capable of measuring at least a range of 0 % to 10 % carbon dioxide. The linearity of the analyser shall be 1 % of full scale or better. The response time of the analyser shall be not more than 12 s (as measured in accordance with C.2.2). The output from the analyser to the data acquisition system shall have a resolution of maximum 100 ppm.

4.6.4 Light attenuation system, of the white light type, mounted with a flexible connection to the side ducts of the exhaust duct, and consisting of the following:

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

b) Lens system, to align the light to a parallel beam with a diameter of at least 20 mm. The photocell aperture shall be placed at the focus of the lens in front of it and it shall have a diameter, d, chosen with regard to the focal length of the lens, f, so that d/f is less than 0,04.

c) Detector, with a spectrally distributed responsivity agreeing with the CIE, V(γ)-function (the CIE photopic curves) to an accuracy of at least ± 5 %. The detector output shall, over an output range of at least two decades, be linear within 3 % of the measured transmission value or 1 % of the absolute transmission.

For the calibration of the light attenuation system, see C.1.5. The 90 % response time of the system shall be not more than 3 s.

To prevent smoke being trapped in the side ducts and the deposition of soot on the optics, air shall be introduced into the side ducts either by self-suction or pressurized airflow. If pressurized airflow is used, the flow rate shall be no more than 5 l/min.

5.7 Other general equipment

4.7.1 Thermocouple, ofthe K-type in accordance with Annex C, diameter (2 ± 1) mm, installed on the outer wall of the testing room within 0,20 m of the trolley opening and less than 0,20 m above the floor, for measuring the ambient temperature of the air flow into the test room.

4.7.2Equipment for measuring the ambient pressure, having an accuracy of ± 200 Pa (2 mbar).

4.7.3 Equipment for measuring the relative ambient air humidity, having an accuracy of ± 5 % within the range 20 % to 80 %.

4.7.4Data acquisition system (used to record the data automatically) having an accuracy equal to or better than 100 ppm (0,01 %) for O2 and CO2, 0,5 °C for the temperature measurements, 0,01 % of full scale instrument output for all other instruments and 0,1 s for time.

The data acquisition system shall record and store the following quantities every 3 s (information on a data file format is given in Annex F):

a) time, in seconds;

b) mass flow of propane gas through the burner, in milligrams per second;

c) pressure difference from the hemispherical probe, in pascals;

d) relative light intensity, dimensionless;

e) O2 concentration, in (VO2/Vair) %;

f) CO2 concentration, in (VCO2/Vair) %;

g) ambient temperature at air inlet at bottom of trolley, in kelvins;

h) three temperatures in general measurement section, in kelvins.

6 Test specimen

6.1 Dimensions of specimen

5.1.1 The corner specimen consists of two wings, designated the short and long wings. The maximum thickness of a specimen is 200 mm.

Sheet products shall have the following dimensions:

a) short wing: (495 ± 5) mm × (1 500 ± 5) mm;

b) long wing: (1 000 ± 5) mm × (1 500 ± 5) mm.

NOTE If additional products are used to construct the specimen (in accordance with 5.3.2), the given dimensions refer to the total specimen dimensions.

5.1.2 Specimens with a thickness of more than 200 mm shall be reduced to a thickness of 200^{0}_{-10} mm by cutting away the unexposed surface, unless otherwise specified in the product specification.

5.1.3 Two horizontal lines shall be drawn on the front side of the long wing near the edge of the specimen farthest from the corner, to allow for observation of lateral flame spread reaching the edge between a height of (500 ± 3) mm and (1 000 ± 3) mm above the bottom edge of the specimen. Each line width shall be a maximum of 3 mm.

6.2 Mounting of specimen

6.2.1 Mounting as in end use application

When products are tested, mounted as in their end use application, the test results are valid only for that application.

6.2.2 Standard mounting

When products are tested using a standard mounting, the test results are valid for that end use application and can be valid for a wider range of end use applications. The standard mounting used and its range of validity shall be in accordance with the relevant product specifications, and the following:

a) Boards that are free standing in their end use application shall be tested free standing at a distance of at least 80 mm from the backing board. Boards that have in the end use application a ventilated cavity behind it shall be tested with a cavity of at least 40 mm width as well as with the smallest possible cavity width in the end-use application. For these two types of boards the sides of the cavity farthest away from the corner shall be open, the panels in accordance with 4.4.11 shall be removed and the cavities behind both specimen wings shall be in open connection. For other types of boards the sides of the cavity farthest away from the corner shall be closed, the panels in accordance with 4.4.11 shall be in place and the cavities behind both specimen wings shall not be in open connection.

b) Boards that are fixed mechanically to a substrate in the end use application shall be tested fixed to a substrate using appropriate fixings. Fixings that stick out of the specimen surface shall be placed in such a way that the specimen wing can be placed against the U-profile at the bottom and against the other specimen wing at its side, over its full length.

c) Boards that in their end use application are fixed mechanically to a substrate with a cavity behind it shall be tested with a cavity between substrate and backing board. The distance between the substrate and the backing board shall be at least 40 mm.

d) Products that in their end use application are glued to a substrate shall be tested glued to a substrate.

e) Products tested with a horizontal joint shall be tested with a horizontal joint in the long wing at a height of 500 mm from the bottom edge of the specimen. Products tested with a vertical joint shall be tested with a vertical joint in the long wing at a distance of 200 mm from the corner line, measured when the wings are mounted ready for testing. The centre line of the joint is decisive.

NOTE 1 The bottom edge of the specimen is not visible when the specimen is installed in the trolley. The height is measured from the bottom edge of the specimen, not from the top of the U-profile of the trolley.

f) Multi-layered products with air channels shall be tested with vertical channels.

g) Standard substrates shall meet the requirements of Annex B . The dimensions of the substrates shall be in accordance with the dimensions of the specimens (see 5.1.1):

1. for the short wing, the substrate shall be the length of the small wing plus the specimen and substrate thickness;

2. the substrate for the long wing shall be identical to the lateral and vertical dimensions of the specimen

g) Non-flat products shall be tested in such a way that not more than 30 % of a representative area of 250 mm by 250 mm of the exposed surface area is more than 10 mm behind the vertical plane through the rear side of the U-profile. Non-flat products may be reshaped and/or may partly extend over the U-profile to the side of the burner to fulfil this requirement. A product shall not extend over the burner (i.e. maximum extension over the U-profile is 40 mm).

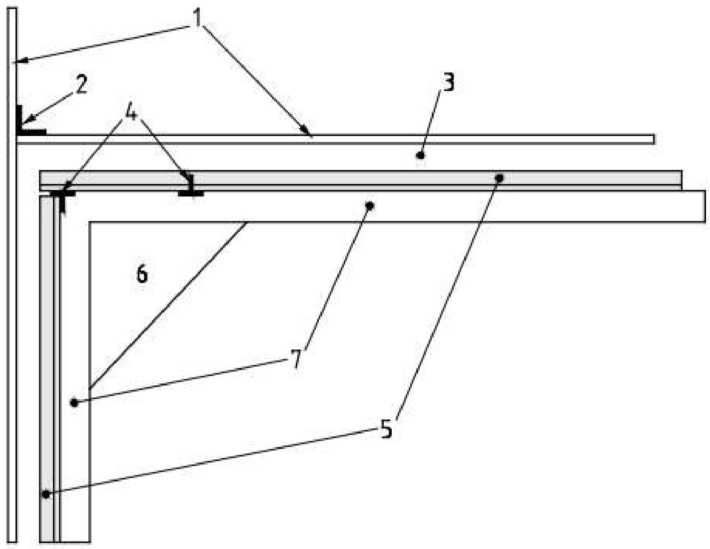
h) If a product is not normally produced in a size large enough to provide one single test specimen for each specimen side, a special specimen shall be prepared as follows:

Installation of full-size products should be started at the bottom of the corner joint between both wings. The specimen shall then be constructed from full size pieces of the product radiating outwards from this bottom corner so that the cut pieces are located at the edges of the specimen walls.

Where the horizontal and/or vertical joint, in accordance with 5.2.2, e), is present in the test specimen, the positioning of the joints shall always prevail. The area of the parts of the long wing formed as a consequence of the horizontal and/or vertical joints shall be filled with full size products starting at the bottom corner, and again, with full size pieces, at the corner between the horizontal and vertical joints.

Products are mounted for testing against the rear side of the U-profile (see 5.3.1). A mounted, totally flat product is therefore positioned in the vertical plane against the rear of the U-profile. Since the position of the surface influences the heat received from the burner flames, the major parts of a non-flat product should not be far behind the vertical plane through the rear side of the U-profile.

NOTE 2 Figure 2 is an example of an arrangement of the specimen and backing board.



Key

1	backing boards
2	L-profile
3	air gap
4	joints
5	specimen wings
6	burner
7	U-profiles

Figure 2 — Example of corner configuration

6.3 Installation of the specimen wings in the trolley

6.3.1 The specimen wings shall be placed in the trolley as follows:

a) The short wing specimen and backing board are placed on the trolley, with the extending part of the backing board at the main (primary) burner side and the bottom edge of the specimen against the short U-profile on the trolley floor.

b) The long wing specimen and backing board are placed on the trolley, with the side edge of the backing board against the extending backing board of the short wing and the bottom edge of the specimen against the long U-profile on the trolley floor.

c) Both wings shall be clamped at the top and the bottom.

d) To ensure that the corner joint within the backing boards does not widen during the test, a metallic L-profile, length 1 500 mm, shall be placed against the reverse side edge of the corner formed between the two wings. Connect the L-profile to the backing boards using fixings at a maximum of 250 mm centres.

5.3.2 The exposed edges of the products and the joint in the corner may be protected using additional products, if this is in accordance with its end use application. When additional products are used, the width of the wings including the additional product shall be in accordance with 5.1.1.

5.3.3 After installation of the specimen on the trolley, the following aspects shall be photographed:

a) A total view of the exposed surface of the long wing. The centre point of the long wing shall be in the centre of the view. The camera shall be directed perpendicular to the surface of the long wing.

b) A close-up of the vertical outer edge of the long wing at a height of 500 mm above the floor of the trolley. The camera angle shall be horizontal and at about 45° to the vertical plane of the wing.

c) If additional products (in accordance with 5.3.2) are used a close-up of the edges and/or joints where the products are applied.

6.4 Number of specimens

At least three specimens (three sets of long plus short wing) shall be tested in accordance with Clause 8.

If the product being tested has an orientational effect and this document or the product standard does not specify the orientation which has to be tested, the one specimen of the product shall be tested once in both directions. The test shall then be completed by test on the configuration with the worst classification parameters a further two times. This is only valid if one orientation has worse results for all classification parameters (FIGRA0,2 MJ, FIGRA0,4 MJ, THR600s, SMOGRA, TSP600s, LSF, burning droplets/particles). If some parameters are worse in one direction and others in the other direction, three specimen shall be tested in both directions.

7 Conditioning

6.1 The conditioning shall be in accordance with Annex B and the requirements of 6.2.

6.2 The parts that compose a specimen may be conditioned separately or fixed together. However, specimens that are tested glued to a substrate shall be glued before conditioning.

NOTE Reaching constant mass can take longer for specimens that are fixed together.

8 Principle

A test specimen, consisting of two vertical wings forming a right-angled corner, is exposed to the flames from a burner placed at the bottom of the corner (the “main (primary) burner”). The flames are obtained by combustion of propane gas, diffused through a sandbox and give a heat output of (30,7 ± 2,0) kW.

The performance of the test specimen is evaluated over a period of 20 min. The performance parameters are: heat production, smoke production, lateral (horizontal) flame spread and falling flaming droplets and particles.

A short period before ignition of the main (primary) burner is used to measure the heat output and smoke development of the burner only, using an identical burner away from the specimen (the “auxiliary (secondary) burner”).

Some measurements are performed automatically, some are made by visual observation. The exhaust duct is equipped with sensors to measure the temperature, light attenuation, O2 and CO2mole fraction and a flow induced pressure difference in the duct. These quantities are recorded automatically and used to calculate the volume flow, the heat release rate (HRR) and the smoke production rate (SPR).

Visual observations are made of the horizontal flame spread and falling of flaming droplets and particles.

9 Test procedure

9.1 General

Perform the steps in 8.2 in sequence, with the measuring equipment operating and the trolley with the test specimen and the main (primary) burner placed in the frame, under the hood. The entire testing procedure until the end of the test shall be carried out within 2 h of removal of the specimen from the conditioning environment.

All electronic devices and pumps shall be switched on sufficiently long beforehand to reach equilibrium before conducting any calibration or testing.

Half an hour has been found suitable for most devices. The stabilization time of gas-analysers however is much longer. It is recommended that the gas-analysers remain on all the time.

9.2 Testing operations

Set the volume flow of the exhaust, V298(t), to (0,60 ± 0,05) m3/s [(calculated in accordance with A.5.1.1, a))]. This volume flow shall be within the range 0,50 m3/s to 0,65 m3/s during the total test period.

NOTE Due to changes in heat output, some exhaust systems (especially those provided with local fans) can need manual or automatic readjustment during the test, to meet the requirement given.

8.2.2 Record the temperatures T1, T2 and T3 of the thermocouples in the exhaust duct and the ambient temperature for at least 300 s. The ambient temperature shall be within (20 ± 10) °C, and the temperatures in the duct shall not differ more than 6 °C from the ambient temperature.

8.2.3 Ignite the pilot flames of both burners (if pilot flames are used). Changes in the gas supply to the pilot flames during the tests shall not exceed 5 mg/s.

8.2.4 Record the pre-test conditions. The data to be recorded are given in 8.3.2.

8.2.5 Start the time measurement with the chronometer and the automatic recording of data. The time of start is t = 0 s. The data to be recorded are given in 8.4.

8.2.6 At t = (120 ± 5) s: Ignite the auxiliary (secondary) burner and adjust the propane mass flow m_{gas} to (647 ± 10) mg/s. The adjustments shall be made before t = 150 s. The mass flow shall be within this range during the total test period.

NOTE The time period 210 s < t < 270 s is used to measure the base line for the heat release rate.8.2.7 At t = (300 ± 5) s: Switch the propane supply from the auxiliary (secondary) burner to the main (primary) burner.

8.2.8 Observe the burning behaviour of the specimen for a period of 1 260 s and record the data on the record sheet. The data to be recorded are given in 8.3.3 and 8.3.4.

NOTE The nominal exposure period of the specimen to the flames of the main (primary) burner is 1 260 s. The performance is evaluated over a period of 1 200 s.8.2.9 At t ≥ 1 560 s:

a) terminate the gas supply to the burner;

b) stop the automatic recording of data.

8.2.10 Record the end of test conditions on the record sheet at least 1 min after any remaining combustion of the specimen has been totally extinguished. The data to be recorded are given in 8.3.5.

The end of test conditions should be recorded without the influence of remaining combustion. If the specimen is difficult to extinguish totally, the trolley can be removed.

9.3 Visual observation and manual recording of data

9.3.1 General

The quantities mentioned in this clause shall be observed visually and recorded in the format given. The observer shall be provided with a chronometer equipped with an event logger. The observations shall be recorded on a record sheet, of which an example is given in Annex G.

9.3.2 Pre-test conditions

The following quantities shall be recorded:

a) ambient pressure (Pa);

b) ambient relative humidity (%H2O);

c) ambient temperature (°C).

9.3.3 Lateral flame spread on the long wing

The lateral (horizontal) flame spread shall be recorded as the occurrence of sustained flames reaching the far edge of the long wing specimen at any height between 500 mm and 1 000 mm at any time during the test. The determining phenomenon shall be the boundary of sustained flaming for a minimum period of 5 s at the surface of the specimen.

If the lateral flame spread criteria is not met, additional tests may be conducted, at request of the sponsor, with the large wing having a width of 1 m plus the thickness of the specimen.

If in three additional tests the flame does not reach the edge of the long wing, the LFS criterion shall be considered to be met.

9.3.4 Flaming particles or droplets

If flaming particles or droplets are expected, the test shall be recorded continuously using a suitable high-resolution camera.

The fall of flaming droplets or particles shall be recorded only within the first 600 s of the exposure period and only when the droplets/particles reach the floor level of the trolley (the level of the lower edge of the specimen) outside the burner zone. The burner zone is defined as the trolley floor area at the front side of the specimen wings, less than 0,3 m from the corner line between the specimen wings, as illustrated in Figure 3. The following occurrences shall be recorded:

a) the fall of a flaming droplet/particle, in the given time interval and area, that remains flaming for not more than 10 s after falling;

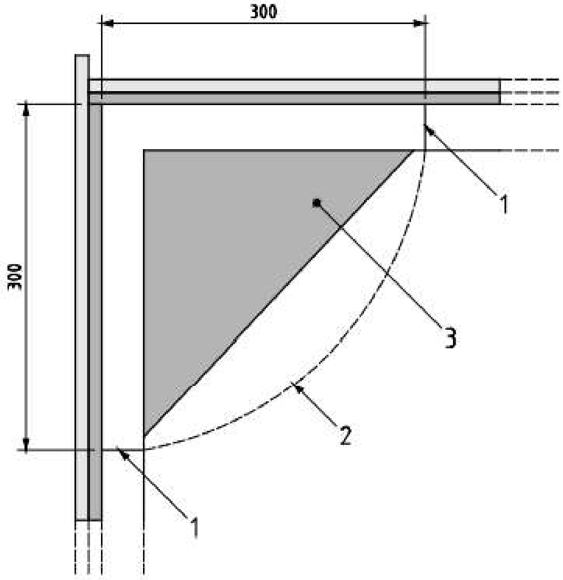
b) the fall of a flaming droplet/particle, in the given time interval and area, that remains flaming for more than 10 s after falling.

A quarter circle drawn on the floor of the trolley is needed to mark the boundary of the burner zone. The line width shall be less than 3 mm.

Flaming parts of the specimen touching the floor of the trolley outside the burner zone should be regarded as fallen particles although the part concerned can still be an integral part of the specimen (e.g. bending of a weakened product).

NOTE To prevent molten material from flowing from inside to outside the burner zone, an obstruction plate is placed in both long and short wing U-profiles on the border of the burner zone (see 4.4.6).

Dimensions in millimetres



Key

1	obstruction plate I U-profile
2	burner zone border
3	burner

Figure 3 — Burner zone

9.3.5 End of test conditions

The following quantities shall be recorded:

a) light transmission at the “general measuring section” in the exhaust duct (%);

b) O2 mole fraction at the “general measuring section” in the exhaust duct;

c) CO2 mole fraction at the “general measuring section” in the exhaust duct.

9.3.6 Recorded events

The following events shall be recorded:

a) occurrence of a surface flash;

b) smoke from the specimen not entering the hood during the test, but flowing out of the trolley into the surrounding testing room;

c) falling of parts of the specimen;

d) development of a gap in the corner (failure of mutual fixing of backing boards);

e) occurrence of one or more of the conditions which justify an early termination of the test in accordance with8.5;

f) occurrence of distortion or collapse of the specimen;

g) all additional events that may be of importance to the correct interpretation of the test results or to the field of application of the product.

9.4 Automated recording of data

8.4.1 The quantities given in 8.4.2 to 8.4.9 shall be measured and recorded automatically every 3 s during the period specified in 8.2 and shall be stored for further processing.

8.4.2 Time (t), in seconds; at the start of recording of data, t = 0 by definition.

8.4.3 Mass flow rate of propane gas to the burner (mgas) in milligrams per second.

8.4.4 Pressure difference over the hemispherical probe (Δp), at the general measuring section in the exhaust duct, in pascals.

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

8.4.6 O2 mole fraction in exhaust flow (xO2), sampled at the gas sampling probe in the general measuring section in the exhaust duct.

8.4.7 CO2 mole fraction in exhaust flow (xCO2), sampled at the gas sampling probe in the general measuring section in the exhaust duct.

The oxygen and carbon dioxide concentrations are measured only in the exhaust duct; both concentrations are assumed to be constant in the air that enters the test room. It should be noted that the air supplied from a space where oxygen is consumed (e.g. by fire tests) cannot fulfil this assumption. Also applies for 8.4.6.

8.4.8 Ambient temperature (T0) at the air inlet at the bottom of the trolley, in kelvins.

8.4.9 The three temperatures (T1, T2 and T3) in the general measuring section in the exhaust duct, in kelvins.

9.5 Early termination of test

The main (primary) burner shall be stopped earlier than the nominal exposure period if the material falls onto the sand-bed of the burner that substantially disturbs the flame of the burner or extinguishes the burner by choking.

Note that consideration should be given to the early termination of the test if half the burner is blocked by fallen material.

Record the time of termination of the gas supply to the burner and the reason why.

The results of a test are not valid for classification purposes when an early termination of the test has occurred.

NOTE An early termination of the test can be prevented by the use of a grid in accordance with 4.4.6.

The following occurrences may damage the test apparatus:

a) a heat release rate of the specimen exceeding 350 kW at any instant, or exceeding 280 kW over a period of 30 s; or

b) an exhaust duct temperature exceeding 400 °C at any instant, or exceeding a mean value of 300 °C over a period of 30 s.

If the above limits are exceeded the operator may consider an early termination of the test. Measured values for the temperature and the heat release rate will contain a certain amount of noise. It is therefore advised not to stop the test on the basis of only one or two successive measurement values from the instruments exceeding the given maximums.

10 Expression of results

9.1 For each test, the burning behaviour of the product shall be represented by graphs of average heat release rate HRRav(t), total heat release THR(t), and 1 000 × HRRav(t)/(t - 300), for the time interval 0 ≤ t ≤ 1 500 s; the values for the fire growth rate indices FIGRA0,2 MJ and

FIGRA0,4 MJ, and the total heat release within 600 s THR600s, calculated in accordance with A.5, and the occurrence or not of lateral flame spread up to the edge of the specimen in accordance with 8.3.3.

9.2 For each test, the smoke production behaviour of the product shall be given as the graphs of SPRav(t), total smoke production TSP(t) and 10 000 × SPRav(t)/(t - 300), for the time interval 0 ≤ t ≤ 1 500 s; and the values for the smoke growth rate index SMOGRA and the total smoke production within 600 s TSP600s, calculated in accordance with A.6.

9.3 For each test, the behaviour of the product regarding the production of flaming droplets and particles shall be given as the occurrence, or not, of one or both categories of fallen flaming droplets and particles, in accordance with 8.3.4, a) or b) respectively.

11 Test report

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

a) a reference that the test was carried out in accordance with this document;

b) any deviations from the test method;

c) name and address of the testing laboratory;

d) date and identification number of the report;

e) name and address of the sponsor;

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

g) date of sample arrival;

h) identification of the product;

i) description of the sampling procedure, where relevant;

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

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

l) details of conditioning;

m) date of test;

n) test results expressed in accordance with Clause 9 including method of smoke calculation (A.6.1.2);

o) photographs in accordance with 5.3.3;

p) observations made during the test;

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

Annex A

(normative)

Calculation precedures

A.1 General

A.1.1 General remarks

A.1.1.1 General

The test procedure is described in Clause 8. Some information is repeated here for convenience.

a) Major events during this procedure are:

   1. t = 0 s : start data acquisition;
   2. t = (120 ± 5) s : start auxiliary (secondary) burner;
   3. t = (300 ± 5) s : switch from auxiliary to main (primary) burner;
   4. t ≥ 1 560 s : stop main (primary) burner and stop data acquisition.

b) The performance of the specimen is evaluated during the first 1 200 s (300 s ≤ t ≤ 1 500 s) in which the specimen is exposed to the flames of the main (primary) burner. This period is called the exposure period.

c) Due to the use of time-averaged quantities, accepted inaccuracies and delay times, a maximum of 60 s additional data under burner flame exposed conditions (after t = 1 500 s) is needed.

d) The time interval 210 s ≤ t ≤ 270 s is used to do measurements on the burner heat output only. This interval is called the base line period. After t = 300 s the average burner heat output during the base line period is subtracted from the total heat output of burner and specimen, to get the output of the specimen only.

   The average burner smoke base line output is determined from the test described in Clause A.6.1.2. In a product test, after t = 300 s the average burner smoke base line output (as determined in A.6.1.2) is subtracted from the total smoke output of burner and specimen, to get the output of the specimen only.

e) The following “raw” data are recorded every 3 s for 1 560 s: gas flow, pressure difference, light attenuation, oxygen and carbon dioxide concentration and the ambient and smoke temperatures, all in accordance with 8.4.

A.1.1.2 Notation

In this annex, a simplified notation is used for averages over a time period:

$f(t_1...t_2)$ is defined as the average value of $f(t)$, in the time period $t_1 \leq t \leq t_2$

A.1.2 Calculations to be performed on the test data

After a test, a series of parameters shall be calculated to evaluate the performance of the product. All calculations in this annex, excluding the calculations in A.2, shall be performed on data shifted in time in accordance with A.2. The following calculations shall be carried out: — synchronization of data;

- calculation of equipment response;
- calculation of exposure period;
- calculation of $HRR(t)$;
- calculation of time-averaged $HRR(t)$: $HRR_{30s}(t)$;
- calculation of $THR(t)$ and THR_{600s};
- calculation of $FIGRA_{0,2MJ}$ and $FIGRA_{0,4MJ}$;
- calculation of $SPR(t)$;
- calculation of time-averaged $SPR(t)$: $SPR_{60s}(t)$;
- calculation of $TSP(t)$ and TSP_{600s};
- calculation of $SMOGRA$.

The results of a test are valid only when the requirements of A.2 and A.3 have been met. The calculations are specified in A.2 to A.6.

A.1.3 Calculations to be performed on calibration data

The calibration procedures are specified in Annex C. The quantities to be calculated are specified in A.7 if not already specified in A.2 to A.6 as part of the analysis of standard test data.

A.1.4 Standard data set

As the calculation methods are complex a standard data set can be used to verify the calculation steps and benchmark software.

A.2 Synchronization of data

A.2.1 A

A.2.2 O2 and CO2 synchronization with Tms.

Due to the switch from auxiliary to main (primary) burner, the major quantities measured show a short peak or dip at the same moment in time. These peaks and dips are used to synchronize the data. It is assumed that this automatic synchronization procedure and/or the measured delay times are erroneous if the shift calculated by this automatic synchronization procedure differs by more than 6 s from the delay times of the analysers determined in the calibration procedure according to C.2.2.

a) Shift the O2 and CO2 data for the delay times found during calibration in accordance with C.2.2.

b) The time t_0_T is calculated as the time of the last data point before the temperature in the general measurement section Tms(t) drops by more than 2,5 K, after t = 270 s, relative to the average of Tms during the base line period (210 s ≤ t ≤ 270 s):

$$\overline{T}_{ms}(210\,\text{s}...270\,\text{s}) - T_{ms}(t_{0\_T}) \le 2,5\,\text{K} \wedge \overline{T}_{ms}(210\,\text{s}...270\,\text{s}) - T_{ms}(t_{0\_T} + 3) > 2,5\,\text{K} \qquad \text{(A.1)}$$

Where:

$T_{ms}(t)$ is the temperature in the general measurement section calculated according to A.3.2.

c) The time t0_O2 is calculated as the time of the last data point before the oxygen concentration rises by more than 0,05 % (500 ppm), after t = 270 s, relative to the average during the base line period (210 s ≤ t ≤ 270 s):

$$xO_2(t_{0\_O2}) - \overline{xO_2}(210\,\text{s}...270\,\text{s}) \le 0,05\,\% \wedge xO_2(t_{0\_O2} + 3) - \overline{xO_2}(210\,\text{s}...270\,\text{s}) > 0,05\,\% \qquad \text{(A.2)}$$

Where:
xO_2 is the oxygen concentration in mole fraction.

d) The time t_{0_CO2} is calculated as the time of the last data point before the carbon dioxide concentration xCO2 drops more than 0,02 % (200 ppm), after t = 270 s, relative to the average during the base line period (210 s ≤ t ≤ 270 s):

$$\overline{xCO_2}(210\,\text{s}...270\,\text{s}) - xCO_2(t_{0\_CO2}) \le 0,02\,\% \wedge \overline{xCO_2}(210\,\text{s}...270\,\text{s}) - xCO_2(t_{0\_CO2} + 3) > 0,02\,\% \qquad \text{(A.3)}$$

where

xCO_2 is the carbon dioxide concentration in mole fraction.

e) The oxygen and carbon dioxide data are shifted so that the O2 peak and the CO2 dip coincides with the dip in Tms (such that t0_T = t0_O2 = t0_CO2). Both shifts shall not be more than 6 s.

$$xO_2(t) = xO_2(t - t_{0\_T} + t_{0\_O2}) \quad \text{(A.4)}$$

where

xO_2	is the oxygen concentration in mole fraction;
t_{0_O2}	is the time as specified in c);
t_{0_T}	is the time as specified in b).

The same equation is valid for CO_2 after replacement of O_2 by CO_2 in the formula.

NOTE In some cases, the peaks and dips used for synchronisation can be too small to be found with the procedure presented here. In those cases, a visual assessment of t0_T, t_{0_O2} and/or t_{0_CO2} is acceptable.

A.2.2 Shift all data to t = 300 s.

After the O_2 and CO_2 synchronization with T_{ms}, the time is shifted for all data such that

$t_0 = t_{0\_T} = t_{0\_O2} = t_{0\_CO2}$ = 300 s for convenience. This shift shall be less than 15 s.

NOTE Here all data (m_{gas}, Δp, I, xO_2, xCO_2, T_0, T_1, T_2, T_3 and T_{ms}) are shifted in time together. In A.2.1, e), the O_2 and CO_2 data were shifted in time relative to the other data.

A.2.3 All calculations in A.3 to A.6 shall be performed on data shifted in time in accordance with this clause.

A.3 Checking equipment response

A.3.1 Temperature readings

The temperature readings of thermocouples 1, 2 and 3, all mounted in the general measurement section, shall differ by not more than 1 % of the average value.

T_{ms} [= $(T_1 + T_2 + T_3)/3$] at any time in more than ten data points with the exception of the following.

If one thermocouple differs by more than 1 % from T_{ms} in more than ten data points and the two remaining thermocouples do not differ more than 1 % from their average in more than ten data points, that thermocouple shall be fully excluded from the calculation of T_{ms} in this test. In other cases all thermocouples shall be used to calculate T_{ms}. The use of only two thermocouples shall be mentioned in the test report.

NOTE 1 This requirement is given to exclude thermocouples that malfunction. A deviation by more than 1 % in only a few data points is not assumed to be the result of a malfunction.

NOTE 2 For the start of tests or calibrations, additional criteria for temperatures are given.

A.3.2 Drift in gas concentration measurement

The drift in both xO_2 and xCO_2 gas concentration measurements is calculated as the difference between the start values calculated as xO_2(30 s...90 s) and xCO_2(30 s...90 s) respectively, and the end values obtained by visual recording after a period of at least 60 s, in which no combustion products enter the exhaust duct.

Criteria:

$$| xO_{2\_begin} - xO_{2\_end}| \leq 0{,}02\% \qquad (A.5)$$

$$| xCO_{2\_begin} - xCO_{2\_end} | \leq 0{,}02\ \% \qquad (A.6)$$

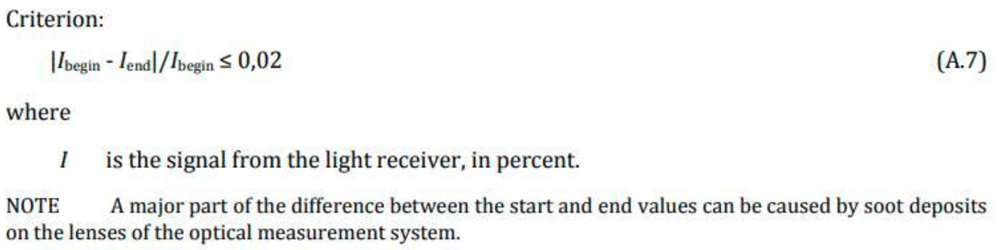
where

xO_2 is the oxygen concentration in mole fraction;

xCO_2 is the carbon dioxide concentration in mole fraction.

A.3.3 Drift in light attenuation measurement

The drift in the light attenuation measurement I is calculated as the difference between the start value, calculated as *I* (30 s…90s) and the end value, obtained by visual recording after a period of at least 60 s in which no combustion products enter the exhaust duct.



Criterion:

$$|I_{begin} - I_{end}|/I_{begin} \leq 0{,}02 \qquad (A.7)$$

where

I is the signal from the light receiver, in percent.

NOTE A major part of the difference between the start and end values can be caused by soot deposits on the lenses of the optical measurement system.

A.4 Exposure period

The specimens are exposed to the flames of the main (primary) burner from $t = t_0 = 300$ s, until the propane supply to the burner is stopped (t'). The exposure period is equal to $t' - t_0$.

Check that the burner has stopped by noting the first moment t' after t_0 at which the propane mass flow is lower than 300 mg/s at t' as well as at the next data point (t'+3 s):

$$[m_{\text{gas}}(t'-3) \geq 300 \ \text{mg/s}] \wedge [m_{\text{gas}}(t') < 300 \ \text{mg/s}] \wedge [m_{\text{gas}}(t'+3) < 300 \ \text{mg/s}] \tag{A.8}$$

where

$m_{\text{gas}}(t')$	is the propane mass flow rate, in milligrams per second.

Criterion: $t' - t_0 \geq 1\,245$ s

A.5 Heat output

A.5.1 Calculation of heat release rate *(HRR)*

A.5.1.1 Total HRR of specimen and burner: *HRR*$_{total}$

a) Calculation of the volume flow of exhaust system, normalized at 298 K, $V_{298}(t)$:

$$V_{298}(t) = cA\frac{k_t}{k_\rho}\sqrt{\frac{\Delta p(t)}{T_{\text{ms}}(t)}} \tag{A.9}$$

where

$V_{298}(t)$	is the volume flow of exhaust system, normalized at 298 K, in cubic metres per second;
c	$= (2T_0/\rho_0)^{0,5} = 22{,}4$ $[\text{K}^{0,5}\cdot\text{m}^{1,5}\cdot\text{kg}^{-0,5}]$
A	is the area of the exhaust duct at the general measurement section, in square metres;
k_t	is the flow profile factor, determined in accordance with C.2.4;
k_ρ	is the Reynolds number correction for the hemispherical probe, taken as 1,24;
$\Delta p(t)$	is the pressure difference, in pascals;
$T_{\text{ms}}(t)$	is the temperature in general measurement section, in kelvins.

b) Calculation of the oxygen depletion factor:

$$\phi(t) = \frac{\left\lfloor \bar{x}\mathrm{O}_2(30\,\mathrm{s}...90\,\mathrm{s})\left(1 - x\mathrm{CO}_2(t)\right)\right\rfloor - \left\lfloor x\mathrm{O}_2(t)\left(1 - \bar{x}\mathrm{CO}_2\left(30\ \mathrm{s}...90\ \mathrm{s}\right)\right)\right\rfloor}{\bar{x}\mathrm{O}_2(30\,\mathrm{s}...90\,\mathrm{s})\left(1 - x\mathrm{O}_2(t) - x\mathrm{CO}_2(t)\right)} \qquad (\mathrm{A}.10)$$

where

$\phi(t)$	is the oxygen depletion factor
$x\mathrm{O}_2(t)$	is the oxygen concentration in mole fraction
$x\mathrm{CO}_2(t)$	is the carbon dioxide concentration in mole fraction
$\bar{x}\mathrm{O}_2\left(30\ \mathrm{s}...90\ \mathrm{s}\right)$	is the average oxygen concentration in mole fraction measured between 30 and 90 s after the start of the test
$\bar{x}\mathrm{CO}_2\left(30\ \mathrm{s}...90\ \mathrm{s}\right)$	is the average carbon dioxide concentration in mole fraction measured between 30 and 90 s after the start of the test

c) Calculation of $x_{\mathrm{a\_O2}}$:

$$x_{\mathrm{a\_02}} = \bar{x}\mathrm{O}_2(30\,\mathrm{s}...90\,\mathrm{s})\left[1 - \frac{H}{100p}\exp\left\{23,2 - \frac{3\ 816}{\bar{T}_{\mathrm{ms}}(30\,\mathrm{s}...90\,\mathrm{s}) - 46}\right\}\right] \qquad (\mathrm{A}.11)$$

where

$x_{\mathrm{a\_02}}$	is the ambient mole fraction of oxygen including water vapour;
$x\mathrm{O}_2(t)$	is the oxygen concentration in mole fraction;
H	is the relative humidity, in percent;
p	is the ambient pressure, in pascals;
$T_{\mathrm{ms}}(t)$	is the temperature in the general measurement section, in kelvins.

d) Calculation of $HRR_{total}(t)$:

$$HRR_{\mathrm{total}}(t) = EV_{298}(t)x_{\mathrm{a\_02}}\left(\frac{\phi(t)}{1 + 0,105\phi(t)}\right) \qquad (\mathrm{A}.12)$$

where

$HRR_{\mathrm{total}}(t)$	is the total heat release rate of the specimen and burner, in kilowatts;
E	is the heat release per unit volume of oxygen consumed at 298 K, = 17 200 (in kilojoules per cubic metre);
$V_{298}(t)$	is the volume flow of the exhaust system, normalized at 298 K, in cubic metres per second;
$x_{\mathrm{a\_02}}$	is the ambient mole fraction of the oxygen including water vapour;
$\phi(t)$	is the oxygen depletion factor.

A.5.1.2 HRR of the burner

The *$HRR_{burne}r(t)$* is equal to *$HRR_{total}(t)$* during the base line period. The average HRR of the burner is calculated as the average *$HRR_{total}(t)$* during the base line period (210 s ≤ *t* ≤ 270 s):

$$HRR_{\text{av\_burner}} = \overline{\text{HRR}}_{\text{total}}\,(210\ \text{s} \ldots 270\ \text{s}) \tag{A.13}$$

where

$HRR_{\text{av\_burner}}$ is the average heat release rate of the burner, in kilowatts;

$HRR_{\text{total}}(t)$ is the total heat release rate of specimen and burner, in kilowatts.

The standard deviation of HRR_{burner}, σ_{bh}, during the period 210 s ≤ *t* ≤ 270 s is calculated as follows, using the “non-biased” or “*n* - 1” method:

$$\sigma_{\text{bh}} = \sqrt{\frac{n \sum_{t=210\ \text{s}}^{270\ \text{s}} [\text{HRR}_{\text{burner}}(t)]^2 \quad \left\{ \sum_{t=210\ \text{s}}^{270\ \text{s}} \text{HRR}_{\text{burner}}(t) \right\}^2}{n(n-1)}} \tag{A.14}$$

where

$HRR_{\text{av\_burner}}$ is the average heat release rate of the burner, in kilowatts;

$HRR_{\text{burner}}(t)$ is the heat release rate of the burner, in kilowatts;

n is the number of data points ($n = 21$).

The level and stability of the burner during this base line period shall meet the following criteria.

Criteria:

$$HRR_{\text{av\_burner}} = (30{,}7 \pm 2{,}0)\ \text{kW} \tag{A.15}$$

and

$$\sigma_{\text{bh}} < 1\ \text{kW} \tag{A.16}$$

where

$HRR_{\text{av\_burner}}$ is the average heat release rate of the burner, in kilowatts;

σ_{bh} is the standard deviation of HRR_{burner} during the period 210 s ≤ *t* ≤ 270 s.

The ratio of carbon dioxide production to oxygen depletion during the base line period (210 s ≤ t ≤ 270 s; combustion of propane only) can be used as a check of the gas analysers before the burner switch operates. The ratio should be equal to 0,60 ± 0,05.

A.5.1.3 HRR of the specimen

In general, the heat release rate of the specimen is taken as the total heat release rate HRRtotal(t) minus the average heat release rate of the burner HRR_{av_burner}:

For $t > 312$ s:

$$HRR(t) = HRR_{total}(t) - HRR_{av\_burner} \qquad (A.17)$$

where

$HRR(t)$	is the heat release rate of the specimen, in kilowatts;
$HRR_{total}(t)$	is the total heat release rate of specimen and burner, in kilowatts;
HRR_{av_burner}	is the average heat release rate of the burner, in kilowatts.

During the switch from the auxiliary to the main (primary) burner at the start of the exposure period, the total heat output of the two burners is less than HRR_{av_burner}. Formula (A.17) then gives negative values for HRR(t) for at most 12 s (burner switch response time). Such negative values and the value for t = 0 are set to zero, as follows:

For $t = 300$ s:

$$HRR(300) = 0 \text{ kW} \qquad (A.18)$$

For 300 s $< t \leq 312$ s:

$$HRR(t) = \max.\{0 \text{ kW}, HRR_{total}(t) - HRR_{av\_burner}\} \qquad (A.19)$$

where

$HRR(\mathrm{t})$	is the heat release rate of the specimen, in kilowatts;
$HRR_{total}(\mathrm{t})$	is the total heat release rate of specimen and burner, in kilowatts;
HRR_{av_burner}	is the average heat release rate of the burner, in kilowatts;
max. $\{a, b\}$	is the maximum of two values a and b.

A.5.1.4 Calculation of HRR30s

A.5.1.4 Calculation of HRR_{30s}

$HRR_{30s}(t)$ is the 30 s average of $HRR(t)$:

$$HRR_{30\,s}(t) = \frac{0,5\mathrm{HRR}(t-15) + \mathrm{HRR}(t-12) + \ldots + \mathrm{HRR}(t+12) + 0,5\mathrm{HRR}(t+15)}{10} \qquad (A.20)$$

where

$HRR_{30s}(t)$	is the average of HRR(t) over 30 s, in kilowatts;
$HRR(t)$	is the heat release rate at time t, in kilowatts.

A.5.2 Calculation of THR(t) and THR600s

The total heat release of the specimen THR(t) and the total heat release of the specimen in the first 600 s of the exposure period (300 s ≤ t ≤ 900 s), THR600s, are calculated as follows:

$$THR(t_a) = \frac{3}{1\ 000} \sum_{300\,\mathrm{s}}^{t_a} (\max.[HRR(t), 0]) \qquad \text{(A.21)}$$

$$THR_{600\,\mathrm{s}} = \frac{3}{1\ 000} \sum_{300\,\mathrm{s}}^{900\,\mathrm{s}} (\max.[HRR(t), 0]) \qquad \text{(A.22)}$$

where

$THR(t_a)$	is the total heat release of the specimen during the period 300 s ≤ t ≤ t_a, in megajoules;
$HRR(t)$	is the heat release rate of the specimen, in kilowatts;
THR_{600s}	is the total heat release of the specimen during the period 300 s ≤ t ≤ 900 s, in megajoules;
max. [a, b]	is the maximum of two values a and b.

A.5.3 Calculation of FIGRA0,2MJ and FIGRA0,4MJ (fire growth rate indices)

The FIGRA indices are defined as the maximum of the quotient HRRav(t)/(t - 300), multiplied by 1 000. The quotient is calculated only for that part of the exposure period in which the threshold levels for HRRav and THR have been exceeded. If one or both threshold values of a FIGRA index are not exceeded during the exposure period, that FIGRA index is equal to zero. Two different THR-threshold values are used, resulting in FIGRA0,2MJ and FIGRA0,4MJ.

a) The average of HRR, HRRav, used to calculate the FIGRA is equal to HRR30s according to A.5.1.4, with the exception of the first 12 s of the exposure period. For data points in the first 12 s, the average is taken only over the widest possible symmetrical range of data points within the exposure period:

1) For t = 300 s: $HRR_{av}(300\ \mathrm{s}) = 0$;

2) For t = 303 s: $HRR_{av}(303\ \mathrm{s}) = \overline{HRR}(300\ \mathrm{s}...306\ \mathrm{s})$;

3) For t = 306 s: $HRR_{av}(306\ \mathrm{s}) = \overline{HRR}(300\ \mathrm{s}...312\ \mathrm{s})$;

4) For t = 309 s: $HRR_{av}(309\ \mathrm{s}) = \overline{HRR}(300\ \mathrm{s}...318\ \mathrm{s})$;

5) For t = 312 s: $HRR_{av}(312\ \mathrm{s}) = \overline{HRR}(300\ \mathrm{s}...324\ \mathrm{s})$;

6) For t ≥ 315 s: $HRR_{av}(t) = HRR_{30\,\mathrm{s}}(t)$. (A.23)

b) Calculate $FIGRA_{0,2MJ}$ for all t where:

$(HRRav(t) > 3\ kW)$ and $(THR(t) > 0{,}2\ MJ)$ and $(300\ s < t \leq 1\ 500\ s)$;

and calculate $FIGRA_{0,4MJ}$ for all t where:

$(HRR_{av}(t) > 3\ kW)$ and $(THR(t) > 0{,}4\ MJ)$ and $(300\ s < t \leq 1\ 500\ s)$;

both using:

$$FIGRA = 1\ 000 \times \max.\left(\frac{HRR_{av}(t)}{t-300}\right) \qquad (A.24)$$

Where:

FIGRA is the fire growth rate index, in watts per second;

$HRR_{av}(t)$ is the average of $HRR(t)$ as specified in a), in kilowatts;

max. $[a(t)]$ is the maximum of $a(t)$ within the given time period.

NOTE As a consequence, specimens with an HRR_{av} value of not more than 3 kW during the total test period or a THR value of not more than 0,2 MJ over the total test period, have a $FIGRA_{0,2MJ}$ equal to zero. Specimens with an HRR_{av} value of not more than 3 kW during the total test period or a THR value of not more than 0,4 MJ over the total test period, have a $FIGRA_{0,4MJ}$ equal to zero.

A.6 Smoke production

A.6.1 Calculation of smoke production rate *(SPR)*

A.6.1.1 Total SPR of specimen and burner: SPR_{total}

a) Calculation of $V(t)$:

$$V(t) = V_{298}(t)\frac{T_{ms}(t)}{298} \tag{A.25}$$

where

$V(t)$	is the volume flow in the exhaust duct, in cubic metres per second;
$V_{298}(t)$	is the volume flow in the exhaust duct, normalized to 298 K, in cubic metres per second;
$T_{ms}(t)$	is the temperature in the general measurement section, in kelvins.

b) Calculation of $SPR_{total}(t)$

$$SPR_{total}(t) = \frac{V(t)}{L}\ln\left[\frac{\bar{I}(30\,s...90\,s)}{I(t)}\right] \tag{A.26}$$

where

$SPR_{total}(t)$	is the total smoke production rate of specimen and burner, in square metres per second;
$V(t)$	is the (non-normalized) volume flow in the exhaust duct, in cubic metres per second;
L	is the length of the light path through the exhaust duct, in metres, and is taken to be the diameter of the exhaust duct;
$I(t)$	is the signal from the light receiver, in percent.

For calculation purposes, set $I(t)$ = MAX[10e-9, $I(t)$]) to avoid possible division by zero errors.

A.6.1.2 *SPR* of the burner

It has been observed that the auxiliary (secondary) burner produces less smoke than the main (primary) burner. In order to ensure that the burner output is not a contributing part of the product's smoke classification, the contribution of the burner is derived from the burner itself. The procedure – which is mandatory – is as follows and results are only valid for tests run on the same testing day:

a) Place clean sheets of calcium silicate “substrate” directly into the trolley to form a corner.

b) Position the trolley in the test room and commence a normal test running the burners and software as normal.

c) The test may be terminated at any time after 600 s.

The average *SPR* of the burner is calculated as the average $SPR_{\text{total}}(t)$ during the period (390 s $\leq t \leq$ 450 s):

$$SPR_{\text{av\_burner}} = SPR_{\text{total}}\ (390\ \text{s} \ldots 450\ \text{s}) \quad \text{(A.27)}$$

where

$SPR_{\text{total}}(t)$ is the total smoke production rate of specimen and burner, in square metres per second;

$SPR_{\text{av\_burner}}$ is the average smoke production rate of the burner, in square metres per second.

The standard deviation of $\text{SPR}_{\text{burner}}(t)$, σ_{bs}, during the period 390 s $\leq t \leq$ 450 s is calculated as follows, using the “non-biased” or “n - 1” method:

$$\sigma_{\text{bs}} = \sqrt{\frac{n \sum_{t=210\,\text{s}}^{270\,\text{s}} \{\text{SPR}_{\text{burner}}(t)\}^2 - \left\{\sum_{t=210\,\text{s}}^{270\,\text{s}} \text{SPR}_{\text{burner}}(t)\right\}^2}{n(n-1)}} \quad \text{(A.28)}$$

where

$SPR_{\text{av\_burner}}$ is the average smoke production rate of the burner, in square metres per second;

$SPR_{\text{burner}}(t)$ is the smoke production rate of the burner, in square metres per second; n is the number of data points (n = 21).

The level and stability of the burner during this base line period shall meet the following criteria.

Criteria:

$$SPR_{\text{av\_burner}} = (0 \pm 0{,}2)\ \text{m}^2/\text{s} \quad \text{(A.29)}$$

and

$\sigma_{bs} < 0{,}01\ m^2/s$ (A.30)

where

SPR_{av_burner} is the average smoke production rate of the burner, in square metres per second;

σ_{bs} is the standard deviation of $RSP_{burner}(t)$, during the period 390 s $\leq t \leq$ 450 s.

A.6.1.3 *SPR* of the specimen

In general, the *SPR* of the specimen is taken as the total smoke production rate $SPR_{total}(t)$, minus the average *SPR* of the burner, SPR_{av_burner}.

$$SPR(t) = SPR_{total}(t) - SPR_{av\_burner} \quad (A.31)$$

where

$SPR_{total}(t)$ is the total smoke production rate of specimen and burner, in square metres per second;

SPR_{av_burner} is the average smoke production rate of the burner, in square metres per second;

$SPR(t)$ is the smoke production rate of the specimen, in square metres per second.

During the switch from auxiliary (secondary) to main (primary) burner at the start of the exposure period, the total smoke production of the two burners might be less than SPR_{av_burner}. Formula (A.31) may then lead to negative values for $SPR(t)$ for a few seconds. Such negative values, and the value for t = 0, are set to zero:

For t = 300 s:

$SPR(300) = 0\ m^2/s$

For 300 s < $t \leq$ 312 s:

$$SPR(t) = \max.[0, (SPR_{total}(t) - SPR_{av\_burner})] \quad (A.32)$$

where

$SPR_{total}(t)$ is the total smoke production rate of specimen and burner, in square metres per second;

SPR_{av_burner} is the average smoke production rate of the burner, in square metres per second;

$SPR(t)$ is the smoke production rate of the specimen, in square metres per second;

max. $[a,b]$ is the maximum of two values a and b.

NOTE The smoke production of the burner flames most probably changes when the specimen starts to produce combustible volatiles. However, the base line smoke production is taken as a first approximation with acceptable accuracy, especially at the start of the exposure period where the base line level is important for the *SMOGRA* calculation.

A.6.1.4 Calculation of SPR_{60s}

$SPR_{60s}(t)$ is the 60 s average of $SPR(t)$.

$$SPR_{60\,s}(t) = \frac{\{0,5SPR(t-30\,s) + SPR(t-27\,s) + \ldots + SPR(t+27\,s) + 0,5SPR(t+30\,s)\}}{20} \qquad (A.33)$$

where

$SPR_{60s}(t)$ is the average of $SPR(t)$ over 60 s, in square metres per second;

$SPR(t)$ is the smoke production rate of the specimen, in square metres per second.

A.6.2 Calculation of *TSP(t)* and TSP_{600s}

The total smoke production of the specimen TSP(t) and the total smoke production of the specimen in the first 600 s of the exposure period (300 s ≤ t ≤ 900 s), TSP600s, are calculated as follows:

$$TSP(t_a) = 3\sum_{300\,s}^{t_a}(\max.[SPR(t),0]) \qquad (A.34)$$

$$TSP_{600\,s} = 3\sum_{300\,s}^{900\,s}(\max.[SPR(t),0]) \qquad (A.35)$$

where

$TSP(t_a)$ is the total smoke production of the specimen within 300 s ≤ t ≤ t_a, in square metres;

$SPR(t)$ is the smoke production rate of the specimen, in square metres per second;

TSP_{600s} is the total smoke production of the specimen 300 s ≤ t ≤ 900 s, in square metres; [equal to $TSP(900)$];

max.[a,b] is the maximum of the two values a and b.

NOTE The factor 3 is introduced since only one data point is available every three seconds.

A.6.3 Calculation of SMOGRA (smoke growth rate index)

The SMOGRA is defined as the maximum of the quotient SPRav(t)/(t - 300), multiplied by 10 000.

The quotient is calculated only for that part of the exposure period in which the threshold levels for SPRav and TSP have been exceeded. If one or both threshold values are not exceeded during the exposure period, SMOGRA is equal to zero.

a) The SPRav, used to calculate the SMOGRA is equal to SPR60s according to A.6.1.4 with the exception of the first 27 s of the exposure period. For data points in the first 27 s, the average is taken only over the widest possible symmetrical range of data points within the exposure period:

1) for $t = 300$ s: $SPR_{\text{av}}(300\ \text{s}) = 0\ \text{m}^2/\text{s}$;

2) for $t = 303$ s: $SPR_{\text{av}}(303\ \text{s}) = \overline{SPR}(300\ \text{s}...306\ \text{s})$;

3) for $t = 306$ s: $SPR_{\text{av}}(306\ \text{s}) = \overline{SPR}(300\ \text{s}...312\ \text{s})$;

etc., until

4) for $t = 327$ s: $SPR_{\text{av}}(327\ \text{s}) = \overline{SPR}(300\ \text{s}...354\ \text{s})$;

5) for $t \geq 330$ s: $SPR_{\text{av}}(t) = SPR_{60\ \text{s}}(t)$ (A.36)

b) Calculate *SMOGRA* for all *t* where:

$(SPR_{\text{av}(t)} > 0{,}1\ \text{m}^2/\text{s})$ and $(TSP(t) > 6\ \text{m}^2)$ and $(300\ \text{s} < t \leq 1\ 500\ \text{s})$

$$SMOGRA = 10\ 000 \times \max.\left(\frac{SPR_{\text{av}}(t)}{t - 300}\right) \tag{A.37}$$

Where:

SMOGRA is the smoke growth rate index, in square metres per square second;

SPRav(t) is the average of SPR(t) as specified in a), in square metres per second;

max.[a(t)] is the maximum of a(t) within the given time period.

NOTE 1 As a consequence, specimens with a SPRav value of not more than 0,1 m2/s during the total test period or a TSP value of not more than 6 m2 over the total test period have a SMOGRA value equal to zero.

NOTE 2 A SMOGRA value given in the units m2/s2 does not have a direct physical meaning because its calculation contains a multiplication factor of 10 000.

11.1.1 A.7Calculations for calibrations – Propane heat release

A.7.1 The theoretical heat release rate of the propane mass flow is calculated as:

$$q_{\text{gas}}(t) = \Delta h_{\text{c,eff}} m_{\text{gas}}(t) \qquad \text{(A.38)}$$

where $q_{\text{gas}}(t)$ is the theoretical heat release rate of the propane mass flow, in kilowatts;

$\Delta h_{\text{c,eff}}$ is the effective lower heat of combustion of propane = 46 360 kJ/kg;

$m_{\text{gas}}(t)$ is the propane mass flow rate, in kilograms per second. **A.7.2** The 30 s average of $q_{\text{gas}}(t)$, is calculated as:

$$q_{\text{gas},30\,\text{s}}(t) = \frac{\{(0,5q_{\text{gas}}(t-15) + q_{\text{gas}}(t-12) + \dots + q_{\text{gas}}(t+12) + 0,5q_{\text{gas}}(t+15)\}}{10} \qquad \text{(A.39)}$$

where

$q_{\text{gas, 30 s}}(t)$ is the average of $q_{\text{gas}}(t)$ over 30 s, in kilowatts;

$q_{\text{gas}}(t)$ is the theoretical heat release rate of the propane mass flow, in kilowatts.

Annex B
(normative)

Conditioning procedures and general rules for selection of substrates

B.1 Conditioning procedures

B.1.1 General

Test specimens used by the laboratory to conduct tests according to ISO 1182, ISO 1716, ISO 9239-1, andISO 11925-2shall be conditioned at a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %.

NOTE This corresponds to the recommended atmosphere and normal tolerances given in ISO 554.

Test specimens shall be arranged within the conditioning environment in such a way that air can circulatearound each individual test specimen.

Test specimens shall be conditioned either until constant mass is achieved (see B.1.2) or for a fixed period (see B.1.3).

B.1.2 Conditioning to constant mass

Before testing, the test specimens shall be conditioned in the atmosphere specified in 4.1 for a minimum period of 48 h, until constant mass is achieved.

Constant mass is considered to be achieved when two successive weighing operations, carried out at aninterval of 24 h, do not differ by more than 0.1 % of the mass of the specimen or 0.1 g, whichever is the greater. A number of weighing devices may be necessary. At least one weighing device shall have an accuracy of at least 0.1 g.

B.1.3 Conditioning for a fixed period

Before starting conditioning for a fixed period, the test specimens shall be properly cured in accordancewith manufacturer's instructions and shall not contain excess water. The content of excess water shall be measured and shall be below 40 % before the test specimens are placed in the conditioning environment. Before testing the test specimens shall be conditioned in the atmosphere specified in 4.1 for the following minimum periods:

a) Minimum conditioning period of eight weeks:

1. fire retardant treated wood and fire-retardant treated wood-based products;
2. cement based products;

b) Minimum conditioning period of four weeks:

1. not fire-retardant treated wood and not fire-retardant treated wood-based products;

   2. calcium silicate products;
   3. gypsum and gypsum-based products;
   4. all other products containing hygroscopic materials;

c) Minimum conditioning period of two weeks: all other products.

B.2 General rules for selection of substrates

B.2.1 General

The substrates used by the laboratory to conduct tests according to ISO 9239-1 and ISO 11925-2shall be evaluated when appropriate to determine their reaction to fire test performance and thus compliance with this standard. One indicative test shall be conducted on each batch of substrates.

B.2.2 Standard substrates for floorings

5.2.1 Test results using a standard substrate complying with the requirements of 5.2.2 or 5.2.3 are applicable if the density of the end use substrate is at least 75 % of the nominal value of the density of that standard substrate.

5.2.2 End use substrates of classes A1 and A2-s1,d0 are represented by fibre cement board (in accordance with ISO 390) with thickness (8 ± 2) mm, with density (1 800 ± 200) kg/m3 and with classification A2fl-s1, when – insofar as for the ISO 9239-1 test – the fibre cement board is tested as flooring but without a substrate.

5.2.3 End use substrates of wood and of classes A1 and A2-s1,d0 are represented by not fire retardant treated particleboard with thickness (20 ± 2) mm, with density (680 ± 50) kg/m3and with classification Cfl-s1 when tested (according to ISO 9239-1) as flooring but without a substrate.

5.2.4 When the end use substrates are not of wood and not of class A1 and not of class A2-s1,d0, the flooring shall be tested in end use condition.

5.2.5 The method of attachment (e.g. adhesive) of floorings shall be representative of end use application.

The method of attachment in end use practice shall be reproduced in the preparation of the test specimens, i.e. end use adhesive and end use quantities, etc. If the order in which the attachments are conducted is known, this shall also be reproduced in the test specimens, e.g. if in end use practice the adhesive is applied to the substrate and not to the flooring, then it shall be applied to the substrate during the test specimen preparation. The same or greater time for curing and drying as used in end use practice shall also be allowed.

If in practice different types of adhesive are used, test specimens with each of the different adhesives shall be prepared.

NOTE Some floorings may also be tested without attachment (e.g. adhesive).

B.2.3 Standard substrates for construction products excluding floorings

5.3.1 A list of standard substrates is given in Table 1.

5.3.2 The choice of the substrate for the test specimens shall be made in view of the field of application of test results, taking into account the end use substrate and the following rules which apply together:

5.3.2.1 Each standard substrate represents end use substrates which have a density of at least 75 % of the nominal value of the density of that standard substrate.

5.3.2.2 Standard substrates of classes A1 and A2-s1,d0 represent end use substrates of classes A1 and A2-s1,d0 only.

5.3.2.3 The standard particleboard substrate and the standard plywood substrate represents end use wood based substrates and also any end use substrate of classes A1 and A2-s1,d0.

5.3.2.4 The standard gypsum plasterboard substrate is representative of end use gypsum plasterboard substrates and also any end use substrate of classes A1 and A2-s1,d0. The standard calcium silicate board substrate is not representative of a gypsum plasterboard end use substrate.

5.3.2.5 The standard steel sheet substrate is only representative of end use metal substrates with a melting point equal to or greater than 1 000 °C.

5.3.2.6 The standard aluminium sheet substrate is only representative of end use metal substrates with a melting point equal to or greater than 500 °C.

5.3.2.7 Where in the end use of a surface product an air gap is incorporated, this shall be reproduced as part of the test specimens up to a maximum depth of 25 mm, unless a higher value is specified in the applicable test standard.

5.3.2.8 For a surface product, where there are layers behind the immediate substrate which can influence the performance of the product, e.g. an insulating material behind a painted steel sheet, the surface product together with its immediate substrate and the additional layers shall be representative of the end use application and shall be included in the test specimens.

5.3.2.9 Surface products with end use substrates not represented by a standard substrate shall be tested in end use condition.

5.3.2.10 The method of attachment (e.g. adhesive) of surface products shall be representative of end use application.

The method of attachment in end use practice shall be reproduced in the preparation of the test specimens, i.e. end use adhesive and end use quantities, etc. If the order in which the attachments are conducted is known, this shall also be reproduced in the test specimens, e.g. if in end use practice the adhesive is applied to the substrate and not to the surface product, then it shall be applied to the substrate during the test specimen preparation. The same or greater time for curing and drying as used in end use practice shall also be allowed.

Annex C
(normative)

Thermocouple designations

C.1 Thermocouple designations

When a thermocouple is identified by the materials of its conductors, the positive conductor shall be listed first, thus: ‘positive conductor / negative conductor’.

The positive conductor is the conductor having a positive electric potential with respect to the other conductor when the measuring junction is at a higher temperature than the reference junction.

Table 1 lists the thermocouple types for which EMFs are specified in this standard. Each letter designation of the table identifies the EMF-temperature reference function in the Tables 2 to

11. The designation may be applied to any thermocouple conforming to the relevant function within the stated tolerances specified in Clause 5, regardless of its composition.

Conformity with alloy specification listed in this clause does not guarantee conformity with the EMF-temperature relationship of this standard.

Table 1 – Thermocouple types

Letter designation	Elements and nominal alloy compositions by weight	
	Positive conductor	Negative conductor
R	Platinum – 13 % rhodium	Platinum
S	Platinum – 10 % rhodium	Platinum
B	Platinum – 30 % rhodium	Platinum – 6 % rhodium
J	Iron	Copper – nickel
T	Copper	Copper – nickel
E	Nickel – chromium	Copper – nickel
K	Nickel – chromium	Nickel – aluminium
N	Nickel – chromium - silicon	Nickel – silicon
C	Tungsten – 5 % rhenium	Tungsten – 26 % rhenium
A	Tungsten – 5 % rhenium	Tungsten – 20 % rhenium

NOTE

- Standard alloy compositions have not been established for base metal thermocouple alloys except Type N, but it should be noted that the compositions are not so critical as the matching of the positive and negative conductor. In particular, the negative conductor of Type J, Type E and Type T thermocouples are generally not interchangeable with each other. Likewise positive conductors of Type C and A are not necessary interchangeable.

- For Type N thermocouple the following composition (percentages of total by weight) is recommended in order to obtain the desired properties like good stability and oxidation resistance.

Positive conductor (known as Nicrosil): 13,7% to 14,7 % Cr%, 1,2 to 1,6 % Si, less than 0,15 % Fe, less than 0,05 % C, less than 0,01 % Mg, balance Ni.

Negative conductor (known as Nisil): less than 0,02 % Cr, 4,2 % to 4,6 % Si, less than 0,15 % Fe, less than 0,05 % C, 0,0 5% to 0,2 % Mg, balance Ni.

4 EMF – Temperature reference functions

The temperature and EMF relationships of this standard are defined by reference functions which give EMF, E/μV, as a function of the temperature, t90/°C, with a reference temperature of 0 °C.

The reference function of polynomial form for each type of thermocouple, except for Type K in the temperature range from 0 °C to 1 300 °C, is defined by the following equation.

$$E = \sum_{i=0}^{n} a_i \times (t_{90})^i$$

where

E is EMF, expressed in microvolts (µV);

t_{90} is ITS-90 temperature, expressed in degrees Celsius (°C);

a_i is the ith coefficient of the polynomial;

n is the order of the polynomial.

The values of ai and n are dependent on the type of thermocouple and temperature range.

Those for each thermocouple are given in the Tables 2 to 11.

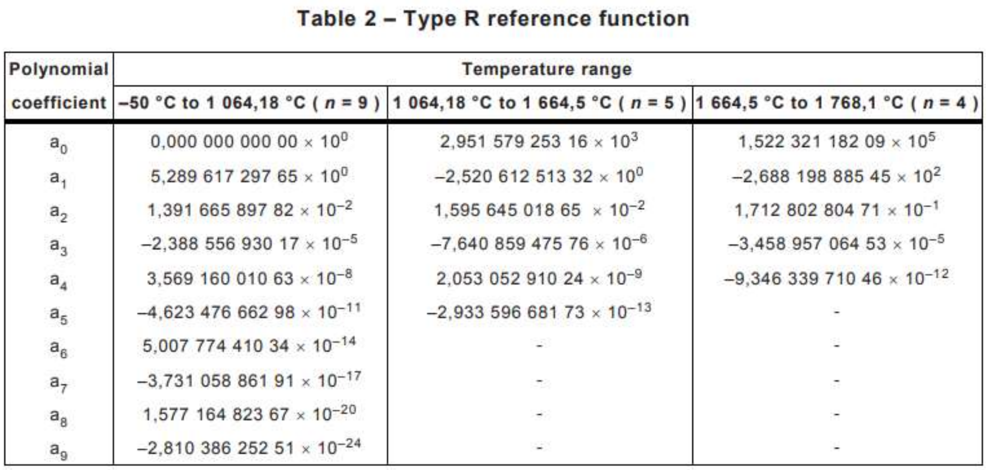
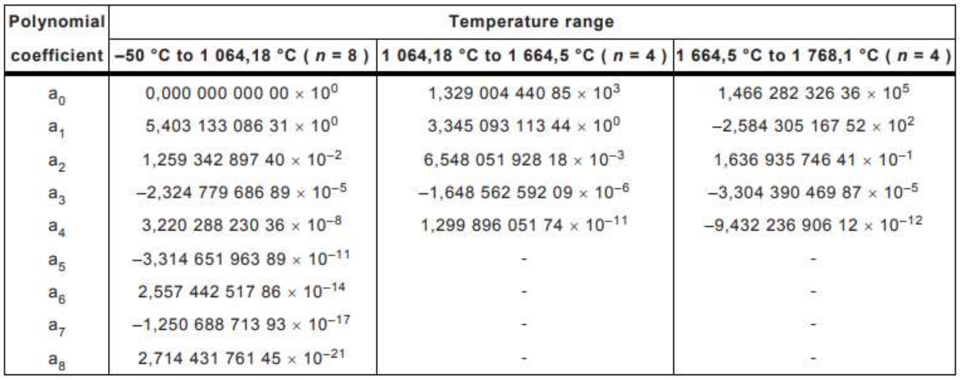


Table 2 – Type R reference function

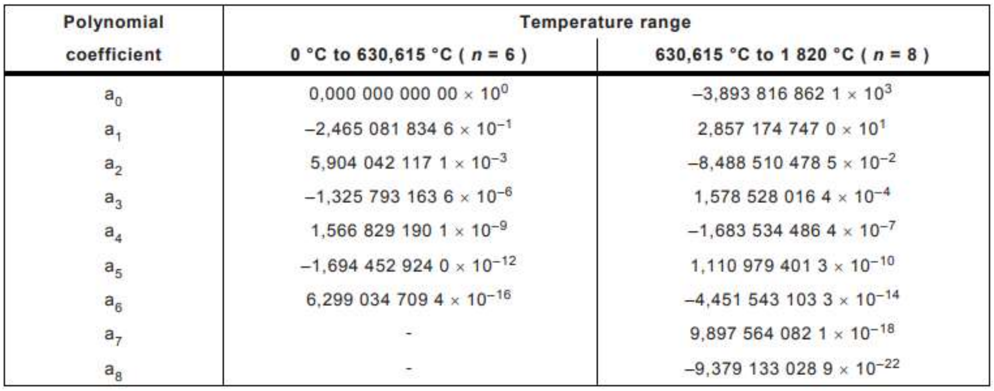
Polynomial coefficient	Temperature range		
	−50 °C to 1 064,18 °C (n = 9)	1 064,18 °C to 1 664,5 °C (n = 5)	1 664,5 °C to 1 768,1 °C (n = 4)
a_0	$0{,}000\ 000\ 000\ 00 \times 10^{0}$	$2{,}951\ 579\ 253\ 16 \times 10^{3}$	$1{,}522\ 321\ 182\ 09 \times 10^{5}$
a_1	$5{,}289\ 617\ 297\ 65 \times 10^{0}$	$-2{,}520\ 612\ 513\ 32 \times 10^{0}$	$-2{,}688\ 198\ 885\ 45 \times 10^{2}$
a_2	$1{,}391\ 665\ 897\ 82 \times 10^{-2}$	$1{,}595\ 645\ 018\ 65 \times 10^{-2}$	$1{,}712\ 802\ 804\ 71 \times 10^{-1}$
a_3	$-2{,}388\ 556\ 930\ 17 \times 10^{-5}$	$-7{,}640\ 859\ 475\ 76 \times 10^{-6}$	$-3{,}458\ 957\ 064\ 53 \times 10^{-5}$
a_4	$3{,}569\ 160\ 010\ 63 \times 10^{-8}$	$2{,}053\ 052\ 910\ 24 \times 10^{-9}$	$-9{,}346\ 339\ 710\ 46 \times 10^{-12}$
a_5	$-4{,}623\ 476\ 662\ 98 \times 10^{-11}$	$-2{,}933\ 596\ 681\ 73 \times 10^{-13}$	-
a_6	$5{,}007\ 774\ 410\ 34 \times 10^{-14}$	-	-
a_7	$-3{,}731\ 058\ 861\ 91 \times 10^{-17}$	-	-
a_8	$1{,}577\ 164\ 823\ 67 \times 10^{-20}$	-	-
a_9	$-2{,}810\ 386\ 252\ 51 \times 10^{-24}$	-	-

Table 3 – Type S reference function



Polynomial coefficient	Temperature range –50 °C to 1 064,18 °C (*n* = 8)	 1 064,18 °C to 1 664,5 °C (*n* = 4)	 1 664,5 °C to 1 768,1 °C (*n* = 4)
a_0	0,000 000 000 00 × 10^{0}	1,329 004 440 85 × 10^{3}	1,466 282 326 36 × 10^{5}
a_1	5,403 133 086 31 × 10^{0}	3,345 093 113 44 × 10^{0}	–2,584 305 167 52 × 10^{2}
a_2	1,259 342 897 40 × 10^{-2}	6,548 051 928 18 × 10^{-3}	1,636 935 746 41 × 10^{-1}
a_3	–2,324 779 686 89 × 10^{-5}	–1,648 562 592 09 × 10^{-6}	–3,304 390 469 87 × 10^{-5}
a_4	3,220 288 230 36 × 10^{-8}	1,299 896 051 74 × 10^{-11}	–9,432 236 906 12 × 10^{-12}
a_5	–3,314 651 963 89 × 10^{-11}	-	-
a_6	2,557 442 517 86 × 10^{-14}	-	-
a_7	–1,250 688 713 93 × 10^{-17}	-	-
a_8	2,714 431 761 45 × 10^{-21}	-	-

Table 4 – Type B reference function



Polynomial coefficient	Temperature range 0 °C to 630,615 °C (*n* = 6)	 630,615 °C to 1 820 °C (*n* = 8)
a_0	0,000 000 000 00 × 10^{0}	–3,893 816 862 1 × 10^{3}
a_1	–2,465 081 834 6 × 10^{-1}	2,857 174 747 0 × 10^{1}
a_2	5,904 042 117 1 × 10^{-3}	–8,488 510 478 5 × 10^{-2}
a_3	–1,325 793 163 6 × 10^{-6}	1,578 528 016 4 × 10^{-4}
a_4	1,566 829 190 1 × 10^{-9}	–1,683 534 486 4 × 10^{-7}
a_5	–1,694 452 924 0 × 10^{-12}	1,110 979 401 3 × 10^{-10}
a_6	6,299 034 709 4 × 10^{-16}	–4,451 543 103 3 × 10^{-14}
a_7	-	9,897 564 082 1 × 10^{-18}
a_8	-	–9,379 133 028 9 × 10^{-22}

Table 5 – Type J reference function

Polynomial coefficient	Temperature range	
	–210 °C to 760 °C (*n* = 8)	**760 °C to 1 200 °C (*n* = 5)**
a_0	0,000 000 000 0 × 10^{0}	2,964 562 568 1 × 10^{5}
a_1	5,038 118 781 5 × 10^{1}	–1,497 612 778 6 × 10^{3}
a_2	3,047 583 693 0 × 10^{-2}	3,178 710 392 4 × 10^{0}
a_3	–8,568 106 572 0 × 10^{-5}	–3,184 768 670 1 × 10^{-3}
a_4	1,322 819 529 5 × 10^{-7}	1,572 081 900 4 × 10^{-6}
a_5	–1,705 295 833 7 × 10^{-10}	–3,069 136 905 6 × 10^{-10}
a_6	2,094 809 069 7 × 10^{-13}	-
a_7	–1,253 839 533 6 × 10^{-16}	-
a_8	1,563 172 569 7 × 10^{-20}	-

The specified function for Type J (Table 5) extends up to 1 200 °C; however, it should be noted that when a Type J thermocouple has been used above 760 °C, its performance below 760 °C may not conform to the lower part of the function within specified tolerances.

Table 6 – Type T reference function

Polynomial coefficient	Temperature range	
	–270 °C to 0 °C (*n* = 14)	**0 °C to 400 °C (*n* = 8)**
a_0	0,000 000 000 0 × 10^{0}	0,000 000 000 0 × 10^{0}
a_1	3,874 810 636 4 × 10^{1}	3,874 810 636 4 × 10^{1}
a_2	4,419 443 434 7 × 10^{-2}	3,329 222 788 0 × 10^{-2}
a_3	1,184 432 310 5 × 10^{-4}	2,061 824 340 4 × 10^{-4}
a_4	2,003 297 355 4 × 10^{-5}	–2,188 225 684 6 × 10^{-6}
a_5	9,013 801 955 9 × 10^{-7}	1,099 688 092 8 × 10^{-8}
a_6	2,265 115 659 3 × 10^{-8}	–3,081 575 877 2 × 10^{-11}
a_7	3,607 115 420 5 × 10^{-10}	4,547 913 529 0 × 10^{-14}
a_8	3,849 393 988 3 × 10^{-12}	–2,751 290 167 3 × 10^{-17}
a_9	2,821 352 192 5 × 10^{-14}	-
a_{10}	1,425 159 477 9 × 10^{-16}	-
a_{11}	4,876 866 228 6 × 10^{-19}	-
a_{12}	1,079 553 927 0 × 10^{-21}	-
a_{13}	1,394 502 706 2 × 10^{-24}	-
a_{14}	7,979 515 392 7 × 10^{-28}	-

Table 7 – Type E reference function

Polynomial coefficient	Temperature range	
	–270 °C to 0 °C (*n* = 13)	0 °C to 1 000 °C (*n* = 10)
a_0	0,000 000 000 0 × 10^{0}	0,000 000 000 0 × 10^{0}
a_1	5,866 550 870 8 × 10^{1}	5,866 550 871 0 × 10^{1}
a_2	4,541 097 712 4 × 10^{-2}	4,503 227 558 2 × 10^{-2}
a_3	–7,799 804 868 6 × 10^{-4}	2,890 840 721 2 × 10^{-5}
a_4	–2,580 016 084 3 × 10^{-5}	–3,305 689 665 2 × 10^{-7}
a_5	–5,945 258 305 7 × 10^{-7}	6,502 440 327 0 × 10^{-10}
a_6	–9,321 405 866 7 × 10^{-9}	–1,919 749 550 4 × 10^{-13}
a_7	–1,028 760 553 4 × 10^{-10}	–1,253 660 049 7 × 10^{-15}
a_8	–8,037 012 362 1 × 10^{-13}	2,148 921 756 9 × 10^{-18}
a_9	–4,397 949 739 1 × 10^{-15}	–1,438 804 178 2 × 10^{-21}
a_{10}	–1,641 477 635 5 × 10^{-17}	3,596 089 948 1 × 10^{-25}
a_{11}	–3,967 361 951 6 × 10^{-20}	-
a_{12}	–5,582 732 872 1 × 10^{-23}	-
a_{13}	–3,465 784 201 3 × 10^{-26}	-

Table 8 – Type K reference function

Polynomial coefficient	Temperature range	
	–270 °C to 0 °C (*n* = 10)	0 °C to 1 300 °C
a_0	0,000 000 000 0 × 10^{0}	–1,760 041 368 6 × 10^{1}
a_1	3,945 012 802 5 × 10^{1}	3,892 120 497 5 × 10^{1}
a_2	2,362 237 359 8 × 10^{-2}	1,855 877 003 2 × 10^{-2}
a_3	–3,285 890 678 4 × 10^{-4}	–9,945 759 287 4 × 10^{-5}
a_4	–4,990 482 877 7 × 10^{-6}	3,184 094 571 9 × 10^{-7}
a_5	–6,750 905 917 3 × 10^{-8}	–5,607 284 488 9 × 10^{-10}
a_6	–5,741 032 742 8 × 10^{-10}	5,607 505 905 9 × 10^{-13}
a_7	–3,108 887 289 4 × 10^{-12}	–3,202 072 000 3 × 10^{-16}
a_8	–1,045 160 936 5 × 10^{-14}	9,715 114 715 2 × 10^{-20}
a_9	–1,988 926 687 8 × 10^{-17}	–1,210 472 127 5 × 10^{-23}
a_{10}	–1,632 269 748 6 × 10^{-20}	-
c_0	–	1,185 976 × 10^{2}
c_1	–	–1,183 432 × 10^{-4}

In the temperature range 0 °C to 1 300 °C, for Type K (Table 8) use equation (2) with constants c_0,c_1 as given in the above Table.

Table 9 – Type N reference function

Polynomial coefficient	Temperature range	
	−270 °C to 0 °C (*n* = 8)	**0 °C to 1 300 °C (*n* = 10)**
a_0	0,000 000 000 0 × 10^{0}	0,000 000 000 0 × 10^{0}
a_1	2,615 910 596 2 × 10^{1}	2,592 939 460 1 × 10^{1}
a_2	1,095 748 422 8 × 10^{-2}	1,571 014 188 0 × 10^{-2}
a_3	−9,384 111 155 4 × 10^{-5}	4,382 562 723 7 × 10^{-5}
a_4	−4,641 203 975 9 × 10^{-8}	−2,526 116 979 4 × 10^{-7}
a_5	−2,630 335 771 6 × 10^{-9}	6,431 181 933 9 × 10^{-10}
a_6	−2,265 343 800 3 × 10^{-11}	−1,006 347 151 9 × 10^{-12}
a_7	−7,608 930 079 1 × 10^{-14}	9,974 533 899 2 × 10^{-16}
a_8	−9,341 966 783 5 × 10^{-17}	−6,086 324 560 7 × 10^{-19}
a_9	-	2,084 922 933 9 × 10^{-22}
a_{10}	-	−3,068 219 615 1 × 10^{-26}

Table 10 – Type C reference function

Polynomial coefficient	Temperature range	
	0 °C to 630,615 °C (*n* = 6)	**630,615 °C to 2 315 °C (*n* = 6)**
a_0	0,000 000 0 × 10^{0}	4,052 882 3 × 10^{2}
a_1	1,340 603 2 × 10^{1}	1,150 935 5 × 10^{1}
a_2	1,192 499 2 × 10^{-2}	1,569 645 3 × 10^{-2}
a_3	−7,980 635 4 × 10^{-6}	−1,370 441 2 × 10^{-5}
a_4	−5,078 751 5 × 10^{-9}	5,229 087 3 × 10^{-9}
a_5	1,316 419 7 × 10^{-11}	−9,208 275 8 × 10^{-13}
a_6	−7,919 733 2 × 10^{-15}	4,524 511 2 × 10^{-17}

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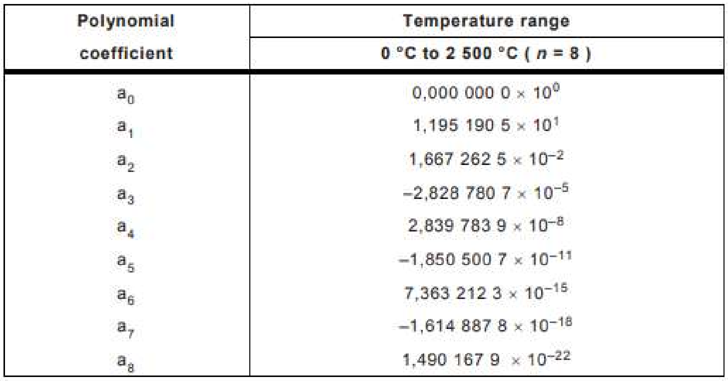
Table 11 – Type A reference function



Polynomial coefficient	Temperature range
	0 °C to 2 500 °C ($n = 8$)
a_0	$0{,}000\ 000\ 0 \times 10^{0}$
a_1	$1{,}195\ 190\ 5 \times 10^{1}$
a_2	$1{,}667\ 262\ 5 \times 10^{-2}$
a_3	$-2{,}828\ 780\ 7 \times 10^{-5}$
a_4	$2{,}839\ 783\ 9 \times 10^{-8}$
a_5	$-1{,}850\ 500\ 7 \times 10^{-11}$
a_6	$7{,}363\ 212\ 3 \times 10^{-15}$
a_7	$-1{,}614\ 887\ 8 \times 10^{-18}$
a_8	$1{,}490\ 167\ 9 \times 10^{-22}$

NOTE 2 The coefficient a_0 is here set to zero, contrary to the specification of GOST R 8.585, 2001.

C.2 Thermocouple tolerances

Thermocouple tolerances shall be as specified in Table 12. Users are cautioned that the

tolerances in Table 12 apply to new wire only and do not allow for changes in the EMF which may occur with use.

The temperature limits referred to in Table 12 are not necessarily recommended operating temperature limits. Guidance on operating temperature limits is given in Annex C

For the purpose of testing there should be no discontinuity of conductors between the measuring and the reference junction.

Table 12 – Thermocouple tolerances

Thermocouple type	Tolerance values1) (±°C) and temperature limits of validity		
	Class 1	Class 2	Class 32)
	0,5 or 0,004 × $\lvert t \rvert$	1 or 0,007 5 × $\lvert t \rvert$	1 or 0,015 × $\lvert t \rvert$
Type T3)	–40 °C to 350 °C	–40 °C to 350 °C	–200 °C to 40 °C
	1,5 or 0,004 × $\lvert t \rvert$	2,5 or 0,007 5 × $\lvert t \rvert$	2,5 or 0,015 × $\lvert t \rvert$
Type E	–40 °C to 800 °C	–40 °C to 900 °C	–200 °C to 40 °C
Type J	–40 °C to 750 °C	–40 °C to 750 °C	-
Type K	–40 °C to 1 000 °C	–40 °C to 1 200 °C	–200 °C to 40 °C
Type N	–40 °C to 1 000 °C	–40 °C to 1 200 °C	–200 °C to 40 °C
	1 for $t < 1\ 100$°C, [1 + 0,003 × (t – 1 100)] for $t > 1\ 100$ °C	1,5 or 0,002 5 × $\lvert t \rvert$	4 or 0,005 × $\lvert t \rvert$
Type R or S	0 °C to 1 600 °C	0 °C to 1 600 °C	-
Type B	-	600 °C to 1 700 °C	600 °C to 1 700 °C
	-	0,01 × $\lvert t \rvert$	-
Type C	-	426 °C to 2 315 °C	-
	-	0,01 × $\lvert t \rvert$	
Type A	-	1 000 °C to 2 500 °C	-

1) Except Type C and Type A the tolerance value is expressed either as a deviation in degrees Celsius or as a function of the temperature t (degree Celsius of ITS-90) listed above table. The greater value applies.

2) Base metal thermocouple materials are normally supplied to meet the manufacturing tolerances specified in the Table for temperatures above –40 °C. These materials, however, may not fall within the manufacturing tolerances for the lower temperature range given under Class 3 for Types E, K and N thermocouples. If thermocouples are required to meet the limits of Class 3, as well as those of Class 1 and/or Class 2, the purchaser shall state this, as selection of materials is usually required.

3) For Type T thermocouples it is unlikely that a specific material will meet the requirements of both Class 2 and Class 3 tolerances over their entire tolerance temperature range. In this case, a reduction in the ranges of validity will probably be necessary.

Tolerances and ranges of validity which differ from values given in Table 12 shall be agreed between manufacturer and user.

Annex D
(informative)

Precision of test method

D.1 General remarks and results

The determination of the precision of the test method is based on the results of the SBI round robin test series, performed in 1997 and in 2015-2016. The 1997 round robin was conducted by 15 laboratories, testing 30 products three times. The products of the 1997 round robin are presented in Table B.1. The products of the 2015-2016 round robin kindly made available by EGOLF are presented in Table B.2.

The statistical analysis was performed according to ISO 5725-1 and ISO 5725-2 on the continuous parameters ($FIGRA_{0,2\text{MJ}}$, $FIGRA_{0,4\text{MJ}}$, $THR_{600\text{s}}$, $SMOGRA$ and $TSP_{600\text{s}}$). No statistical analysis was performed on the pass-fail parameters.

Table B.1 — Products tested in the SBI round robin (1997)

Code	Product (Products are not fire retardant treated,unless specified as such (with 'FR'))	Thickness mm	Density kg/m^3	Surface weight g/m^2
M01	Paper-faced gypsum plasterboard	13	700	
M02	FR PVC	3	1 180	
M03	FR XPS	40	32	
M04	Alu/paper foil faced PUR foam panel	40	PUR: 40	
M05	Spruce laths (joinery timber), varnished	10	380	
M06	FR chip board	12	780	
M07	FR PC panel, 3-layered	16	175	
M08	Painted paper-faced gypsum plaster board	13	700	Paint: 145
M09	Paper wall covering on gypsum pl.board	13	Gyps.: 700	Paper: 200
M10	PVC wall carpet on gypsum pl.board	13	Gyps.: 700	PVC: 1 500
M11	Plastic-faced steel sheet on mineral wool	0,15 + 1 + 50	Wool: 160	
M12	Spruce laths (joinery timber), unvarnished	10	450	

M13	Gypsum plasterboard on polystyrene	13 + 100	EPS: 20	
M14	Phenolic foam	40		
M15	Intumescent coat on particle board	12	700	Paint: 500
M16	Melamine faced MDF board	12	MDF: 750	Melamine: 120
M17	PVC water pipe	diam.: 32; d: 2		
M18	PVC covered electric cables			
M19	Unfaced rockwool	50	145	
M20	Melamine faced particle board	12	680	
M21	Steel sheet on EPS	0,5 + 100	EPS: 20	
M22	Ordinary particle board	12	700	
M23	Ordinary plywood (birch)	12	650	
M24	Paper wall covering on particle board	12		Paper: 200
M25	Medium density fibreboard (1)	12	700	
M26	Low density fibreboard	12	250	
Code	Product	Thickness	Density	Surface weight
M27	Gypsum plaster board on FR PUR	13 + 87	PUR: 38	
M28	Painted acoustic mineral fibre tiles	18	Wool: 220	
M29	Textile wall paper on CaSi board	10	CaSi: 875	Textile: 400
M30	Paper-faced glass wool	100	18	90

Table B.2 — Products tested in the SBI round robin (2015–2016)

Product	Thickness	Density	Square density	Mounting
Non-fire-retardant treated particle board	12 mm	680 kg/m^3	-	Without joints and no air gap
Decorative paper based wall paper glued on plasterboard				Without joints and no air gap
Plasterboard	12,5 mm	700 kg/m^3	-	
Wallpaper	0,24 mm	-	160 g/m^2	
Wallpaper glue	-	-	250 g/m^2	

D.2 Calculation of test results

The continuous parameters were calculated from the test data using the calculations given in

Annex A of this document. However, since parts of the test and calculation procedures have been amended after the 1997 test series, a part of the 1997 test data does not meet the requirements given in Annex A. Therefore, the calculations performed with the 1997 test data are based on the method described in Annex A with the exception of the deviations given in a) to f). These deviations result in a larger set of data being available for the statistical analysis. The precision of the method calculated on the basis of this larger data set is expected to be relatively pessimistic.

a) Check of thermocouples. The round robin was carried out with two compulsory and different thermocouples instead of three. The requirement used for the two thermocouples was a maximum difference from their average temperature of 2 % in a maximum of 20 sampling points.

b) Synchronization. For tests that did not meet the synchronization requirements of Annex A, the synchronization was continued to the time t = 420 s, with decreased limit values equal to a drop of 1,5 K in temperature, 0,03 % for increase of O2 and 0,012 % drop of CO2.

c) Burner switch response time. Only tests with a determining FIGRA or SMOGRA time within the first minute and a burner response time higher than 15 s were omitted.

d) Smoke measurement. Only tests in which the light signal returns to less than 90 %, were omitted.

e) Miscellaneous requirements. The other requirements for disregarding a test were not used in this analysis, e.g. return of the O2 or CO2 signal to the start level.

f) Test period. Because of the shorter test period, all calculations were based upon values up to the time t = 1 470 s.

For the 2015-2016 round robin, the entire procedure of EN 13823:2010+A1:2014 was followed.

D.3 Statistical analysis

The calculation and the statistical analyses are based on algorithms only, which means that omission of outliers is based upon the numerical technique according to ISO 5725-2:1994, 7.3.2.

Cochran's test is repeated a maximum of four times, where the standard recommends a maximum of two times. With the fourth repetition there were still some laboratories, which were omitted for the SMOGRA value.

D.4 Statistical results

The statistical means (m) and standard deviations for repeatability and reproducibility (sr and sR) are given in Table B.4 per parameter for all 30 products tested.

Also added are the standard deviations relative to the mean values (sr/m and sR /m). Although not fully statistically justifiable the average sr /m and average sR /m give an indication of the precision of the method. In Table B.3 these averages are presented excluding the sr /m and sR /mvalues where the mean value is very small 1.

Table B.5 and Table B.6 give the sr/m and sR /m for two materials. The results are kindly shared by EGOLF, organizer of the round robin exercise that lies on the basis of these results.

Table B.3 — Average relative standard deviations (1997)

	$FIGRA_{0,2MJ}$	$FIGRA_{0,4MJ}$	THR_{600s}	$SMOGRA$	TSP_{600s}
Average (s_r /m)	14 %	15 %	11 %	15 %	18 %
Average (s_R /m)	23 %	25 %	21 %	40 %	44 %

Table B.4 — Statistical results (1997)

FIGRA 0.2MJ	[W/s]																													
	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
No. of laboratories	14	14	15	14	13	14	14	14	15	13	15	14	12	15	15	15	14	14	10	14	12	14	14	13	12	13	15	10	13	14
Mean value (m)	21	81	1375	1869	681	25	1028	16	202	380	78	440	9	82	16	601	92	435	1	381	21	404	399	479	436	1103	17	0	162	4073
No. of tests	41	40	41	41	38	42	40	39	40	38	44	41	35	45	45	42	40	39	30	39	30	40	42	39	36	35	38	29	38	42
s_r	19	14	174	229	64	3	474	17	28	34	24	47	18	14	14	66	14	42	1	30	17	26	38	40	24	93	16	0	22	456
s_R	23	20	753	229	96	11	963	20	30	51	27	79	20	22	14	83	20	133	2	50	25	49	58	58	35	196	19	0	29	679
s_r/m	89	18	13	12	9	14	46	102	14	9	30	11	210	17	84	11	16	10	200	8	84	7	10	8	6	8	92		13	11
s_R/m	106	25	55	12	14	43	94	122	15	13	35	18	228	27	84	14	22	31	269	13	127	12	14	12	8	18	108		18	17

$FIGRA_{0,4MJ}$ [W/s]

	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15
No. of laboratories	13	14	15	14	13	14	14	14	15	13	13	14	8	14	15
Mean value (m)	8	73	1375	1869	681	21	1027	6	154	374	33	440	0	49	14
No. of tests	38	40	41	41	38	42	40	38	43	38	38	41	23	42	45
s_r	9	12	174	229	64	3	475	7	31	36	11	47	0	8	7
s_R	12	21	753	229	96	9	964	9	34	53	11	79	0	13	7
s_r/m	121	17	13	12	9	16	46	110	20	9	33	11		16	52
s_R/m	148	29	55	12	14	43	94	143	22	14	33	18		26	54

	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
No. of laboratories	15	14	14	14	14	11	14	14	13	12	13	15	13	14	13
Mean value (m)	601	92	435	3	381	11	404	399	479	436	1103	6	1	108	3923
No. of tests	42	40	39	42	39	27	40	42	39	36	35	38	37	40	39
s_r	66	15	42	4	30	13	26	38	40	24	93	5	4	34	309
s_R	83	21	133	6	50	17	49	58	58	35	196	7	4	39	630
s_r/m	11	16	10	134	8	115	7	10	8	6	8	81	439	32	8
s_R/m	14	23	31	181	13	152	12	14	12	8	18	114	439	36	16

THR_{600s} [MJ]																														
	M 01	M 02	M 03	M 04	M 05	M 06	M 07	M 08	M 09	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29	M 30
No. of laboratories	15	14	15	13	14	15	14	14	15	14	15	13	14	15	15	5	14	13	15	14	13	13	15	12	12	12	15	15	13	14
Mean value (m)	1,0	5,9	40,5	28,6	15,1	2,3	17,2	0,8	1,4	6,5	1,2	15,7	0,8	3,2	1,9	24,0	9,4	45,4	0,7	20,1	1,3	26,9	21,7	26,7	33,4	39,7	0,7	0,7	1,9	6,7
No. of tests	44	41	42	38	42	45	41	42	44	41	45	39	41	45	45	43	41	36	45	39	36	37	45	36	36	34	43	43	37	42
s_r	0	2	7	1	1	0	3	0	0	0	0	1	0	0	1	2	3	2	0	2	2	1	2	1	1	3	1	0	0	1
s_R	1	2	17	4	2	1	12	0	0	1	1	2	1	1	1	2	4	10	1	2	2	2	4	2	2	5	1	0	0	1
s_r/m	38	35	18	5	9	10	19	33	27	7	36	8	51	9	50	7	35	5	58	10	151	4	9	5	4	7	72	38	22	8
s_R/m	61	35	41	13	11	33	70	51	34	17	48	13	69	17	58	9	39	23	95	11	151	8	18	7	6	13	72	47	22	13

SMOG RA	[m²/s²]																													
	M 01	M 02	M 03	M 04	M 05	M 06	M 07	M 08	M 09	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29	M 30
No. of laboratories	10	12	9	11	11	13	11	10	12	13	11	14	9	11	9	12	11	6	11	9	12	11	12	8	8	9	12	10	8	14
Mean value (m)	0	120	216	212	2	12	167	0	0	114	67	3	0	1	1	1	224	109	0	2	5	3	1	2	1	9	0	0	0	3
No. of tests	28	31	22	29	28	36	28	29	34	36	31	37	25	31	27	27	27	14	33	26	27	25	36	17	20	21	35	29	22	41
s_r	0	17	21	26	1	1	58	0	0	14	6	1	0	0	1	1	21	17	0	0	2	1	1	0	1	6	0	0	0	3
s_R	0	32	80	36	2	5	169	0	0	37	19	2	1	1	1	1	56	61	0	2	5	2	1	2	1	7	1	0	0	6
s_r/m		14	10	12	38	10	35	272	198	12	9	31	10	46	86	73	9	16		14	36	42	80	10	72	68	79			108
s_R/m		27	37	17	90	38	101	381	249	32	29	72	360	143	153	118	25	56		54	102	63	110	97	102	71	131			155

TSP_{600s} [m²]																														
	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
No. of laboratories	14	12	9	11	12	12	11	14	15	15	11	14	13	13	14	12	12	6	12	11	12	10	12	8	9	9	13	15	12	14
Mean value (m)	29	937	1057	410	45	101	531	29	30	164	108	47	34	43	55	24	1629	458	26	39	44	29	19	18	20	79	30	31	31	43
No. of tests	40	32	23	29	30	34	29	41	44	42	31	38	34	37	41	27	29	14	36	31	26	22	36	19	22	21	38	44	34	41
s_r	3	136	208	38	8	5	94	5	5	16	13	10	8	6	5	7	289	49	3	8	11	8	4	7	10	39	5	7	6	10
s_R	12	198	474	60	22	28	412	17	16	47	33	22	22	22	24	16	391	122	10	17	20	19	12	18	15	57	12	12	15	22
s_r/m	12	17	20	9	18	5	18	17	17	10	12	20	22	14	10	30	18	11	13	20	25	27	23	36	48	49	17	22	20	24
s_R/m	41	21	45	15	50	28	78	59	53	28	30	46	64	52	44	68	24	27	38	42	45	65	66	99	77	71	41	37	47	51

Table B.5 — Statistical results from testing of particle board (2015–2016)

	No. of laboratories	No. of tests	General mean value, m	Repeatability		Reproducibility	
				standard deviation s_r	s_r/m	standard deviation s_R	s_R/m
$FIGRA_{0.2}$	29	86	405	27	7 %	52	13 %
$FIGRA_{0.4}$	29	86	405	27	7 %	52	13 %
THR_{600s}	29	86	21,9	1,2	5 %	2,4	11 %
SMOGRA	27	80	4	1	28 %	2	51 %
TSP_{600s}	27	80	49	7	15 %	18	35 %

Table B.6 — Statistical results from testing of wallpaper on gypsum board (2015–2016)

	No. of laboratories	No. of tests	General mean value, m	Repeatability		Reproducibility	
				standard deviation s_r	s_r/m	standard deviation s_R	s_R/m
$FIGRA_{0.2}$	29	86	101	12	12 %	22	21 %
$FIGRA_{0.4}$	29	86	57	15	26 %	24	43 %
THR_{600s}	27	80	1,3	0,2	14 %	0,3	25 %
SMOGRA	26	77	0,2	0,2	89 %	1,0	512 %
TSP_{600s}	27	80	26	3	10 %	12	46 %

Annex E
(informative)

Calibration procedures

E.1 Procedures for separate pieces of equipment

E.1.1 General

Instruments shall be maintained and calibrated in accordance with the manufacturer's specification.

Gas concentration percentages are represented by

$100\ V_{O2}/V_{air}$ and $100\ V_{CO2}/V_{air}$

where

V_{O2} or V_{CO2} is the volume of oxygen or CO_2 present in a volume V_{air} of air.

E.1.2 Oxygen analyser adjustment

The oxygen analyser shall be adjusted for zero and span, each day on which tests are performed.

The span width shall be within 0,04 % of the width defined by the calibration gases used, and expressed as % VO2/Vair. The analyser output for dried ambient air shall be (20,95 ± 0,01) %. A possible procedure to perform the adjustment is given in D.1.2.

E.1.3 Oxygen analyser output noise and drift

E.1.3.1 General

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

E.1.3.2 Procedure

The procedure for checking the noise and drift of the oxygen analyser output shall be as follows:

Range of analyser should be at least 16 Vol% to 21 Vol%.

a) Calibrate the analysers.

b) Set the volume flow in the exhaust duct to (0,60 ± 0,05) m3/s.

c) Switch to sampling air from the exhaust duct with the same flow rate, pressure and drying procedure as for sample gases. When the analyser reaches equilibrium, adjust the analyser output to (20,95 ± 0,01) %.

d) Start recording the oxygen analyser output at 3 s intervals for a period of 30 min.

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

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

E.1.3.3 Criteria

The sum of drift and noise (both taken as positive values) shall be not more than 0,01 % (VO2/Vair).

E.1.3.4 Calibration report

The calibration report shall include the following information:

a) the graphs of O2(t) in % VO2/Vair;

b) the noise and drift values calculated according to C.1.3.2, d) and e) in % VO2/Vair.

E.1.4 Carbon dioxide analyser adjustment

The carbon dioxide analyser shall be adjusted for zero and span each day on which tests are performed. The span width shall be within 0,1 % VCO2/Vair of the width defined by the calibration gases used. The analyser output for carbon dioxide-free nitrogen gas shall be (0,00 ± 0,01) %.

Alternatively, the analyser can use dry ambient air and the output shall be (0,04 ± 0,01) %. A possible procedure to perform the adjustment is given in D.1.3.

E.1.5 Light system calibration

E.1.5.1 General

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

E.1.5.2 Stability check

Perform the following steps with the measuring equipment operating and with the trolley (excluding specimen, including backing boards) in the frame, under the hood.

a) Set the volume flow of the exhaust to: V298 = (0,60 ± 0,05) m3/s [calculated in accordance with A.5.1.1 a)].

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

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

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

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

E.1.5.3 Optical filter check

The light system shall be calibrated with at least five neutral density filters in the optical density range of 0,05 to 2,0. The optical density calculated with the measured light receiver signal shall be within either ± 5 % or ± 0,01 of the actual value of the filters, whichever represents a wider tolerance. A possible procedure to perform the calibration is given in D.1.5. The neutral density filters used for calibration shall have dispersed attenuant. Coated filters shall not be used.

E.2 System response calibrations

E.2.1 Burner switch response time

The burner switch response time is the difference between t_{up} and t_{down}, where:

t_{up} is the time of the first data point at which the oxygen concentration has passed the “90% burner output level” in the upwards direction after t = 270 s; and

t_{down} is the time of the first data point thereafter at which the oxygen concentration has passed the same level in the downwards direction.

$$xO_2(t_{up}) > 0,1\overline{xO_2}(30\,\mathrm{s}...90\,\mathrm{s}) + 0,9\overline{xO_2}(210\,\mathrm{s}...270\,\mathrm{s}) \qquad (C.1)$$

$$t_{down} > t_{up} \wedge xO_2(t_{down}) < 0,1\overline{xO_2}(30\,\mathrm{s}...90\,\mathrm{s}) + 0,9\overline{xO_2}(210\,\mathrm{s}...270\,\mathrm{s}) \qquad (C.2)$$

Criterion:

$$9\,\mathrm{s} \leq t_{down} - t_{up} \leq 12\,\mathrm{s} \qquad (C.3)$$

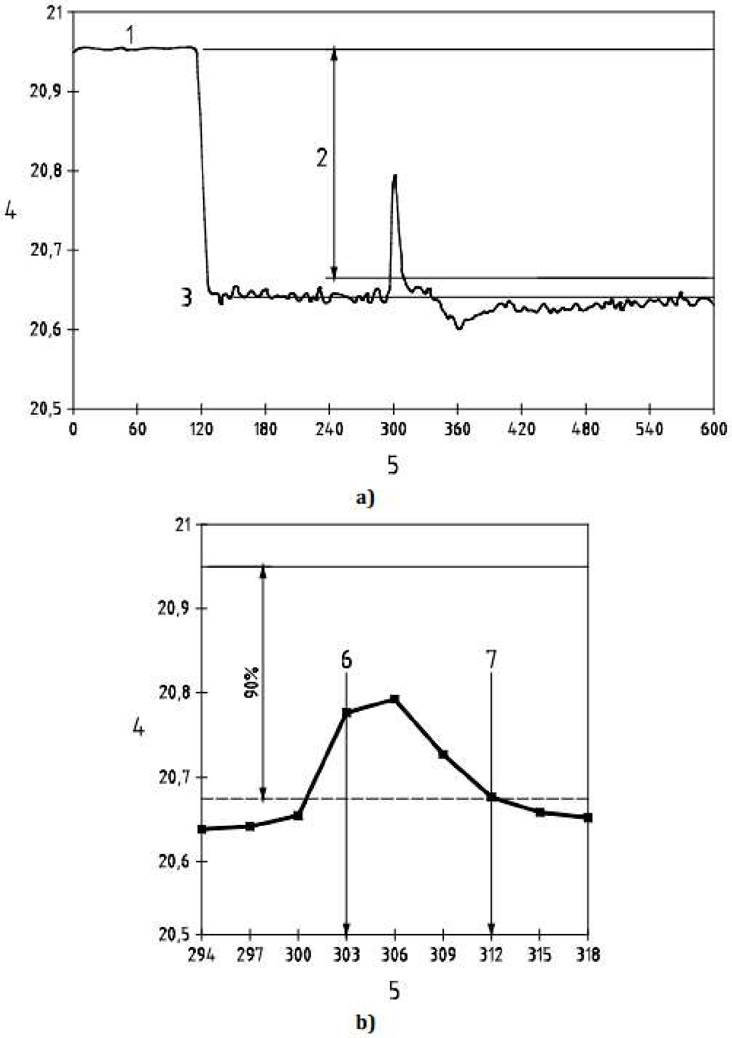
where

$xO_2(t)$ is the oxygen concentration in mole fraction.

NOTE 1 The data are synchronized to t = 300 s. Time tup is equal to 300 s or 303 s, therefore tdown is never later than t = 315 s. Meeting the criterion is of major importance for the correct assessment of FIGRA and SMOGRA values.

During the switch from auxiliary (secondary) burner to main (primary) burner (at t approximately 300 s), for a short time, the total heat output from both burners is lower than the standard heat output of one burner. As a consequence, the heat release rate has a dip and the oxygen level has a peak (see Figure C.1). The peak in xO2 is about 25 % to 50 % of the contribution of one burner. The width of the peak should be small since this “missing” heat output is subtracted from the heat output of the specimen as described below. The peak width is measured at a level of 90 % of the normal burner contribution, and is called the burner switch response time. In the example presented in Figure C.1, the response time is 9 s.

NOTE 2 The 90 % burner output level is calculated as 90 % of the step from the test start level to the base line level, added to the test start level. The oxygen test start level used here is the average oxygen concentration before ignition of the burners (30 s ≤ t ≤ 90 s). The oxygen base line level is the average oxygen concentration during burning of the auxiliary (secondary) burner (210 s ≤ t ≤ 270 s).



a)

b)

Key

1	start level
2	90 % of normal burner contribution
3	base line level
4	oxygen concentration in percentage
5	time (s)
6	t_{up} (= 303 s)
7	t_{down} (= 312 s)

Figure C.1 — Oxygen concentration during the first part of the test

NOTE 3 Main events: (1) auxiliary (secondary) burner on at t approximately 120 s; (2) switch from auxiliary (secondary) burner to main (primary) burner at t approximately 300 s. The time interval around

t = 300 s is magnified in Figure C.1 b). The calculated burner response time is 9 s in this case.

E.2.2 Burner heat output step calibration

E.2.2.1 General

This calibration procedure uses the standard burner at three different levels of heat output. It is used to determine the response and delay time of the gas analysers, the burner switch response time, the thermocouples' response time and the conversion factor for calculation of the heat release rate. This calibration procedure shall be performed at least once a month or after 30 tests, whichever occurs first.

NOTE As part of the system calibration process, the response times of the gas analysers are determined using relatively large step changes in heat release of around 30 kW and 60 kW, which represents changes in oxygen concentrations of about 0,3 % (v/v) and 0,6 % (v/v). The measured response times are influenced by preset damping factors of the analysers.

It should be noted that some gas analysers utilize additional damping factors when measuring relatively small (typically in the order of 100 ppm) changes in gas concentration. This additional damping factor can be used to eliminate noise but the bandwidth should not be so large as to adversely affect the response time of the system.

E.2.2.2 Procedure

Perform the following steps with the measuring equipment operating and with the trolley (excluding specimen, including backing boards) in the frame, under the hood.

a) Set the volume flow of the exhaust to: V298 = (0,60 ± 0,05) m3/s [calculated in accordance with A.5.1.1 a)]. This volume flow shall be between 0,65 m3/s and 0,50 m3/s during the total calibration period.

b) Record the temperatures T1, T2 and T3 in the exhaust duct and the ambient temperature during at least 300 s. The ambient temperature shall be within (20 ± 10) °C, and the temperatures in the duct shall not differ by more than 4 °C from the ambient temperature.

c) Record the pre-test conditions on the record sheet. The data to be recorded are given in 8.3.2.

d) Start the time measurement and the automatic recording of data: at this point t = 0 s, by definition. The data to be recorded every 3 s are t, mgas, xO2, xCO2, Δp and T0 to T3, according to 8.4.

e) Ignite the auxiliary (secondary) burner and adjust the propane mass flow in accordance with Table C.1 within the first 5 s of each step.

Table C.1 — Propane supply to the auxiliary (secondary) burner

Step Number	Time min	Propane mass flow in auxiliary burner mg/s
1	0 to 2	0
2	2 to 5	647 ± 50

f) Switch the propane supply from the auxiliary (secondary) burner to the main (primary) burner, and adjust the propane mass flow in accordance with Table C.2 within the first 5 s of each step.

Table C.2 — Propane supply to the main (primary) burner

Step Number	Time min	Propane mass flow in main (primary) burner mg/s
3	5 to 8	647 ± 50
4	8 to 11	2 000 ± 100
5	11 to 14	647 ± 50
6	14 to 17	0

g) Stop the automatic recording of data at the end of step 6.

h) Record the end of test conditions. The data to be recorded are given in 8.3.5.

NOTE 1 The burner produces approximately 0 kW, 30 kW and 93 kW at the requested propane mass flow levels.

NOTE 2 The margins used in the mass flow settings are larger than in the test procedure to allow for fast adjustments in the mass flow.

E.2.2.3 C.2.2.3Calculations

Based on the unshifted data, calculate:

a) for each step, except step 3:

1. t_{gas} the start time of the step as the time of the first data point at which the propane flow has changed by 100 mg/s in comparison with the mean value in the last 2 min of the previous step;
2. t_T the time of the first data point at which the temperature T_{ms} has changed 2,5 K in comparison with the mean value in the last 2 min of the previous step;
3. t_{O2} the time of the first data point at which the oxygen concentration has changed 0,05 % in comparison with the mean value in the last 2 min of the previous step;
4. t_{CO2} the time of the first data point at which the carbon dioxide concentration has changed 0,02 % in comparison with the mean value in the last 2 min of the previous step;
5. $t_{O2,10\,\%}$ the time of the first data point at which the oxygen concentration has reached 10 % of its deflection using the mean values in the last 2 min of the previous and the current step;
6. $t_{O2,90\,\%}$analogous to $t_{O2,10\,\%}$, however for 90 % instead of 10 % deflection;
7. $t_{CO2,10\,\%}$ the time of the first data point at which the carbon dioxide concentration has reached 10 % of its deflection using the mean values in the last 2 min of the previous and the current step;
8. $t_{CO2,90\,\%}$ analogous to $t_{CO2,10\,\%}$, however for 90 % instead of 10 % deflection;
9. $t_{T,10\,\%}$ the time of the first data point at which the temperature T_{ms} has reached 10 % of its deflection using the mean value in the last 15 s of the previous step and the mean value between 15 s and 30 s after the start of the current step;
10. $t_{T,75\,\%}$ analogous to $t_{T,10\,\%}$, however for 75 % instead of 10 % deflection;

b) the delay time of the oxygen analyser as the mean of $t_{O2} - t_T$ found for steps 4, 5 and 6;

c) the delay time of the carbon dioxide analyser as the mean of $t_{CO2} - t_T$ found for steps 4, 5 and 6;

d) the response time of the oxygen analyser as the mean of $t_{O2,90\,\%} - t_{O2,10\,\%}$ found for steps 4, 5 and 6;

e) the response time of the carbon dioxide analyser as the mean of $t_{CO2,90\,\%} - t_{CO2,10\,\%}$ found for steps 4, 5 and 6;

f) the burner switch response time as specified in C.2.1;

g) the temperature response time as the mean of $t_{\mathrm{T},75\,\%} - t_{\mathrm{T},10\,\%}$ found for steps 2, 4, 5 and 6;

h) $q_{\mathrm{gas}}(t)$ and $q_{\mathrm{gas,30s}}(t)$, in accordance with A.7;

i) the mean value of $q_{\mathrm{gas}}(t)$ according to h) during the two minutes in the middle (starting 30 s after switching to the next gas flow value) of steps 2, 3 and 5 ($q_{\mathrm{gas,step2}}$, $q_{\mathrm{gas,step3}}$ and $q_{\mathrm{gas,step5}}$).

Shift the O_2 and CO_2 data backwards in time in accordance with the analyser delay times found, and calculate:

j) $HRR(t)$, equal to $HRR_{\mathrm{total}}(t)$ in accordance with A.5.1.1 but with E = 16 800 kJ/m^3 (value for propane);

k) $HRR_{\mathrm{30s}}(t)$, in accordance with A.5.1.4, using $HRR(t)$ in accordance with j);

l) the average values of $HRR(t)$ in accordance with k) during the two minutes in the middle of steps 2, 3 and 5 (HRR_{step2}, HRR_{step3} and HRR_{step5});

m) the flow profile factor $k_{\mathrm{t,qgas}}$, as:

$$k_{t,\mathrm{qgas}} = k_{t'} \cdot \frac{q_{\mathrm{gas,step2}} + q_{\mathrm{gas,step3}} + q_{\mathrm{gas,step5}}}{\mathrm{HRR}_{\mathrm{step2}} + \mathrm{HRR}_{\mathrm{step3}} + \mathrm{HRR}_{\mathrm{step5}}} \tag{C.4}$$

where

$k_{\mathrm{t,qgas}}$	is the flow profile factor adjusted to the propane energy content;
$k_{\mathrm{t'}}$	is the flow profile factor used for the calculation of *HRR* in j);
$HRR_{\mathrm{step}x}$	is the heat release rate of the burner at step *x*, in accordance with l), in kilowatts;
$q_{\mathrm{gas,step}x}$	is the rate of production of energy from the propane mass flow in step *x*, in accordance with i), in kilowatts.

NOTE 1 The delay and response time of the analysers in step 2 are used as a check. The difference with the time delays in steps 4, 5 and 6 can point to additional time delay(s) in the propane supply system.

NOTE 2 The temperature response time is calculated to check for dysfunction of, and soot deposits on the thermocouples. The criterion for the thermocouple response time takes account of the influence of the thermal response of the exhaust system as a whole.

E.2.2.4 Criteria

The following criteria shall be met:

a) the delay time of both analysers shall not exceed 30 s;

b) the response time of both analysers shall not exceed 12 s;

c) the burner switch response time shall not exceed 12 s;

d) the temperature response time shall not exceed 6 s;

e) the equipment response shall meet the criteria of A.3.2 and A.3.3; the end values in A.3.2 and A.3.3 shall be taken as the mean over the last 30 s of step 6;

f) the ratio $q_{\text{gas30s}}(t)/HRR_{\text{30s}}(t)$ shall continuously be within (100 ± 5) % during the intervals between 40 s and 160 s after the start of steps 2, 3, 4 and 5. For the start of steps 2, 4 and 5, t_T is used; the start of step 3 is taken as t = 300 s;

g) the averages HRR_{step2} and HRR_{step3} according to C.2.2.3 shall not differ by more than 0,5 kW.

E.2.2.5 Calibration report

The calibration report shall include the following information:

a) the graphs of $q_{\text{gas}}(t)/HRR(t)$ and $q_{\text{gas,30s}}(t)/HRR_{\text{30s}}(t)$;

b) the maximum and minimum of the ratio $q_{\text{gas30s}}(t)/HRR_{\text{30s}}(t)$ during each of the four intervals according to C.2.2.4, f);

c) the delay and response times of both analysers;

d) the burner switch response time;

e) the temperature response time;

f) the value of $q_{\text{gas,stepx}}$, and HRR_{stepx}, for steps 2, 3 and 5;

g) the value of k_t used in the $HRR(t)$ calculation;

h) the value of $k_{t,\text{qgas}}$.

E.2.3 Heptane calibration

E.2.3.1 General

The calibration shall be performed before a test is conducted after set up, maintenance, repair or replacement of the measurement system holder or other major components of the exhaust system and at least once a year. The measurements are made using:

a) circular open steel fuel tray of internal diameter (350 ± 5) mm, with an internal wall height of 152 mm and a wall thickness of 3 mm; and

b) n-heptane (>99 % purity).

E.2.3.2 Procedure

Perform the following steps with the measuring equipment operating and with the trolley (excluding specimen, including backing boards) in the frame, under the hood.

a) Set the volume flow of the exhaust to: V_{298} = (0,60 ± 0,05) m^3/s (calculated in accordance with A.5.1.1 a)). This volume flow shall be within the range 0,65 m^3/s to 0,50 m^3/s during the total calibration period.

b) Record the ambient temperature T_0 and the temperatures T_1, T_2 and T_3 in the exhaust duct during at least 300 s. Measure the surface temperature of the fuel tray. The ambient temperature shall be within (20 ± 10) °C. The temperatures in the duct and the temperature of the fuel tray shall not differ by more than 4 °C from the ambient temperature.

c) The fuel tray is placed over the trolley platform, on a standard calcium silicate board with dimensions of 400 mm × 400 mm. Supports of 100 mm high raise the calcium silicate board above the conduit that runs diagonally across the floor of the trolley. The fuel tray is positioned such that the distance between the internal corner of the specimen holder and the side wall of the fuel tray is 500 mm. When positioned correctly, the side wall of the fuel tray is at least 300 mm from both the back and side panels.

d) Pour (2 000 ± 10) g of water into the fuel tray.

e) Record the pre-test conditions on the record sheet. The data to be recorded are given in 8.3.2.

f) Start the time measurement and the automatic recording of data: at this point $t = t_0$, by definition. The data to be recorded every 3 s are t, m_{gas}, xO_2, xCO_2, Δp, T_0 to T_3 and the signal from the light receiver, in accordance with 8.4.

g) Wait at least 2 min then gently pour (2 840 ± 10) g of n-heptane onto the water in the fuel tray.

h) Wait at least 1 min, then ignite the n-heptane (t_1).

i) When the burning ceases, the data recording is continued for a further 5 min and then stopped (t_2).

j) Record the end of test conditions. The data to be recorded are given in 8.3.5.

E.2.3.3 Calculations

Calculate the following quantities:

a) the total smoke production *TSP* in accordance with A.6 over the time interval between t_1 and t_2. The *TSP* is then divided by the mass of fuel used (m);

b) the total heat release *THR* in accordance with A.5 over the time interval between t_1 and t_2. The heat release calculation (A.5.1.1) shall be carried out using an E value of 16 500 kJ/m^3 (value for n-heptane). The *THR* is then divided by the mass of fuel used (m);

c) the flow profile factor $k_{t,\text{qheptane}}$, as:

$$k_{t,\text{qheptane}} = k_{t'} \frac{Y}{\text{THR}} \tag{C.5}$$

where

$k_{t,\text{qheptane}}$	is the flow profile factor adjusted to the n-heptane energy content;
$k_{t'}$	is the flow profile factor used for calculation of *THR* in b);
THR	is the total heat release of n-heptane, in accordance with b), in megajoules per kilogram;
Y	is the energy content of n-heptane, = 44,56 MJ/kg.

E.2.3.4 Criteria

The following criteria shall be met:

a) the ratio *THR*/*m* (MJ/kg) shall be 44,56 MJ/kg ± 5 %;

b) at t_2, the signal from the light receiver shall be within 1 % of its initial value (i.e. between 99 % and 101 % of I(30 s…90 s));

c) the equipment response shall meet the criteria of A.3.2 and A.3.3.

The ratio *TSP*/*m* (m^2/kg) can be used as an indication for the performance of the smoke measurement system. Its value should be (125 ± 25) m^2/kg.

E.2.3.5 Calibration report

The calibration report shall include the following information: a) the graphs of
SPR(t) and *HRR*(t);

a) the ratios *TSP*/*m* and *THR*/*m*;

b) the values of k_t used in the *HRR*(t) calculation and of $k_{t,\text{qheptane}}$.

E.2.4 Velocity profile factor $k_{t,v}$

E.2.4.1 General

The $k_{t,v}$ factor shall be measured after set up, maintenance, repair or replacement of the hemispherical 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.

E.2.4.2 Measurement specifications

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, ten times when traversing outwards from the centre, and ten times when traversing inwards to the centre. It is not necessary to record the 10 measurements if a suitable anemometer is used which automatically measures and calculates a suitable mean value.

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 and 1,000 (centre). The positions are indicated in Figure C.2.

NOTE For the duct diameter used (315 mm), these positions are (in millimetres from the centre): 0 mm; 43,7 mm; 89,1 mm; 109,5 mm; 133,4 mm; 151,5 mm.

Dimensions in millimetres

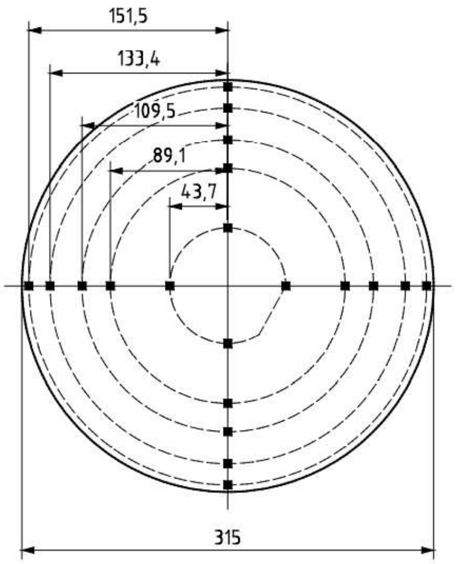


Figure C.2 — Section of the exhaust duct – Positions for measurement of the gas velocity

E.2.4.3 Actions

Perform the following steps:

a) Set the volume flow of the exhaust to: V_{298} = (0,60 ± 0,05) m^3/s [as calculated in accordance with A.5.1.1, a)].

b) Record the temperatures T_1, T_2 and T_3 in the exhaust duct and the ambient temperature for at least 300 s. The ambient temperature shall be within (20 ± 10) °C, and the temperatures in the duct shall not differ by more than 4 °C from the ambient temperature.

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.

E.2.4.4 Calculation of $k_{t,v}$

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 $k_{t,v}$ is then:

$$\frac{1}{5}\sum\frac{v_N}{v_C}$$

E.2.4.5 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 $k_{t,v}$.

E.2.5 Flow factor k_t

The k_t factor (used for the calculation of the heat release rate in A.5.1) shall be calculated as the average of the three values $k_{t,v}$, $k_{t,qgas}$, and $k_{t,qheptane}$ which shall meet the following criteria:

$$k_t = (k_{t,v} + k_{t,qgas} + k_{t,qheptane}) / 3 \quad \text{(C.6)}$$

Criteria:

$| (k_t - k_{t,v}) / k_t | \leq 5\ \%$

$| (k_t - k_{t,qgas}) / k_t | \leq 5\ \%$

$| (k_t - k_{t,qheptane}) / k_t | \leq 5\ \%$

Where:

$k_{t,v}$ is the velocity profile factor measured in accordance with C.2.4;

$k_{t,qgas}$ is the flow profile factor calculated in accordance with C.2.2;

$k_{t,qheptane}$ is the flow profile factor calculated in accordance with C.2.3.

Historical development of each of the k_t values should be monitored. Changes can be used as a warning signal that an overhaul of the duct system equipment and instrumentation may be required.

Annex F
(informative)

Calibration procedures

F.1 Procedures for separate pieces of equipment

F.1.1 General

This clause includes calibration procedures that meet the performance-based calibration requirement they referto.

Gas concentration percentages are represented by 100 V_{O2}/V_{air} and 100 V_{CO2}/V_{air}.

F.1.2 Oxygen analyser adjustment

The oxygen analyser may be adjusted using the following procedure.

a) For zeroing, feed the analyser with oxygen-free nitrogen gas, with the same flow rate and pressure as for sample gases. When the analyser reaches equilibrium, adjust the analyser output to (0,00 ± 0,01) %.

b) For the span calibration either dried ambient air or a specified gas with an oxygen content of (21,0 ± 0,1) % may be used. If ambient air is used for the span calibration the exhaust system should be running at (0,6 ± 0,05) m^3/s during the entire calibration. If a specified gas is used, the exhaust system is not needed. When the analyser reaches equilibrium, adjust the analyser output to (20,95 ± 0,01) % if dried air is used and to within 0,01 % of the actual oxygen content if the specified gas is used.

NOTE For certain analysers the terms zero and span can have a different meaning, e.g. for analysers with a smaller range than 0 % to 21 % oxygen. In these cases, calibration gases within the range of the analysers can be used.

F.1.3 Carbon dioxide analyser adjustment

The carbon dioxide analyser may be adjusted using the following procedure.

a) For zeroing, feed the analyser with carbon dioxide-free nitrogen gas, with the same flow rate and pressure as for sample gases. When the analyser reaches equilibrium, adjust the analyser output to (0,00 ± 0,01) %.

b) For span calibration a specified gas with a carbon dioxide content between 5 % and 10 % should be used. Feed the analyser with the gas, with the same flow rate and pressure as for sample gases. When the analyser reaches equilibrium, adjust the analyser output to the carbon dioxide content of the specified gas ± 0,01 %.

F.1.4 Check of propane mass flow controller

F.1.4.1 General

The accuracy of the mass flow controller may be checked by using a single cylinder of propane and the main (primary) burner at the propane mass flow rate as used during standard tests (647 ± 10) mg/s. The gas usage rate is determined from the initial and final mass of the gas cylinder. Use a balance or weighing platform with an accuracy of 5 g or better.

F.1.4.2 .4.2Procedure

a) Place the cylinder on the weighing platform and connect it to the supply system.

b) Set up the test facility as in a standard calibration test with backing boards fitted. Ignite the main (primary) burner and adjust the gas supply to (647 ± 10) mg/s, to have the main (primary) burner running at the standard rate as used during standard tests.

c) Record the mass of the cylinder and simultaneously start a timing device.

d) After (3 600 ± 30) s, again record the mass of the cylinder and simultaneously stop the timing device.

e) Determine the average rate of usage of gas in milligrams per second.

D.1.4.3Criterion

The average rate of usage of gas set in b) and determined in e) should be equal to within 6 mg/s.

F.1.5 Optical filter check

F.1.5.1 General

The light system may be calibrated using the following procedure.

F.1.5.2 Procedures

Perform the following steps with the measuring equipment operating and with the trolley (excluding specimen, including backing boards) in the frame, under the hood.

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

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

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

d) Introduce one of the following filters with optical density (*d*) equal to 0,1, 0,3, 0,5, 0,8, 1,0 and 2,0 and record the corresponding signal for at least 1 min.

e) Repeat step d) for the other filters.

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

F.1.5.3 Criterion

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

NOTE The theoretical transmission values for the given *d* values 0,1, 0,3, 0,5, 0,8, 1,0 and 2,0 using the given equation are 79,43 %, 50,12 %, 31,62 %, 15,85 %, 10 % and 1 %.

F.2 Check of the thermal attack on the specimens

F.2.1 General

The repeatability of the heat flux on the specimens should be checked after set up, maintenance, repair or replacement of the main (primary) burner or other major components that may influence the flames of the burner, by measuring the heat flux in the following three positions on the long wing:

— position 1: 8 cm from the corner and 16 cm from the upper edge of the burner;

— position 2: 8 cm from the corner and 75 cm from the upper edge of the burner;

— position 3: 20 cm from the corner and 30 cm from the upper edge of the burner.

For regular calibrations, or if there is a modification of the burner (for example: the old sand is replaced by a new sand), a measurement of the heat flux at position 3 is sufficient.

This check is performed with a large wing calcium silicate backing board (see 4.4.10) having three holes (diameter = 26 mm) at the positions given.

F.2.2 Procedure

Before ignition of the burner, place a heat flux meter in one of the holes in the long wing backing board (with the small wing backing board being also in place), and close the other holes.

The heat flux meter should be a 25,4 mm diameter Schmidt-Boelter which is calibrated between 0 kW/m^2 and 100 kW/m^2. The flux meter should be cooled by water at a temperature above 20 °C. The flux meter black body surface should be on the backing board surface.

With the SBI apparatus working under normal conditions (see 8.2), record the heat flux for 5 min after the ignition of the burner. Then calculate the mean of the heat flux measured between 240 s and 300 s after ignition.

After set up, maintenance, repair or replacement of the main (primary) burner or other major components that may influence the flames of the burner, repeat the measurement five times. Calculate the mean of the results of the five measurements for each position. The relative standard deviation should be less than 4 %.

For regular calibrations (in position 3), one measurement is sufficient. If the deviation between this result and the mean of the means of the five replicant measurements is more than 4 %, check the burner or other parts of the apparatus and perform a measurement five times in the three positions.

Annex G
(informative)

Design drawings

Dimensions in millimetres

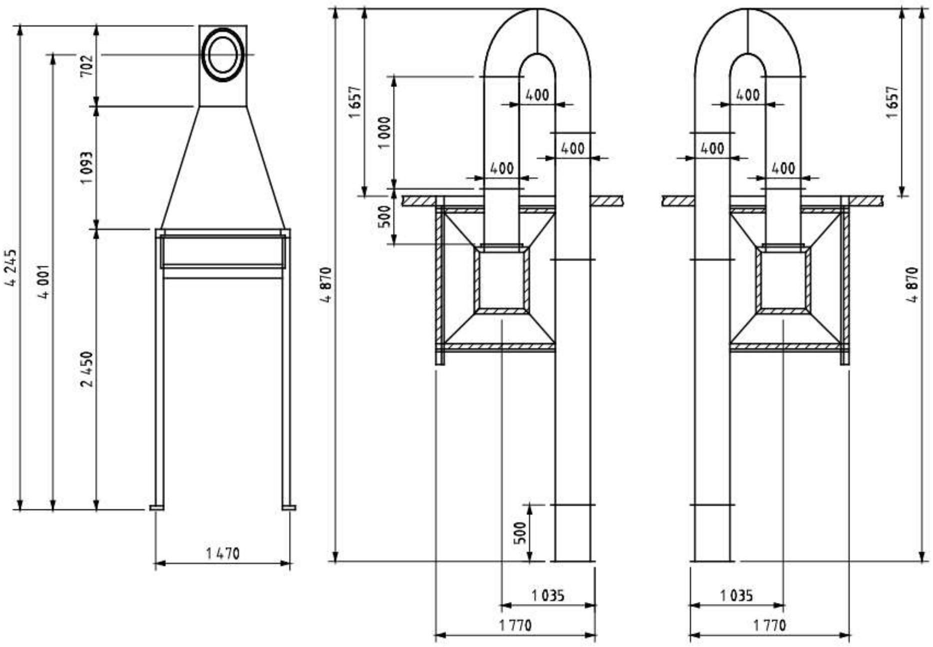
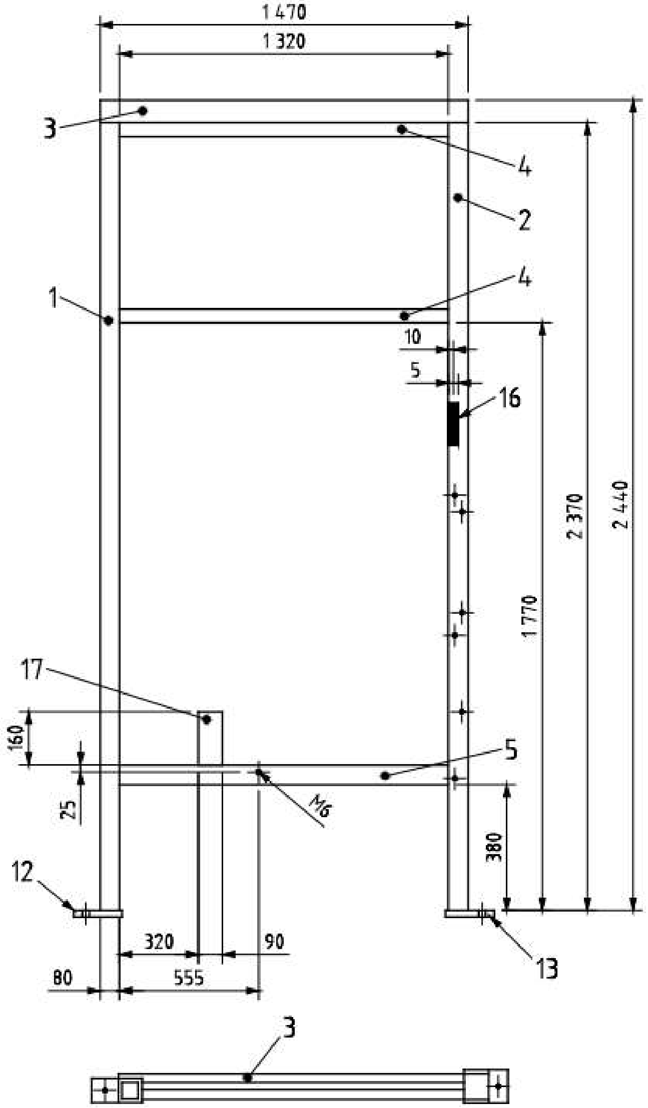


Figure E.1 — Exhaust duct – General view – The two possible configurations (see 4.5.3)

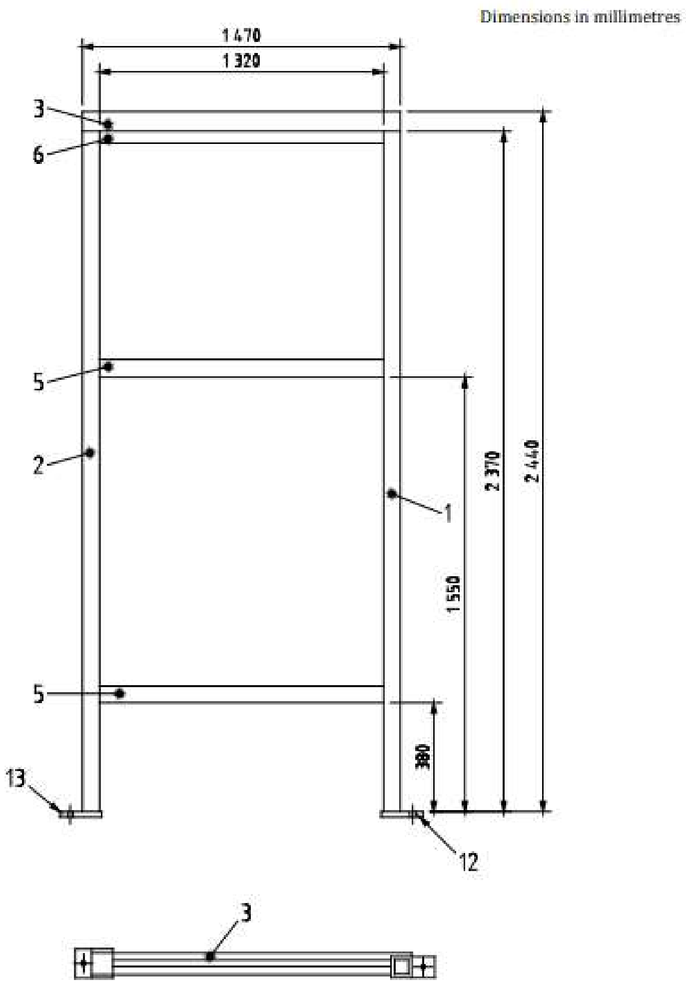
Dimensions in millimetres



Key

Ref.	Description	Number	Ref.	Description	Number
1	Tube profile 80 × 80 × 4 / L = 2 370	2	13	Steel plate 170 × 90 × 10	2
2	Tube profile 70 × 70 × 5 / L = 2 370	2	12	Steel plate 200 × 70 × 10	2
3	Tube profile 70 × 70 × 5 / L = 1 470	2	15	Tube profile 20 × 20 × 2 / L = 60	1
4	Tube profile 40 × 20 × 3 / L = 1 320	2	16	Steel plate 240 × 130 × 5	1
5	Tube profile 60 × 40 × 4 / L = 1 320	3	17	Steel plate 160 × 90 × 5	1

Figure E.2 — Frame – Welded parts – Right part

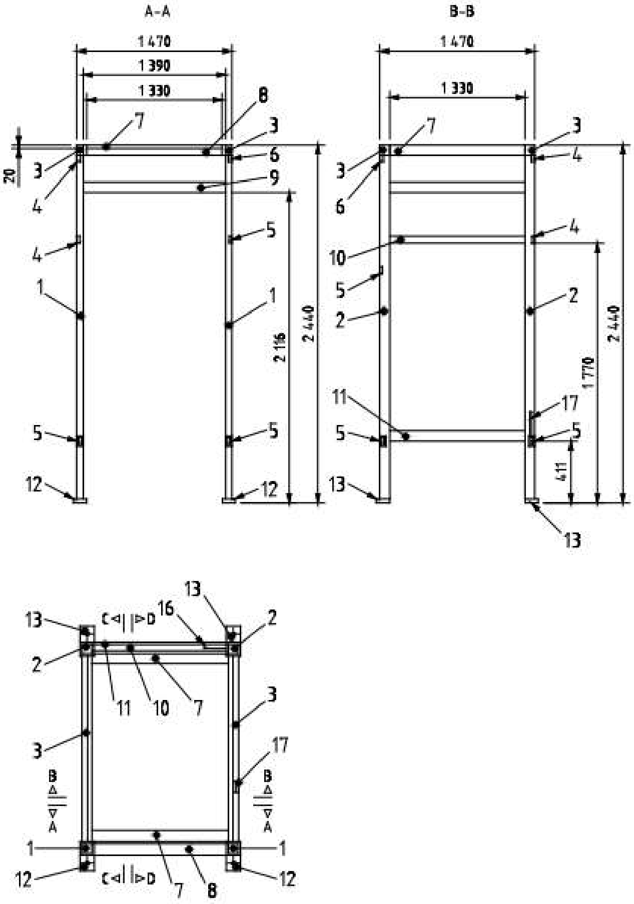


Key

Ref.	Description	Number
1	Tube profile 80 × 40 × 4 / L = 2 370	2
2	Tube profile 70 × 70 × 5 / L = 2 370	2
3	Tube profile 70 × 70 × 5 / L = 1 470	2
5	Tube profile 60 × 40 x4 / L = 1 320	3
6	Tube profile 40 × 40 × 3 / L = 1 320	1
12	Steel plate 200 × 70 × 10	2
13	Steel plate 170 × 90 × 10	2

Figure E.3 — Frame – Welded parts – Left part

Dimensions in millimetres

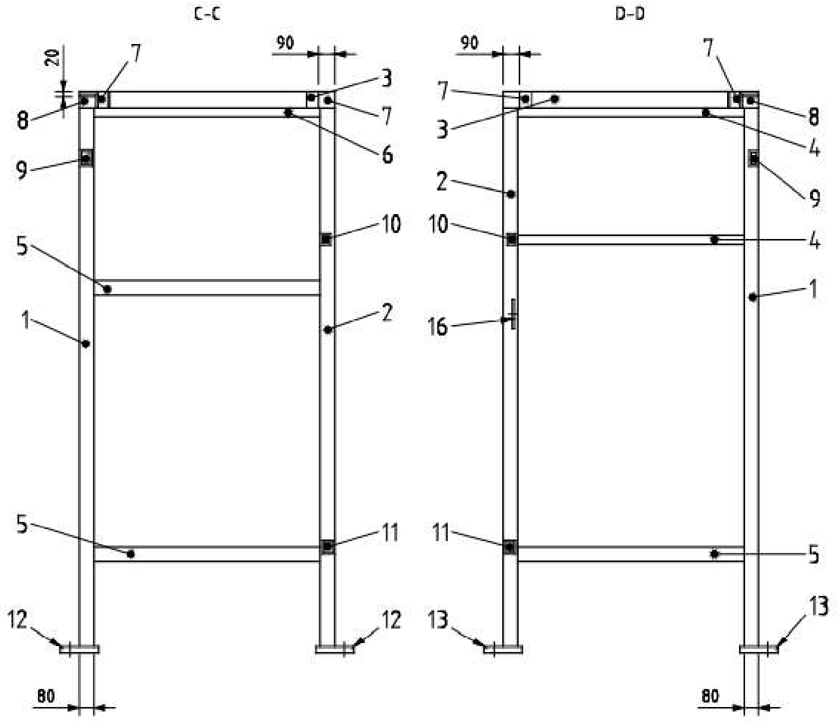


Key

Ref.	Description	Number	Ref.	Description	Number
1	Tube profile 80 × 40 × 4 / L = 2 370	2	9	Tube profile 70 × 70 × 5 / L = 1 390	2
2	Tube profile 70 × 70 × 5 / L = 2 370	2	10	Tube profile 40 × 40 × 3 / L = 1 330	1
3	Tube profile 70 × 70 × 5 / L = 1 470	2	11	Tube profile 70 × 70 × 5 / L = 1 330	1
4	Tube profile 40 × 20 × 3 / L = 1 320	2	12	Steel plate 200 × 70 × 10	2
5	Tube profile 60 × 40 × 4 / L = 1 320	3	13	Steel plate 170 × 90 × 10	2
6	Tube profile 40 × 40 × 3 / L = 1 320	1	16	Steel plate 240 × 130 × 5	1
7	Tube profile 70 × 70 × 5 / L = 1 330	2	17	Steel plate 160 × 90 × 5	1
8	Tube profile 100 × 50 × 5 / L = 1 330	1			

Figure E.4 — Frame – Welded parts – Composition (a)

Dimensions in millimetres

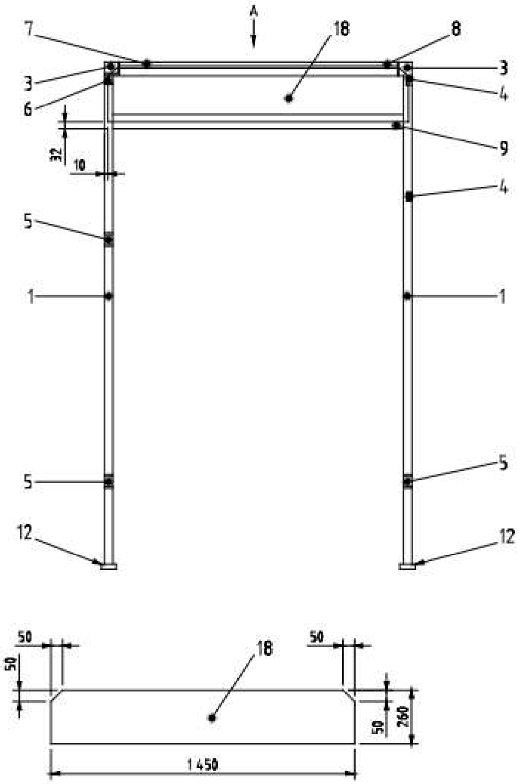


Key

Ref.	Description	Number
1	Tube profile 80 × 40 × 4 / L = 2 370	2
2	Tube profile 70 × 70 × 5 / L = 2 370	2
3	Tube profile 70 × 70 × 5 / L = 1 470	2
4	Tube profile 40 × 20 × 3 / L = 1 320	2
5	Tube profile 60 × 40 × 4 / L = 1 320	1
6	Tube profile 40 × 40 × 3 / L = 1 320	1
7	Tube profile 70 × 70 × 5 / L = 1 330	2
8	Tube profile 100 × 50 × 5 / L = 1 330	1
9	Tube profile 70 × 70 × 5 / L = 1 390	2
10	Tube profile 40 × 40 × 3 / L = 1 330	1
11	Tube profile 70 × 70 × 5 / L = 1 330	1
12	Steel plate 200 × 70 × 10	2
13	Steel plate 170 × 90 × 10	2
16	Steel plate 240 × 130 × 5	1

Figure E.5 — Frame – Welded parts – Composition (b)

Dimensions in millimetres

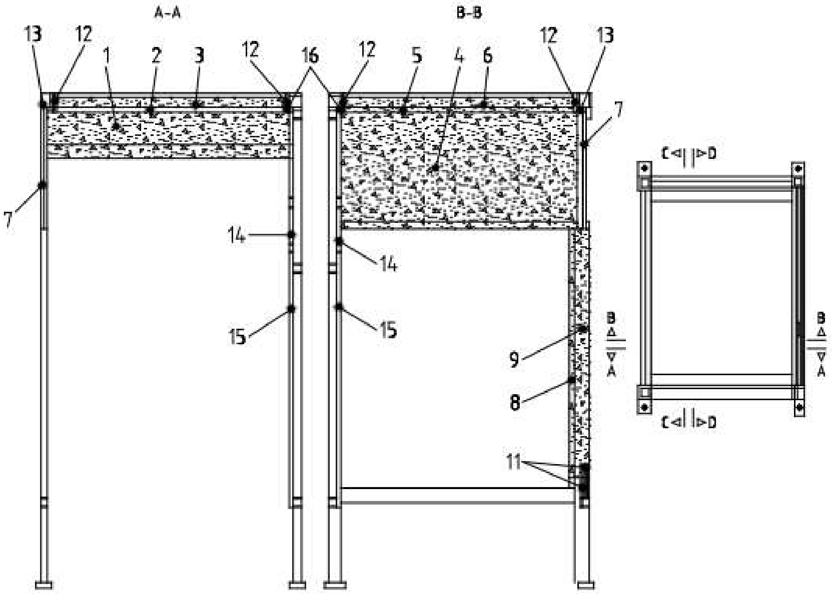


Key

Ref.	Description	Number
A	Front view (fix front plate)	
1	Tube profile 80 × 40 × 4 / L = 2 370	2
3	Tube profile 70 × 70 × 5 / L = 1 470	2
4	Tube profile 40 × 20 × 3 / L = 1 320	2
5	Tube profile 60 × 40 × 4 / L = 1 320	3
6	Tube profile 40 × 40 × 3 / L = 1 320	1
7	Tube profile 70 × 70 × 5/ L = 1 330	2
8	Tube profile 100 × 50 × 5 / L = 1 330	1
9	Tube profile 70 × 70 × 5 / L = 1 390	2
12	Steel plate 200 × 70 × 10	2
18	Steel plate 1 450 × 260 × 2	1

Figure E.6 — Frame – Welded parts – Composition (c)

Dimensions in millimetres

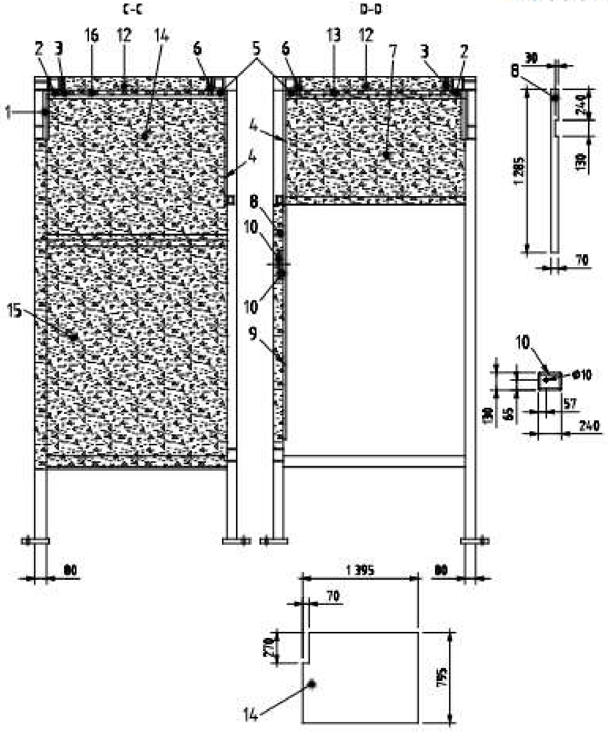


Key

Ref.	Description	Number
1	Calcium silicate (450 kg/m³) 1 375 × 255 × 20	1
2	Calcium silicate (450 kg/m³) 1 375 × 100 × 20	1
3	Calcium silicate (450 kg/m³) 1 300 × 70 × 20	1
4	Calcium silicate (450 kg/m³) 1 375 × 600 × 20	1
5	Calcium silicate (450 kg/m³) 1 345 × 70 × 20	1
6	Calcium silicate (450 kg/m³) 1 325 × 90 × 20	1
7	Calcium silicate (450 kg/m³) 1 320 × 600 × 20	1
8	Calcium silicate (450 kg/m³) 1 285 × 70 × 20	1
9	Calcium silicate (450 kg/m³) 1 235 × 90 × 20	1
11	Calcium silicate (450 kg/m³) 160 × 90 × 12	2
12	Calcium silicate (450 kg/m³) 1 095 × 90 × 20	2
13	Calcium silicate (450 kg/m³) 1 185 × 30 × 20	2
14	Calcium silicate (450 kg/m³) 1 395 × 795 × 12	1
15	Calcium silicate (450 kg/m³) 1 395 × 1200 × 12	1
16	Calcium silicate (450 kg/m³) 1 115 × 18 × 20	1

Figure E.7 — Frame – Covering – Composition (a)

Dimensions in millimetres

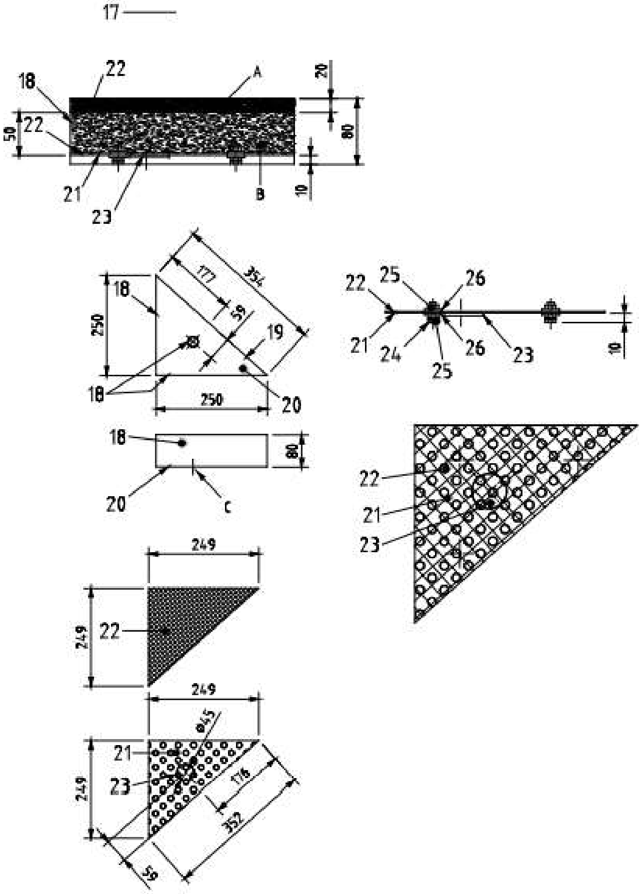


Key

Ref.	Description	Number	Ref.	Description	Number
1	Calcium silicate (450 kg/m³) 1 375 × 255 × 20	1	9	Calcium silicate (450 kg/m³) 1 285 × 70 × 20	1
2	Calcium silicate (450 kg/m³) 1 375 × 100 × 20	1	10	Calcium silicate (450 kg/m³) 1 235 × 90 × 20	2
3	Calcium silicate (450 kg/m³) 1 300 × 70 × 20	1	12	Calcium silicate (450 kg/m³) 1 095 × 90 × 20	2
4	Calcium silicate (450 kg/m³) 1 300 × 70 × 20	1	13	Calcium silicate (450 kg/m³) 1 185 × 30 × 20	1
5	Calcium silicate (450 kg/m³) 1 375 × 600 × 20	1	14	Calcium silicate (450 kg/m³) 1 395 × 795 × 12	1
6	Calcium silicate (450 kg/m³) 1 345 × 70 × 20	1	15	Calcium silicate (450 kg/m³) 1 395 × 1200 × 12	1
7	Calcium silicate (450 kg/m³) 1 325 × 90 × 20	1	16	Calcium silicate (450 kg/m³) 1 115 × 18 × 20	1
8	Calcium silicate (450 kg/m³) 1 320 × 600 × 20	1			

Figure E.8 — Frame – Covering – Composition (b)

Dimensions in millimetres

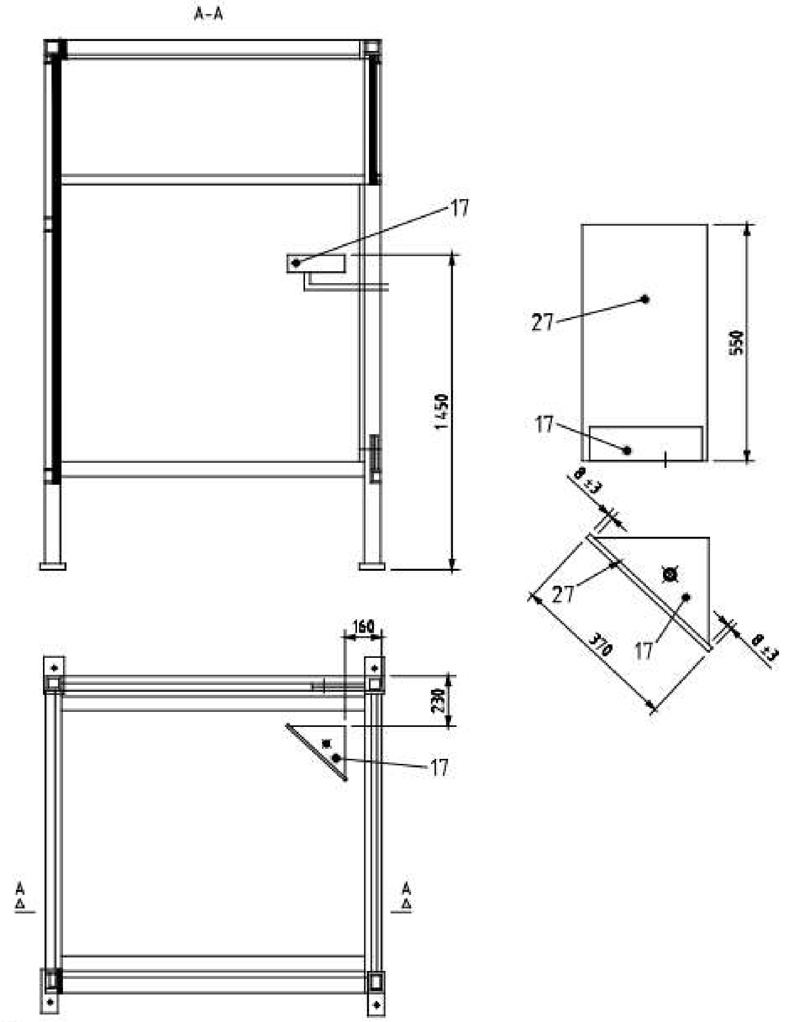


Key

Ref.	Description	Number	Ref.	Description	Number
A	Sand 2–4 mm (rounded)		21	Perforated (50 % ø 10) steel plate 249 × 249 × 2	1
B	Pebbles 4–8 mm (rounded)		22	Wire gauze (<2 x ø 0,5) 249 × 249	2
C	Gas connecting		23	Steel plate ø 25 × 2	1
17	Burner	1	24	Screw M6 × 15	3
18	Steel plate 250 × 80 × 2	2	25	Nut M6	6
19	Steel plate 250 × 80 × 2	1	26	Washer M6	6
20	Steel plate 250 × 250 × 2	1			

Figure E.9 — Frame – Covering – Burner

Dimensions in millimetres

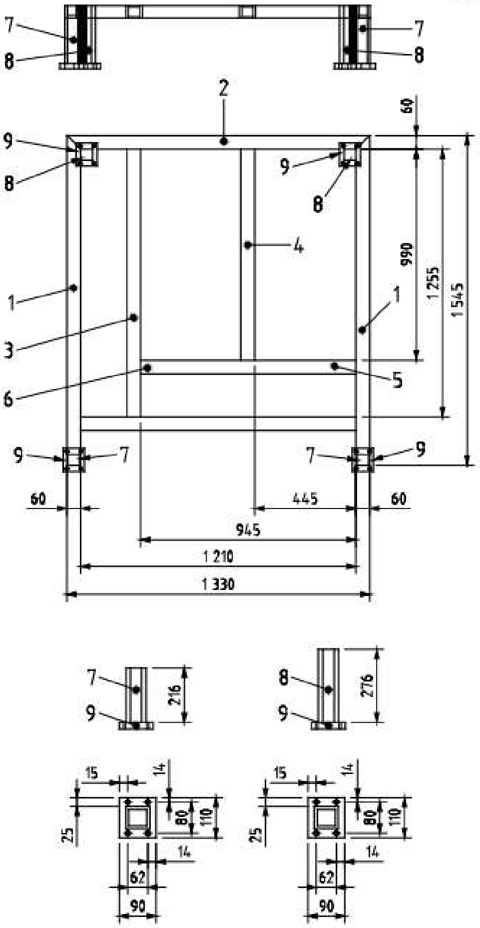


Key

Ref.	Description	Number
17	Burner	1
27	Calcium silicate (870 kg/ m³) 550 × 370 × 12	1

Figure E.10 — Frame - Covering - Composition

Dimensions in millimetres

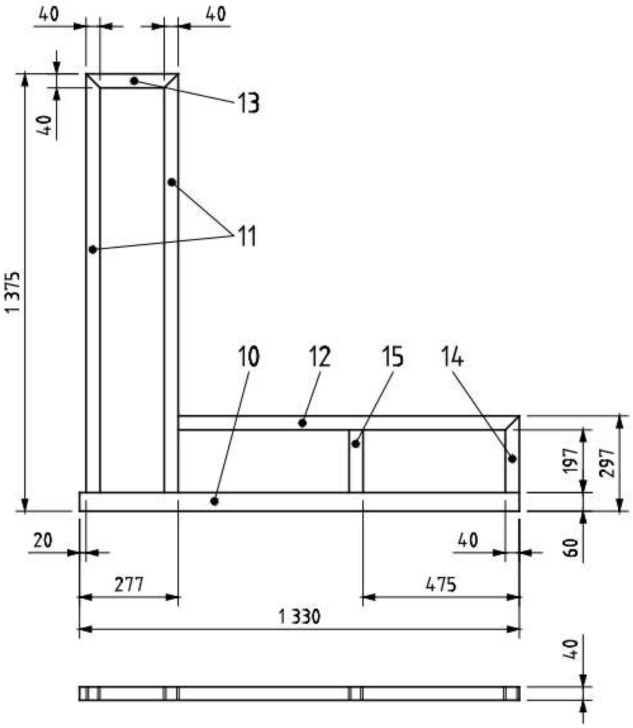


Key

Ref.	Description	Number
1	Tube profile 60 × 60 × 5 / L = 1 545	2
2	Tube profile 60 × 60 × 5 / L = 1 330	1
3	Tube profile 60 × 60 × 5 / L = 1 255	1
4	Tube profile 60 × 60 × 5 / L = 990	1
5	Tube profile 60 × 60 × 5 / L = 945	1
6	Tube profile 60 × 60 × 5 / L = 1 210	1
7	Tube profile 60 × 60 × 5 / L = 216	2
8	Tube profile 60 × 60 × 5 / L = 276	2
9	Steel plate 110 × 90 × 10	4

Figure E.11 — Trolley – Welded parts – Bottom

Dimensions in millimetres

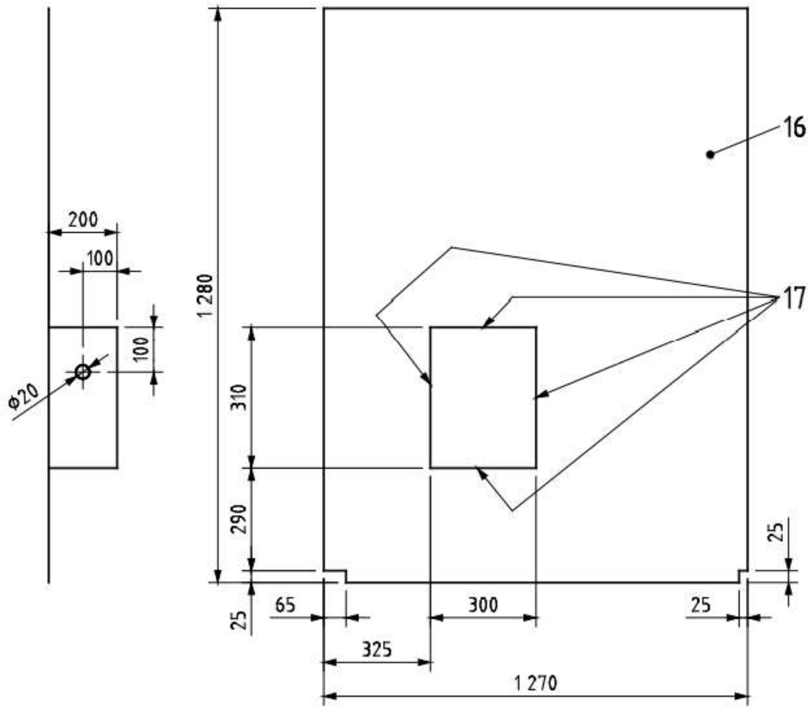


Key

Ref.	Description	Number
10	Tube profile 60 × 40 × 4 / L = 1 330	1
11	Tube profile 40 × 40 × 4 / L = 1 315	2
12	Tube profile 40 × 40 × 4 / L = 1 033	1
13	Tube profile 40 × 40 × 4 / L = 277	1
14	Tube profile 40 × 40 × 4 / L = 237	1
15	Tube profile 40 × 40 × 4 / L = 197	1

Figure E.12 — Trolley – Welded parts – Upper frame

Dimensions in millimetres

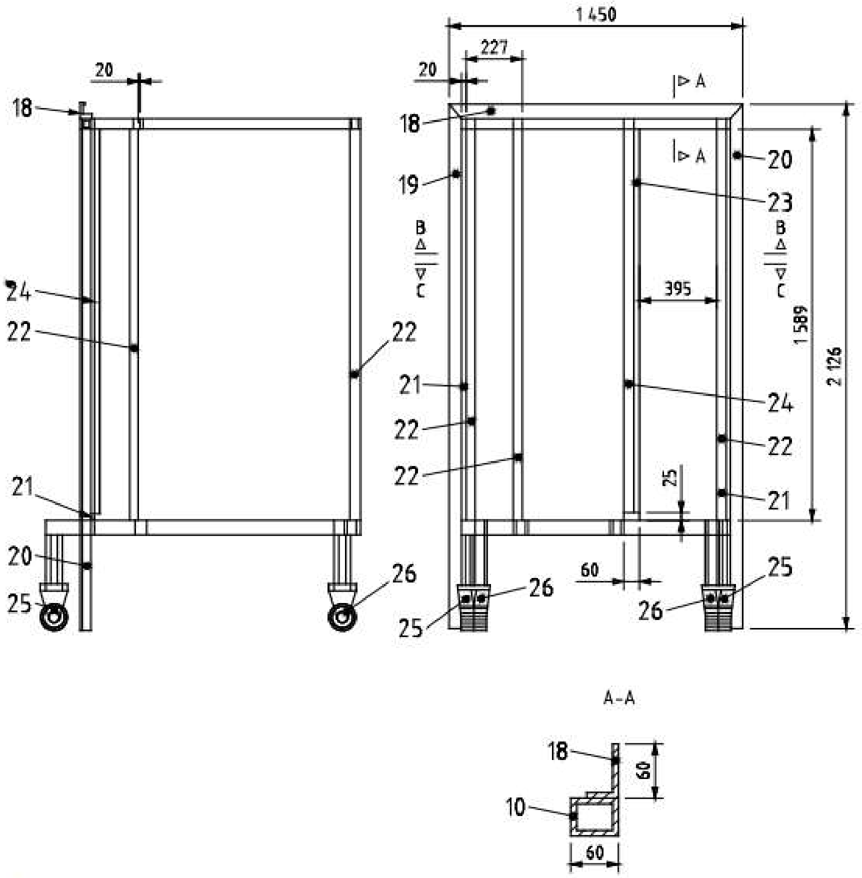


Key

Ref.	Description	Number
16	Steel plate 1280 × 1270 × 2	1
17	Steel plate 310 × 200 × 2	4

Figure E.13 — Trolley – Welded parts – Bottom plate

Dimensions in millimetres

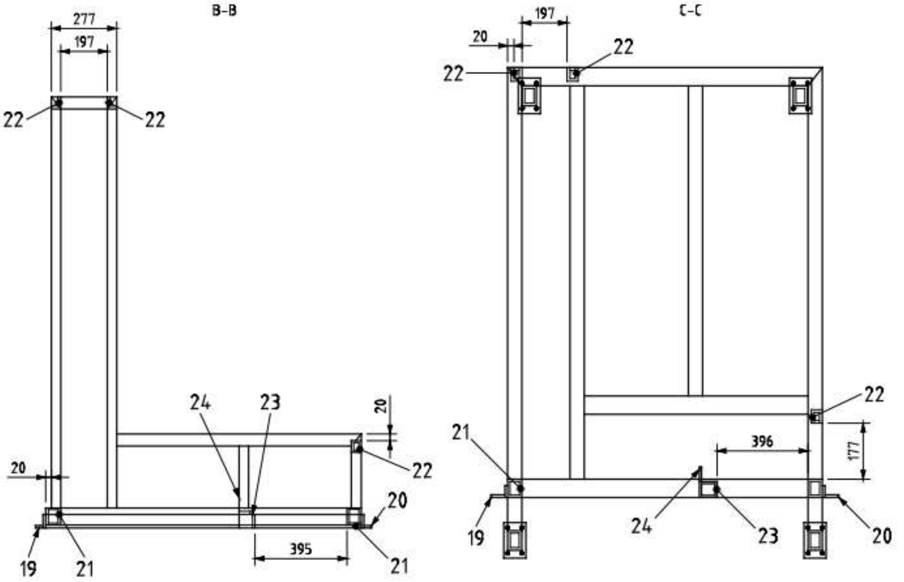


Key

Ref.	Description	Number
18	L profile 60 × 40 × 5 / L = 1 450	1
19	L profile 60 × 40 × 5 / L = 2 126	1
20	L profile 60 × 40 × 5 / L = 2 126	1
21	Tube profile 60 × 60 × 5 / L = 1 586	2
22	Tube profile 60 × 40 × 5 / L = 1 586	3
23	Tube profile 60 × 40 × 5 / L = 1 586	1
24	L profile 30 × 30 × 5 / L = 1 561	1
25	Turning wheel / h = 164	2
26	Fixed wheel / h = 164	2

Figure E.14 — Trolley – Welded parts – Composition (a)

Dimensions in millimetres

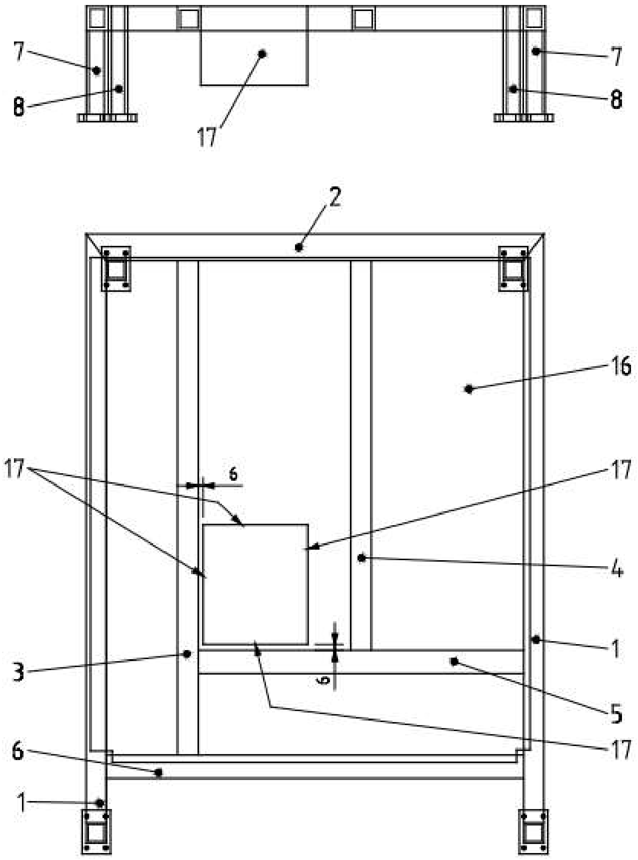


Key

Ref.	Description	Number
19	L profile 60 × 40 × 5 / L = 2 126	1
20	L profile 60 × 40 × 5 / L = 2 126	1
21	Tube profile 60 × 60 × 5 / L = 1 586	2
22	Tube profile 60 × 40 × 5 / L = 1 586	3
23	Tube profile 60 × 40 × 5 / L = 1 586	1
24	L profile 30 × 30 × 5 / L = 1 561	1

Figure E.15 — Trolley – Welded parts – Composition (b)

Dimensions in millimetres

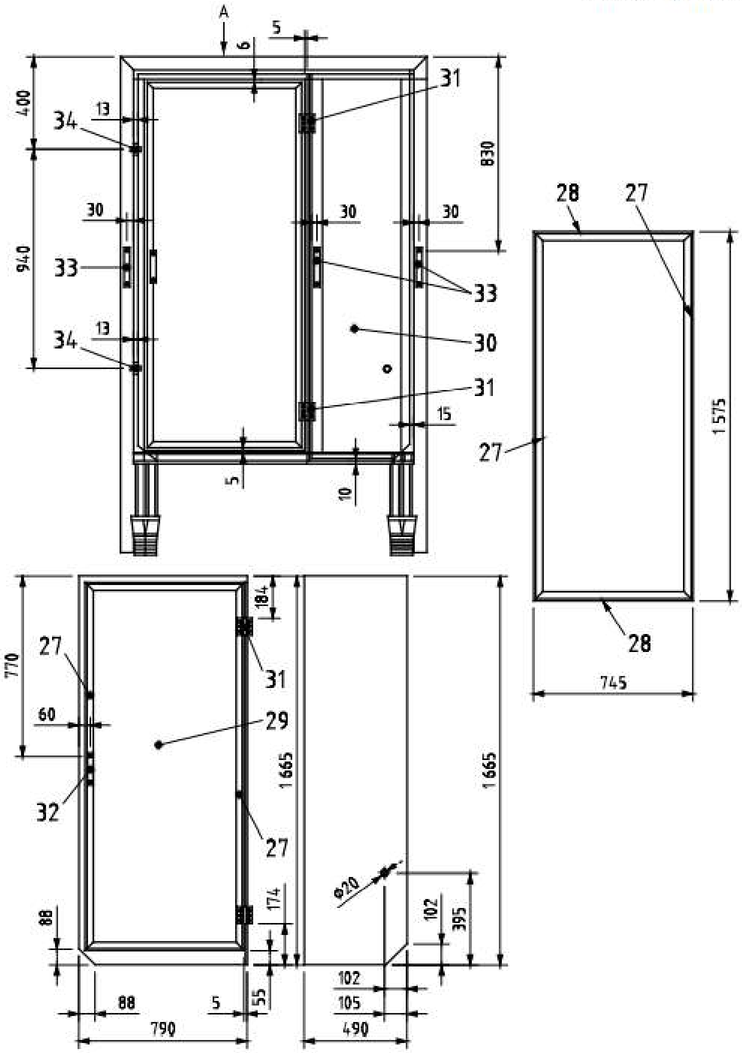


Key

Ref.	Description	Number
1	Tube profile 60 × 60 × 5 / L = 1 545	2
2	Tube profile 60 × 60 × 5 / L = 1 330	1
3	Tube profile 60 × 60 × 5 / L = 1 255	1
4	Tube profile 60 × 60 × 5 / L = 990	1
5	Tube profile 60 × 60 × 5 / L = 945	1
6	Tube profile 60 × 60 × 5 / L = 1 210	1
7	Tube profile 60 × 60 × 5 / L = 216	2
8	Tube profile 60 × 60 × 5 / L = 276	2
16	Steel plate 1 280 × 1 270 × 2	1
17	Steel plate 310 × 200 × 2	4

Figure E.16 — Trolley – Welded parts – Composition (c)

Dimensions in millimetres

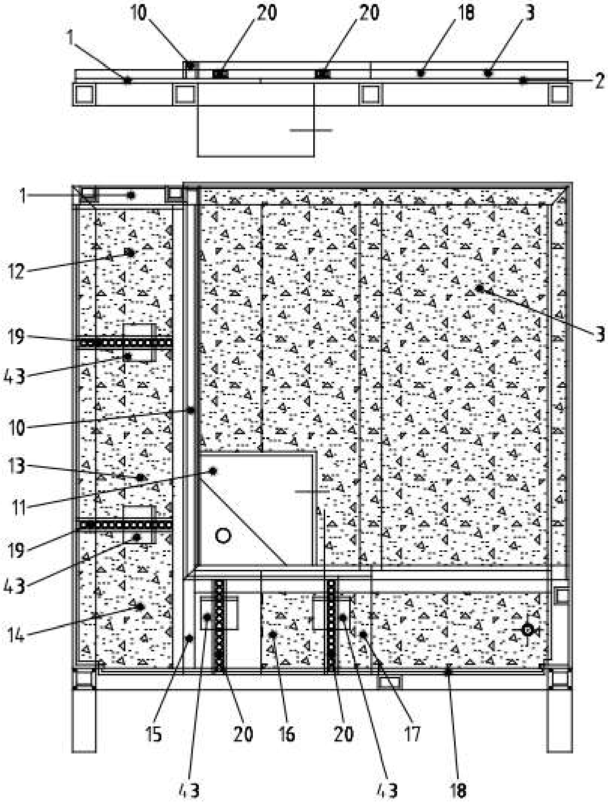


Key

Ref.	Description	Number	Ref.	Description	Number
A	Front view (fix door and front plate)		31	Hinge	2
27	L profile 30 × 30 × 3 / L = 1 575	2	32	Handle 140 × 25	1
28	L profile 30 × 30 × 3 / L = 745	2	33	Handle 170 × 25	3
29	Steel plate 1 665 × 790 × 2	1	34	Lock	2
30	Steel plate 1 665 × 490 × 2	1			

Figure E.17 — Trolley – Welded parts – Composition (d)

Dimensions in millimetres

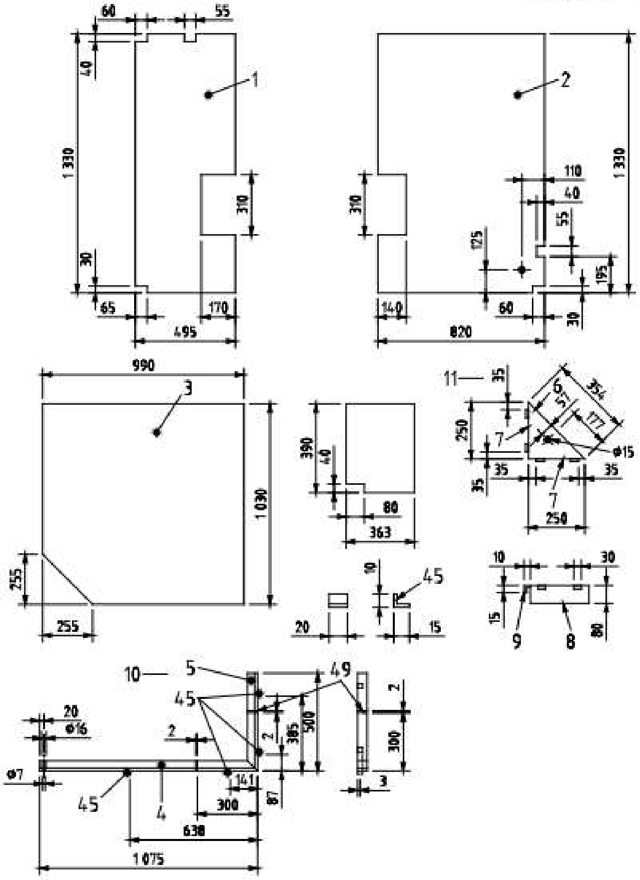


Key

Ref.	Description	Number	Ref.	Description	Number
1	Calcium silicate (870 kg/m³) 1 330 × 495 × 12	1	14	Calcium silicate (450 kg/m³) 390 × 293 × 20	1
2	Calcium silicate (870 kg/m³) 1 330 × 820 × 12	1	15	Calcium silicate (450 kg/m³) 80 × 257 × 20	1
3	Calcium silicate (450 kg/m³) 1 033 × 990 × 20	1	16	Calcium silicate (450 kg/m³) 262 × 257 × 20	1
10	Welded U profiles	1	17	Calcium silicate (450 kg/m³) 86 × 257 × 20	1
11	Burner	1	18	Calcium silicate (450 kg/m³) 527 × 40 × 20	1
12	Calcium silicate (450 kg/m³) 350 × 293 × 20	1	19	C-shaped profile 35 × 20 / L = 293	2
13	Calcium silicate (450 kg/m³) 460 × 293 × 20	1	20	C-shaped profile 35 × 20 / L = 257	2
			43	L profile 55 × 55 × 4 / L = 60	43

Figure E.18 — Trolley — Covering — Composition (a)

Dimensions in millimetres

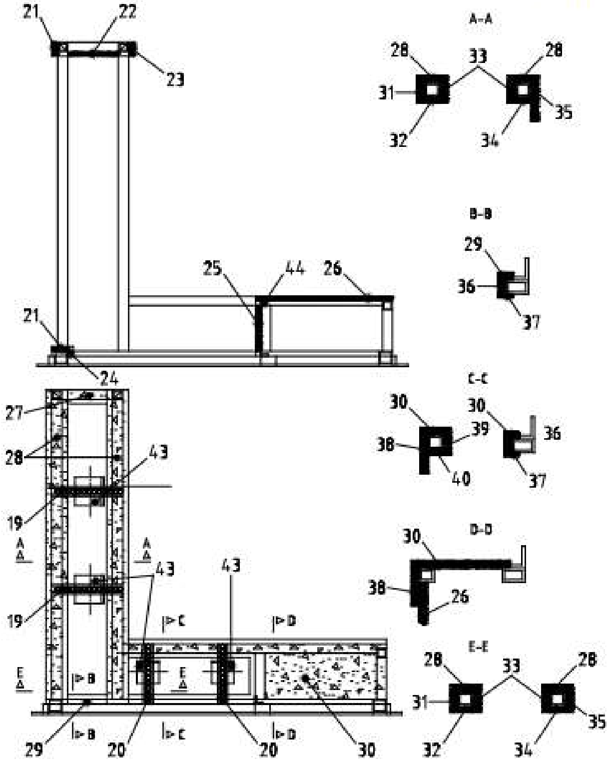


Key

Ref.	Description	Number	Ref.	Description	Number
1	Calcium silicate (870 kg/m^3) 1 330 × 495 × 12	1	8	Steel plate 250 × 250 × 2	1
2	Calcium silicate (870 kg/m^3) 1 330 × 820 × 12	1	9	Steel plate 30 × 27 × 3	4
3	Calcium silicate (450 kg/m^3) 1 033 × 990 × 20	1	10	Welded U profiles	1
4	U profile 40 × 40 × 3 / L = 1 075	1	11	Burner	1
5	U profile 40 × 40 × 3 / L = 500	1	45	Steel plate 27 × 20 × 2	4
6	Steel plate 354 × 80 × 2	1	49	Steel plate 37 × 34 × 2	2
7	Steel plate 250 × 80 × 2	2			

Figure E.19 — Trolley – Covering – Covers (a)

Dimensions in millimetres

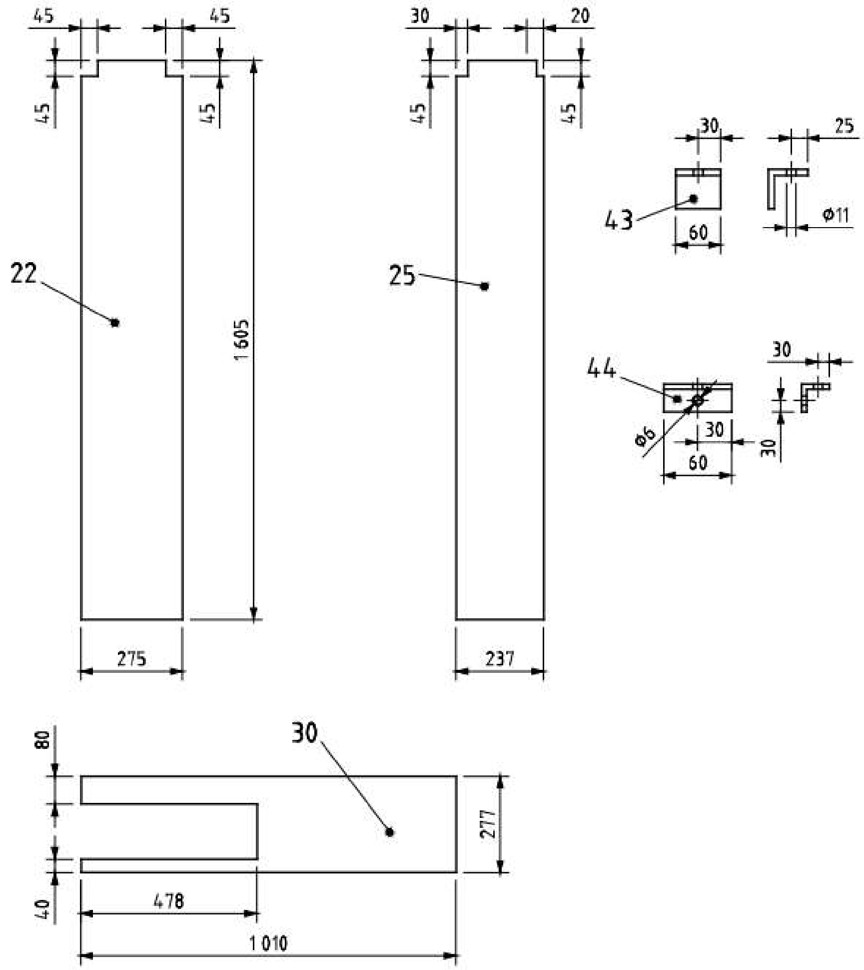


Key

Ref.	Description	Number	Ref.	Description	Number
a)	Upper view		32	Calcium silicate (870 kg/m³) 1 255 × 40 × 12	1
19	Profile 35 × 20 / L = 293	2	33	Calcium silicate (450 kg/m³) 1 235 × 52 × 20	2
20	Profile 35 × 20 / L = 257	2	34	Calcium silicate (870 kg/m³) 1 235 × 40 × 12	1
21	Calcium silicate (450 kg/m³) 1 555 × 60 × 20	2	35	Calcium silicate (870 kg/m³) 1 080 × 110 × 20	1
22	Calcium silicate (450 kg/m³) 1 605 × 275 × 20	1	36	Calcium silicate (450 kg/m³) 198 × 40 × 20	1
23	Calcium silicate (450 kg/m³) 1 450 × 60 × 20	1	37	Calcium silicate (870 kg/m³) 738 × 40 × 12	1
24	Calcium silicate (450 kg/m³) 1 555 × 40 × 20	1	38	Calcium silicate (870 kg/m³) 1 006 × 110 × 20	1
25	Calcium silicate (450 kg/m³) 1 605 × 273 × 20	1	39	Calcium silicate (450 kg/m³) 502 × 52 × 20	1
26	Calcium silicate (450 kg/m³) 1 565 × 530 × 20	1	40	Calcium silicate (870 kg/m³) 502 × 40 × 12	1
27	Calcium silicate (450 kg/m³) 157 × 60 × 20	1	43	L profile 55 × 55 × 4 / L = 60	8
28	Calcium silicate (450 kg/m³) 1 335 × 80 × 20	2	44	L profile 25 × 25 × 2	3
29	Calcium silicate (450 kg/m³) 157 × 40 × 20	1			
30	Calcium silicate (450 kg/m³) 1 010 × 277 × 20	1			
31	Calcium silicate (450 kg/m³) 1 315 × 52 × 20	1			

Figure E.20 — Trolley – Covering – Composition (b)

Dimensions in millimetres

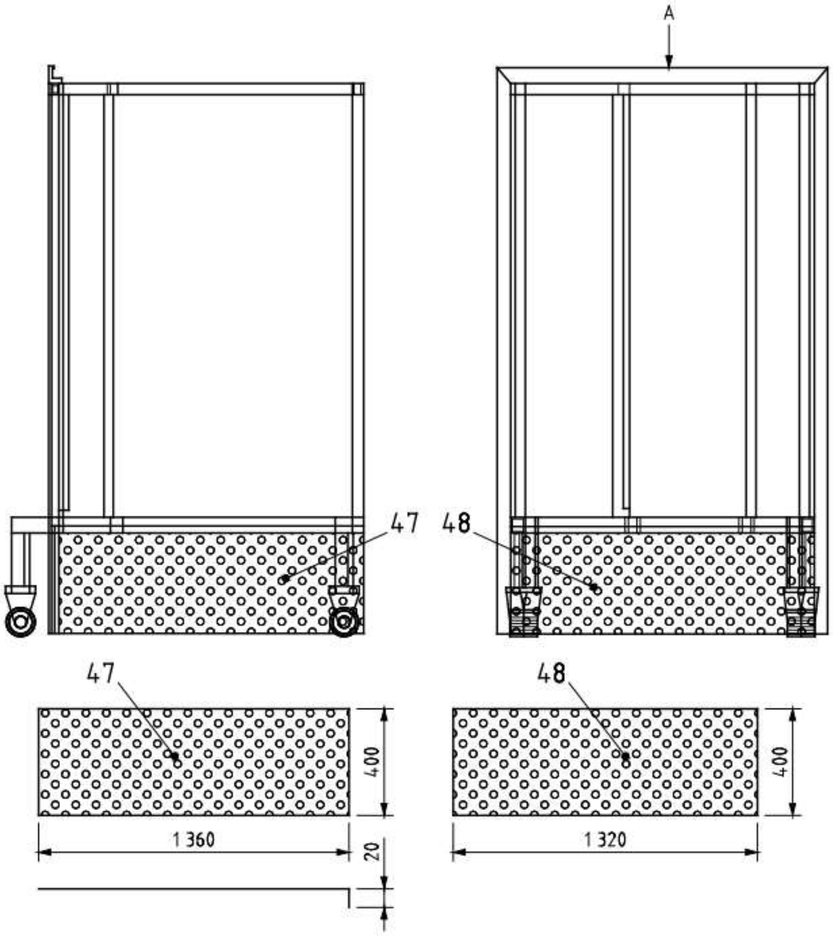


Key

Ref.	Description	Number
22	Calcium silicate (450 kg/m³) 1 605 × 275 × 20	1
25	Calcium silicate (450 kg/m³) 1 605 × 273 × 20	1
30	Calcium silicate (450 kg/m³) 1 010 × 277 × 20	1
43	L profile 55 × 55 × 4 / L = 60	8
44	L profile 25 × 25 × 2 / L = 60	3

Figure E.21 — Trolley – Covering – Covers (b)

Dimensions in millimetres

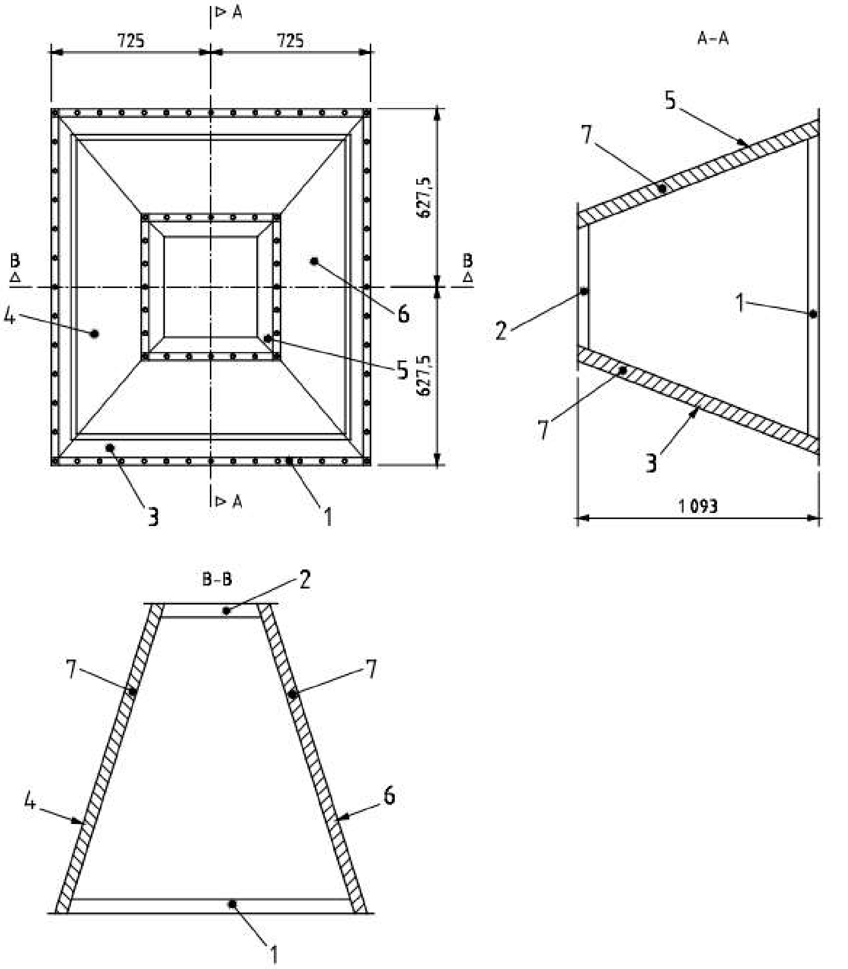


Key

Ref.	Description	Number
A	Back view	
47	Perforated steel plate 1 380 × 400 × 2 (see 4.4.1)	2
48	Perforated steel plate (see 4.4.1)	1

Figure E.22 — Trolley – Covering – Composition (c)

Dimensions in millimetres

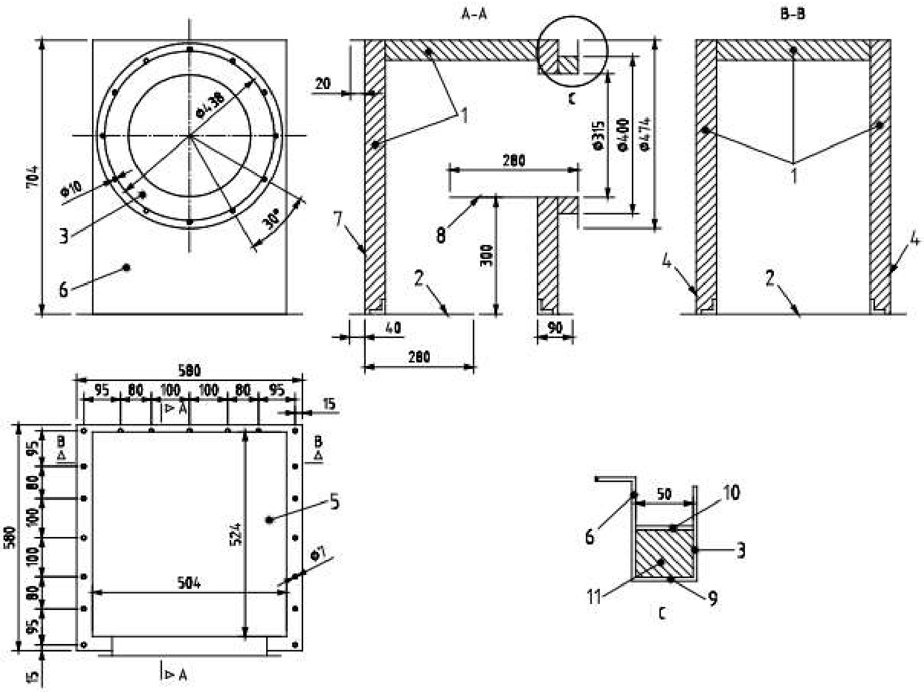


Key

Ref.	Description	Number
1	Lower frame / folded inox plate / *t* = 2	1
2	Upper frame / folded inox plate / *t* = 2	1
3	Side plate 1 / folded inox plate / *t* = 2	1
4	Side plate 2 / folded inox plate / *t* = 2	1
5	Side plate 3 / folded inox plate / *t* = 2	1
6	Side plate 4 / folded inox plate / *t* = 2	1
7	Insulation /vermiculite density = 475 kg/m^3 / *t* = 50	4

Figure E.23 — Phase 4 – Prototype – Hood

Dimensions in millimetres

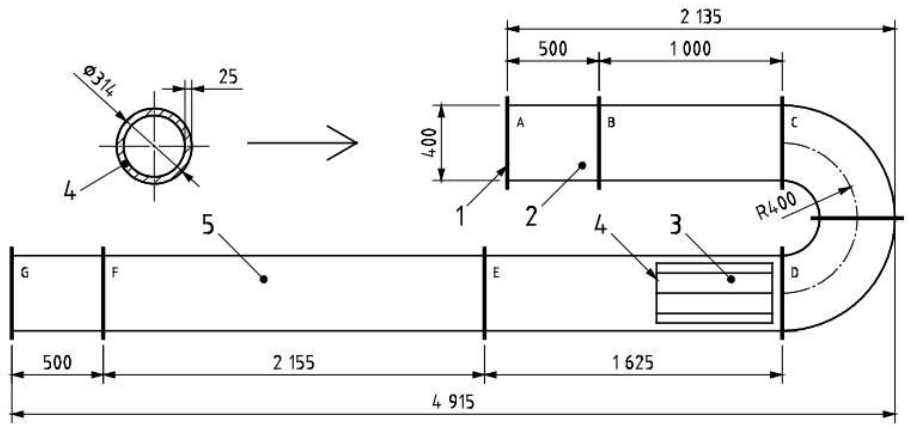


Key

Ref.	Description	Number
C	Detail 1	
1	Vermiculite / density 475 kg/m³	
2	Bottom plate / inox / *t* = 2 mm	1
3	Flange / inox plate / ø 315 – 474 / *t* = 3 mm	3
4	Side plate / inox / *t* = 2 mm	2
5	Top plate / inox / *t* = 2 mm	1
6	Front plate / inox / *t* = 2 mm	1
7	Back plate / inox / *t* = 2 mm	1
8	Inox plate / 500 × 500 / *t* = 2 mm	1
9	Inox tube / ø 315 / L = 50 mm	1
10	Inox tube / ø 400 / *t* = 2 mm / L = 50 mm	1
11	Mineral wool	

Figure E.24 — Collector – General view

Dimensions in millimetres

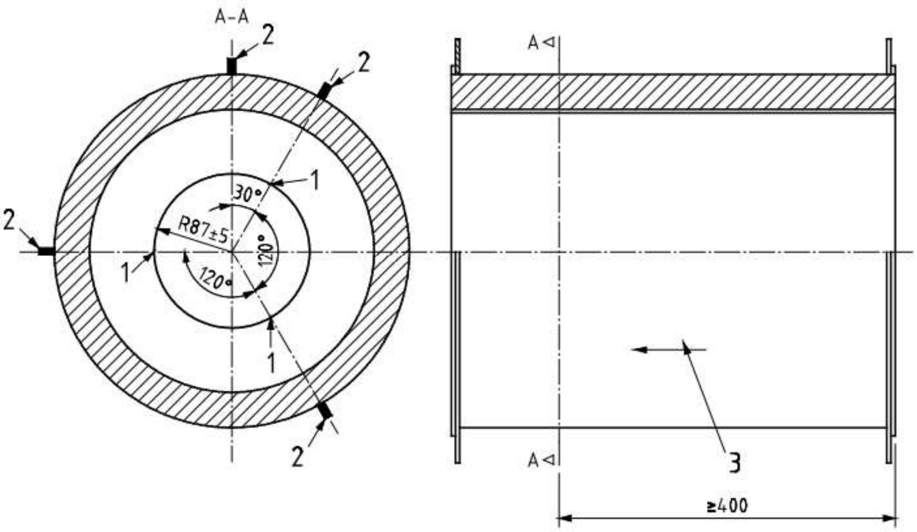


Key

Ref.	Description	Number
1	Connection to collector and hood	
2	Temperature measurement	
3	Guide vanes	
4	Reduction ring (stainless steel, ø 314 / thickness 2 mm)	
5	Measurement section (Δ *p*, tem., smoke, sample	

Figure E.25 — Exhaust duct - General view

Dimensions in millimetres

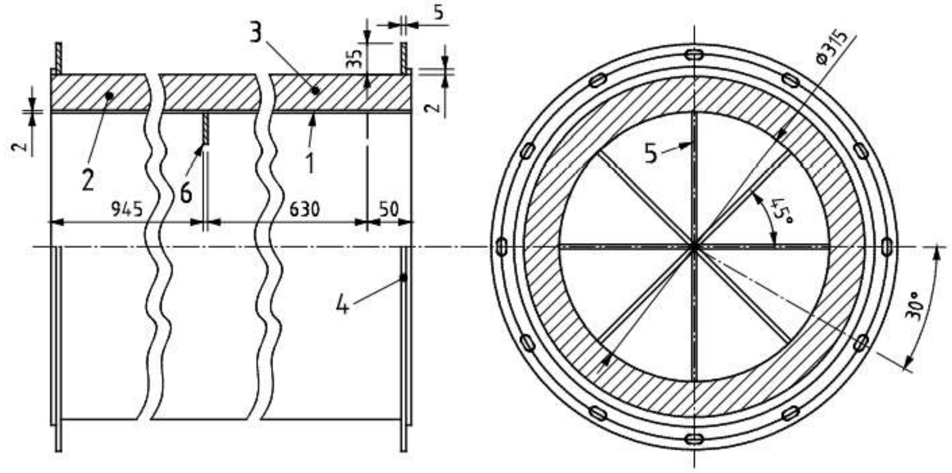


Key

Ref.	Description	Number
1	Sheeted thermocouple / TKI	4
2	Thermolocks / MG 10	4
3	Flow	

Figure E.26 — Measuring tube – Temperature measurement

Dimensions in millimetres

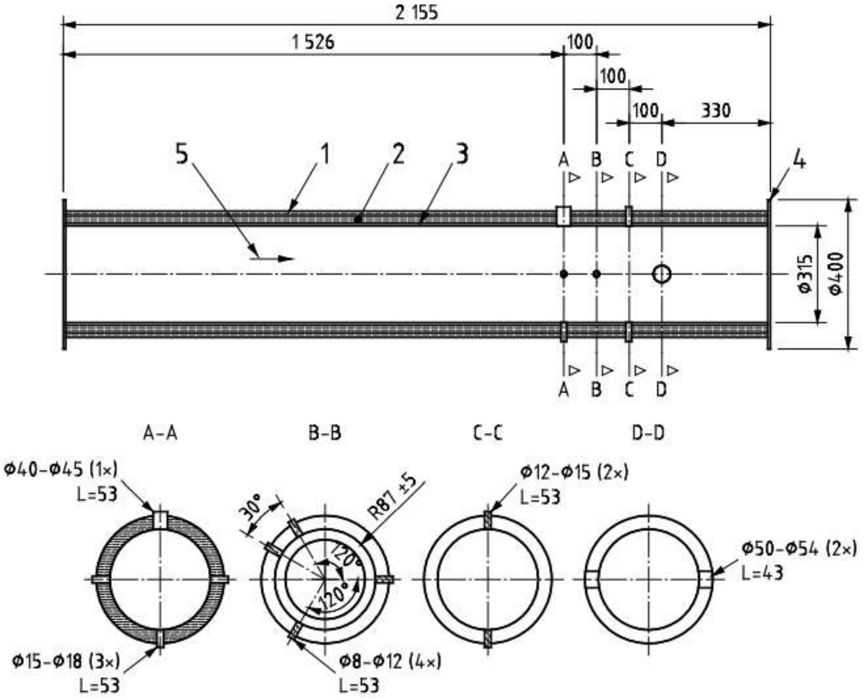


Key

Ref.	Description	Number
1	Tube / inox 304 / ø 315 mm / *t* = 2 mm / L = 1 625 mm	1
2	Insulation / mineral wool / *t* = 50 mm	1
3	Tube / galvanised steel/ ø 400 mm *t* = 2 mm/ L 1 625 mm	1
4	Flange/ inner ø 404/ outer ø 474 mm/*t* = 5 mm	2
5	Guide vanes / inox 304/ *t* = 3 mm / L = 630 mm / *h* = 1 575 mm	8
6	Reduction ring (stainless steel, ø 264, ø 314 / thickness 2 mm	1

Figure E.27 — Measuring tube – Guide vanes

Dimensions in millimetres

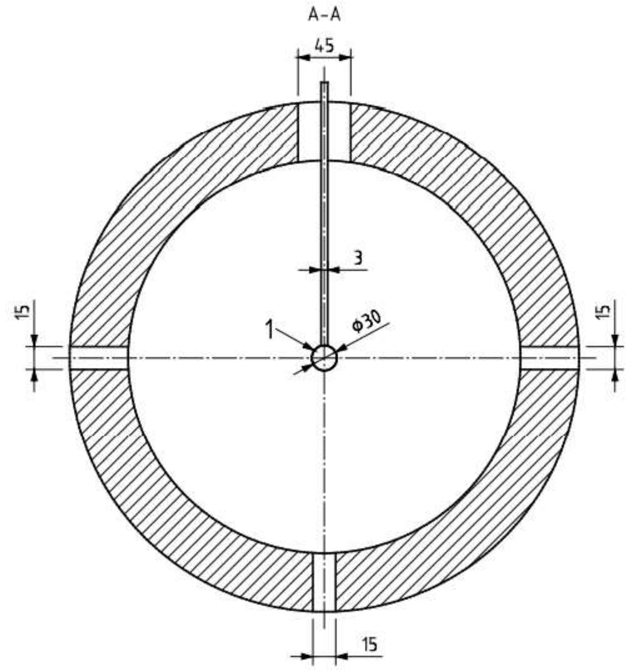


Key

Ref.	Description
1	Galvanized steel 1 mm
2	Mineral wool 159
3	Inox 304–2 mm
4	Flange Inox 4 m 12 holes Ø 10 at Ø 438
5	Flow

Figure E.28 — Exhaust duct – Measurement section

Dimensions in millimetres

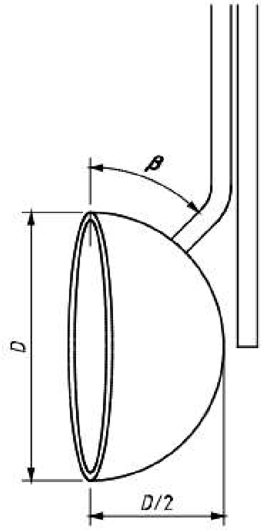


Key

Ref.	Description	Number
1	Hemispherical probe	1

Figure E.29 — Measuring tube – Hemipserical probe

Dimensions in millimetres

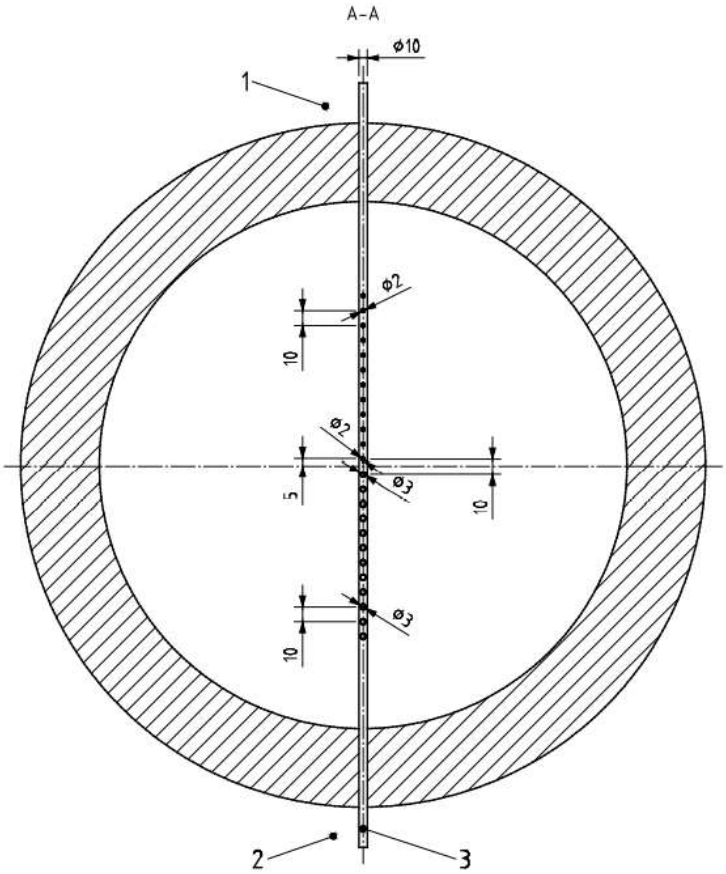


Key

Description	Number
Stainless steel hemispherical shell with D = 30mm (smaller values of D down to 20 mm allowed); (1,0 ± 0,5) mm wall thickness	1
Stainless steel tube / ø 3 mm (diameter up to 5 mm allowed)	2
30° ≤ β ≤ 45°	

Figure E.30 — Measuring tube – Hemispherical probe (b)

Dimensions in millimetres

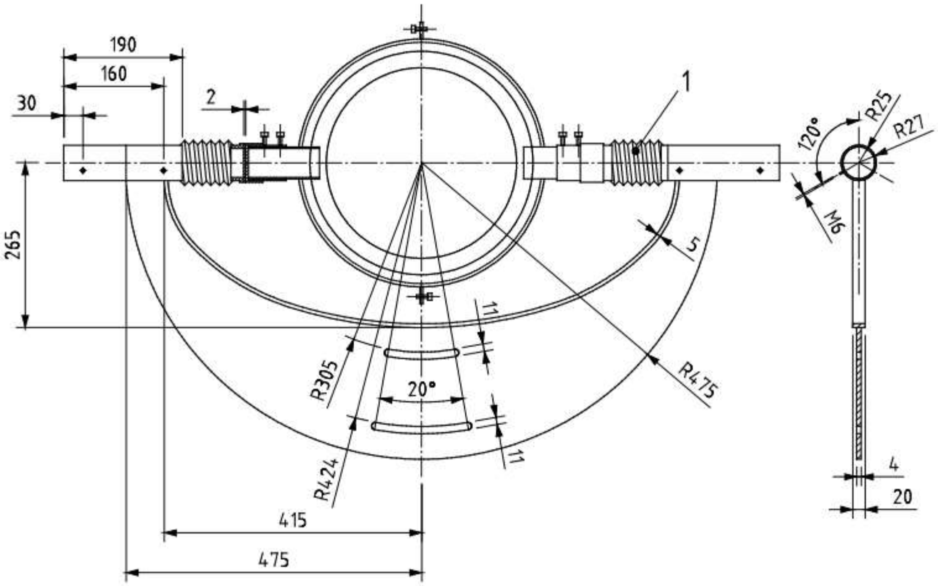


Key

Ref.	Description	Number
1	Open end	
2	Closed end	
3	Gas sampling probe / ø 10/8 mm / L = 500 mm	1

Figure E.31 — Measuring tube – Gas sampling probe and thermocouples

Dimensions in millimetres

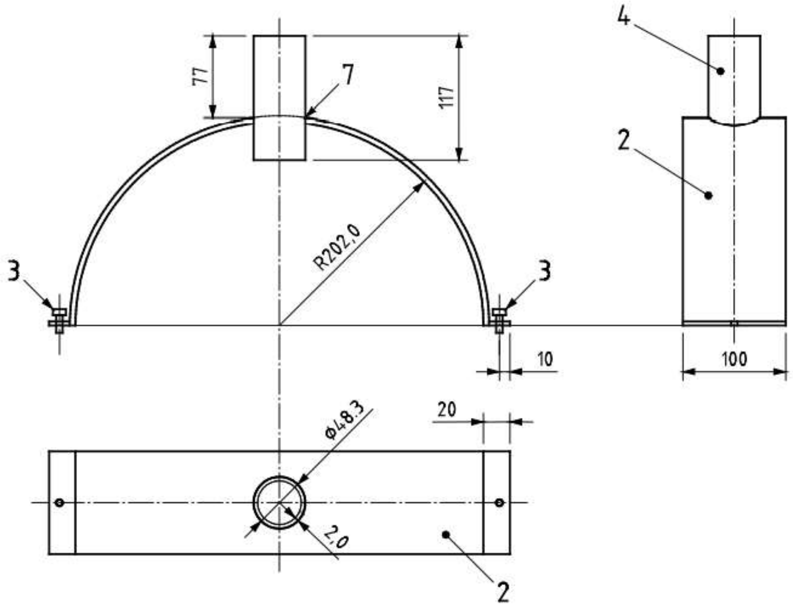


Key

Ref.	Description	Number
1	Accordeon (non-transparent)	

Figure E.32 — Measuring tube – Smoke measuring system holder

Dimensions in millimetres

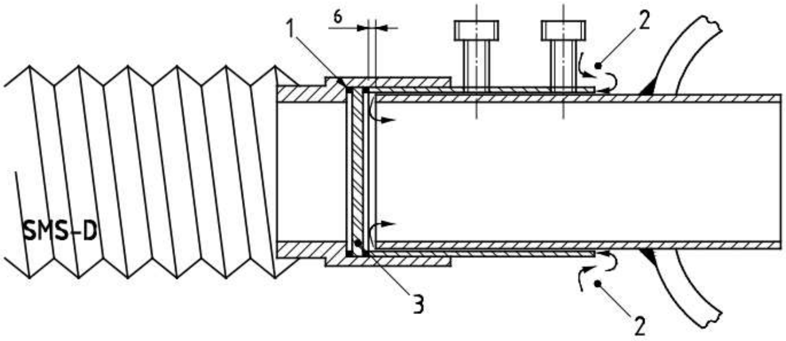


Key

Ref.	Description	Number
2	Steel band / ø 404 / *t* = 1,5 mm / b = 100 mm	2
3	Stainless steel bolt and nut / M10 / L = 40 mm	2
4	Stainless steel tube / ø 48,3/46,3 / L = 117	1
7	Welding	

Figure E.33 — Measuring tube - Part SMS

Dimensions in millimetres

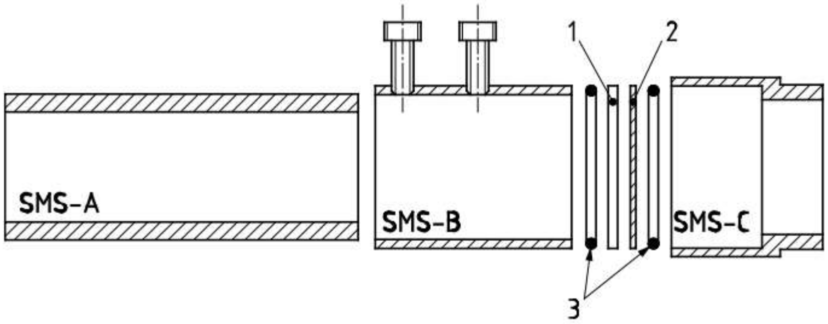


Key

Ref.	Description	Number
1	O-ring on both sides of the glass	
2	Air	
3	Coated glass + (optional) filter *	
* If filter is used, it shall always be protected from eventual combustion gases by the coated glass (away from the exhaust duct).		

Figure E.34 — Measuring tube – SMS holder

Dimensions in millimetres



Key

Ref.	Description	Number
1	Coated glass	
2	(Optional) filter	
3	Rubber O-ring	

Figure E.35 — Measuring tube – SMS holder

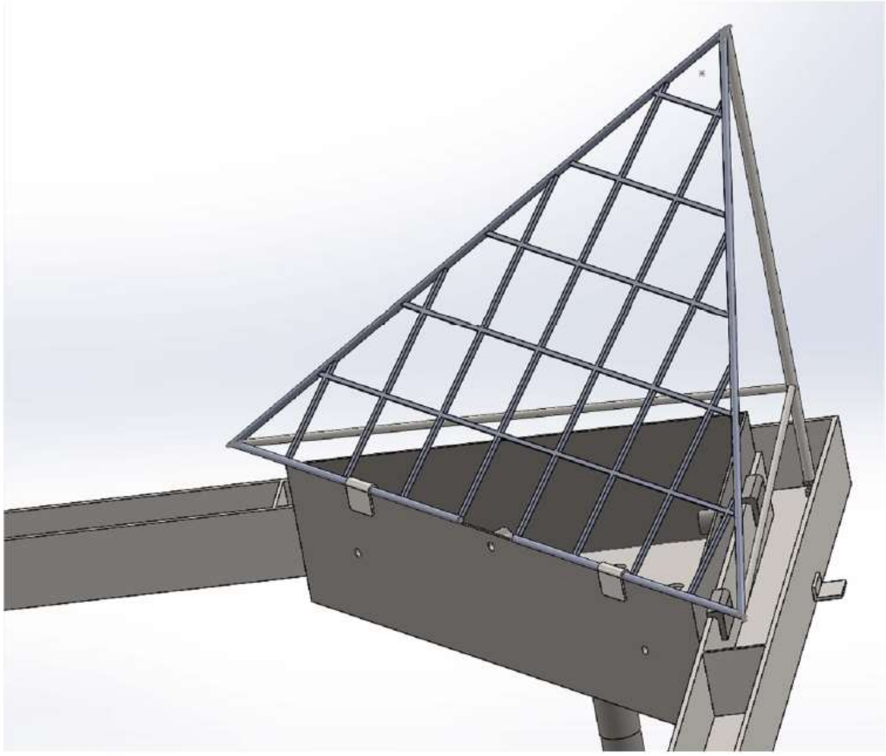


Figure E.36 — Burner guard

Annex H
(informative)

Data file format

For easy exchange of test results, test data should be stored in a standard format. The principal objective is that the file should contain all the required information including both visually observed/recorded and automatically recorded data. It should be possible to perform all requested calculations and (combined with other test results) the assessment of classification.

The data of a test should be stored in an ASCII-file with twelve tab-separated columns of data. More columns (with non-compulsory data) are allowed when they are placed after the compulsory columns, not in between.

The file should contain a two-line header and additional lines with general information and automatically recorded (raw) data per time step. The first header line contains the column header texts:

a) general information;

b) [empty];

c) time (s);

d) m_{gas} (mg/s);

e) Δp (Pa);

f) light signal (%);

g) mole percentage of oxygen (%);

h) mole percentage of CO_2 (%);

i) T_0 (K);

j) T_1 (K);

k) T_2 (K);

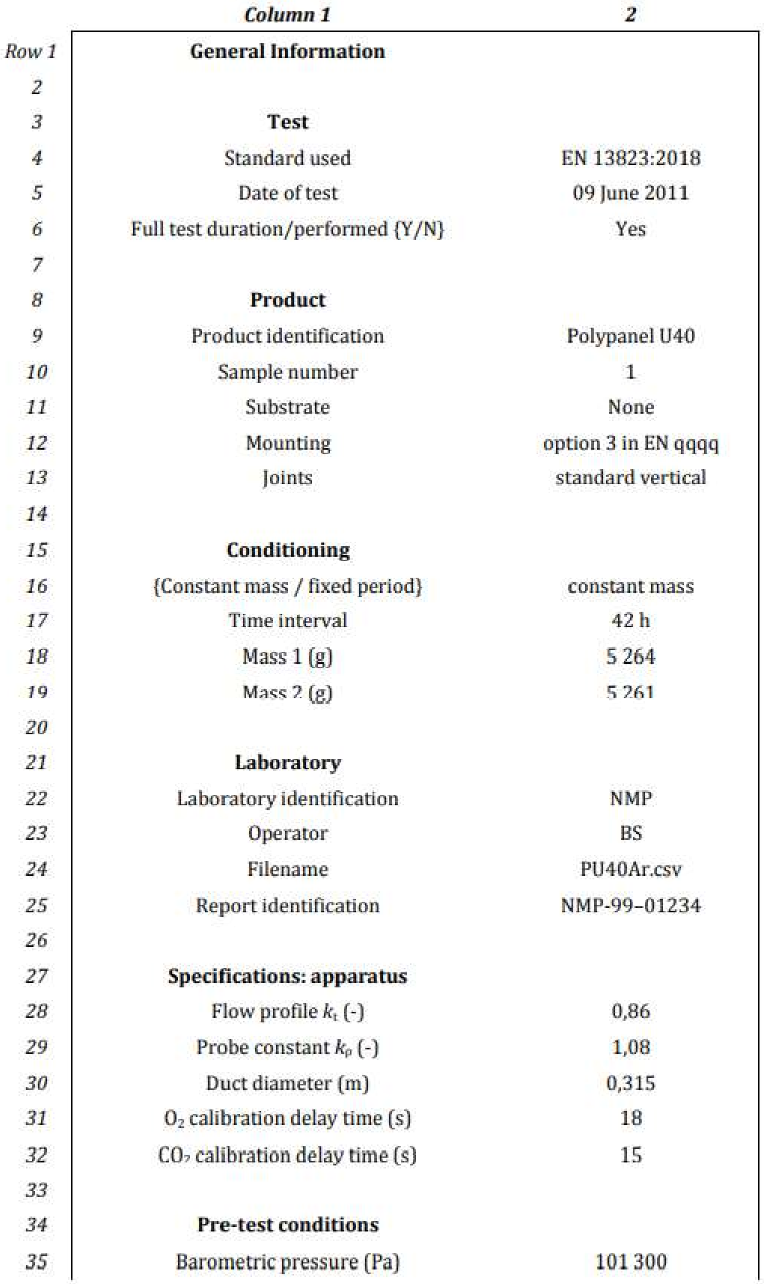
l) T_3 (K).

The second line is not specified (empty by default).

Subsequent lines contain general information in the first two columns and automatically recorded (raw) data in the next ten columns. Only the first 62 lines in columns one and two are used. In columns 3 to 12 this is at least 520 lines (1 560 s time interval with a 3 s step).

The general information (regarding the test, product, laboratory, apparatus, pre-test and end of test conditions, and visual observations) is given in column two, with a description of what is presented in column one. The row order of the different items is given in the example below.

The ten columns with automatically recorded data are in accordance with, and in the same order as in 8.4.



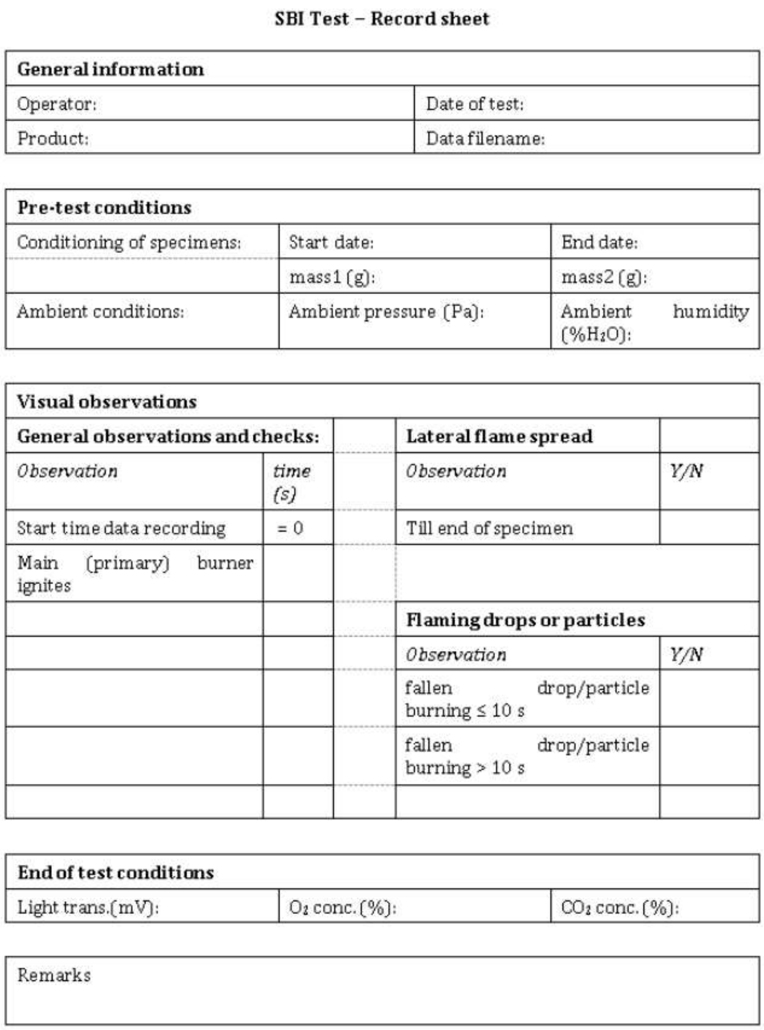
	Column 1	2
Row 1	**General Information**	
2		
3	**Test**	
4	Standard used	EN 13823:2018
5	Date of test	09 June 2011
6	Full test duration/performed {Y/N}	Yes
7		
8	**Product**	
9	Product identification	Polypanel U40
10	Sample number	1
11	Substrate	None
12	Mounting	option 3 in EN qqqq
13	Joints	standard vertical
14		
15	**Conditioning**	
16	{Constant mass / fixed period}	constant mass
17	Time interval	42 h
18	Mass 1 (g)	5 264
19	Mass 2 (g)	5 261
20		
21	**Laboratory**	
22	Laboratory identification	NMP
23	Operator	BS
24	Filename	PU40Ar.csv
25	Report identification	NMP-99–01234
26		
27	**Specifications: apparatus**	
28	Flow profile k_t (-)	0,86
29	Probe constant k_ρ (-)	1,08
30	Duct diameter (m)	0,315
31	O_2 calibration delay time (s)	18
32	CO_2 calibration delay time (s)	15
33		
34	**Pre-test conditions**	
35	Barometric pressure (Pa)	101 300

	Column 1	*2*
36	Relative humidity (%)	50
37	Ambient temperature (°C)	24,7
38	**Visual observations**	
39	*LFS* till edge {Y/N}	No
40	Flaming droplets/particles ≤ *10 s* {Y/N}	No
41	Flaming droplets/particles > 10 s {Y/N}	No
42		
43	**End of test conditions**	
44	Light transmission (%)	99,8
45	Mole percentage of oxygen (%)	20,95
46	Mole percentage of CO_2 (%)	0,039
47		
48	**Recorded events**	
49	Surface flash {Y/N}	No
50	Falling of specimen parts Y/N}	No
51	Smoke not entering hood Y/N}	No
52	Mutual fixing of backing board fails Y/N}	No
53	Conditions justify early stop of test {Y/N}	No
54	Distortion/collapse {Y/N}	No
55	Any other additional event	None
56		
57	**Early termination of test**	
58	Time of gas supply termination (s)	1 563
59	Excessive *HRR* {Y/N}	No
60	Excessive temperature {Y/N}	No
61	Burner substantially disturbed/choked {Y/N}	No
62	Failure of apparatus {Y/N}	No

The data file format presented here only concerns the raw data (before performing the calculations). No file format is given for processed data files. However, it is advisable to build the processed data file from the raw data file by adding columns and rows at the ends (and not in between). In this way a processed data file can easily be used as a raw data input file.

Annex I
(informative)

Record sheet



SBI Test – Record sheet

General information	
Operator:	Date of test:
Product:	Data filename:

Pre-test conditions		
Conditioning of specimens:	Start date:	End date:
	mass1 (g):	mass2 (g):
Ambient conditions:	Ambient pressure (Pa):	Ambient humidity (%H_2O):

Visual observations				
General observations and checks:			**Lateral flame spread**	
Observation	*time (s)*		*Observation*	*Y/N*
Start time data recording	= 0		Till end of specimen	
Main (primary) burner ignites				
			Flaming drops or particles	
			Observation	*Y/N*
			fallen drop/particle burning ≤ 10 s	
			fallen drop/particle burning > 10 s	

End of test conditions		
Light trans.(mV):	O_2 conc. (%):	CO_2 conc. (%):

Remarks

Figure G.1 — SBI Test — Record sheet

Bibliography

[1] [1] ISO 5725-1, Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions

[2] [2] ISO 5725-2:1994, Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method

[3] [3] ISO 3966:2008, Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes

[4] [4] SETTE. BJG, Development of a velocity pressure probe. Fire Mater. 2006 NOV-DEC, 30 (6) pp. 397–414

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