INTERNATIONAL STANDARD

ISO 20632

First edition
2008-04-01

Reaction-to-fire tests — Small room test for pipe insulation products or systems

Essais de réaction au feu — Essai en chambre de petite taille de produits ou systèmes de calorifugeage de tuyauterie

Reference number
ISO 20632:2008(E)

Contents

Page

Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 20632 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

Introduction

The test method described in this document is intended to assess the fire performance of a pipe insulation product, supported on a steel pipe, under controlled conditions.

The method can be used as part of a fire hazard assessment that takes into account all of the factors that are pertinent to a particular end use of a pipe insulation product.

Reaction-to-fire tests — Small room test for pipe insulation products or systems

Caution — So that suitable precautions can be taken to safeguard health, the attention of all concerned in fire tests is drawn to the possibility that toxic or harmful gases can be evolved during combustion of the test specimen.

The test procedures involve high temperatures and combustion processes from ignition to a fully developed room fire. Therefore, hazards can exist for burns, ignition of extraneous objects or clothing. The operators should use protective clothing, helmet, face-shield and equipment for avoiding exposure to toxic gases.

1 Scope

This International Standard specifies a test method for determining the reaction to fire performance of pipe insulation products and some pipe insulation systems installed in a small room.

The scenario is valid for fires in a room where pipe insulation products are installed within building applications, e.g. pipe and duct rooms in public buildings, apartment blocks, hospitals and ships.

This method is suitable for products that cannot be tested in a small-scale test, or for correlation of small-scale test data. The method can also serve as a reference scenario for pipe insulation products or for systems fitted in a room within a building or a ship.

The method is not suitable for pipe insulation in concealed spaces, such as a horizontal or a vertical shaft. This method is not intended for evaluating the fire resistance of pipe insulation systems.

2 Normative references

The following referenced documents are indispensable for the application 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.

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

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

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

3.1
pipe insulation product
thermally-insulating material or product that covers a pipe

NOTE One layer is an insulating material, such as mineral or glass wool or cellular plastics. Facings on one or both sides can protect this insulating layer. Facings can be selected from a variety of materials, such as aluminium foil or glass fibre reinforced resin. The insulating material can be preformed, sprayed or wrapped around the pipe.

3.2
pipe insulation system
system comprising the pipe, the pipe insulation product, a product to keep the joint together such as tape or steel wire, possibly a finish layer or jacketing and pipe hangers

NOTE Pipe hangers can be fitted on the steel pipe (hot applications) or on the insulation product (cold applications).

4 Principle

The test methodology for determining the reaction to fire performance of pipe insulation products consists of assessing the following hazards:

- the potential of fire growth along the lines of pipes in the room by measurement of heat release rate, HRR;
- the potential for sustained fire and subsequent spread by measurement of the total heat release, THR;
- the potential to reach flashover and spread fire outside the room;
- reduced visibility by the measurement of light-obscuring smoke;
- potential for discontinuous fire spread by observation of flaming droplets/particles.

5 Test room

The test room dimensions, the position and size of the doorway and the construction material shall be as described in ISO 9705.

6 Ignition source

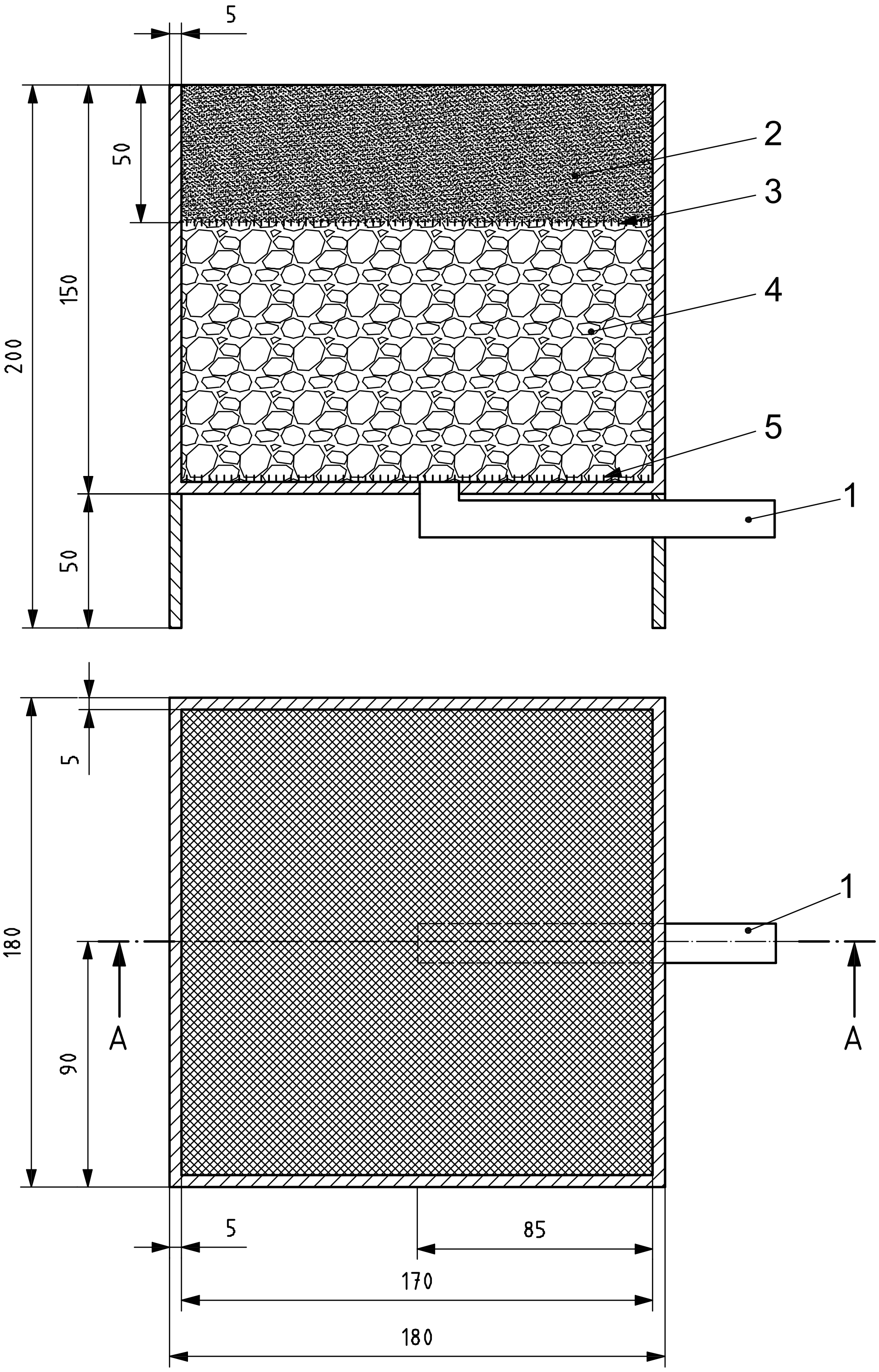
The ignition source shall be identical to the recommended standard ignition source described in Annex A of ISO 9705:1993. The position of the burner shall be 50 mm above floor level.

The ignition source shall be a propane gas burner having a square top surface layer of a porous, inert material, e.g. sand. The burner shall have face dimensions of 170 mm × 170 mm and a height of 200 mm above the floor (see Figure 1). The construction shall be such that an even gas flow is achieved over the entire opening area.

The ignition source is a propane gas burner that consumes relatively large amounts of gas. The attention of all concerned in fire tests is therefore drawn to the following warning.

WARNING — All equipment such as tubes, couplings, flowmeters, etc., shall be approved for propane and installed according to good practice. For reasons of safety, the burner should be equipped with a remote-controlled ignition device, for example, a pilot flame or a glow wire. There should be a warning system for gas leakage and a valve for immediate and automatic cut-off of the gas supply in case of extinction of the ignition flame.

Dimensions in millimetres



Key

1 gas inlet

2 sand (2 mm – 3 mm)

3 brass wire gauze (Ø1,8 mm)

4 gravel (4 mm – 8 mm)

5 brass wire gauze (Ø 2,8 mm)

Figure 1 — Standard ignition source (top view and cross section A-A)

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

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

The burner power output, based on the net (lower) calorific value of propane, shall be 100 kW during the first 10 min and then shall be increased to 300 kW for a further 10 min.

7 Hood and exhaust duct

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

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

8 Instrumentation in the exhaust duct

8.1 Volume flow rate

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

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

8.2 Gas analysis

8.2.1 Sampling line

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

8.2.2 Oxygen

The oxygen consumption shall be measured to an accuracy of at least ± 0,05 % (volume fraction) oxygen. The oxygen analyser shall have a time constant not exceeding 3 s. (See Annex D.)

8.2.3 Carbon monoxide and carbon dioxide

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

8.3 Optical density

8.3.1 General

The optical density of the smoke shall be determined by measuring the light obscuration with a system consisting of a lamp, lenses, an aperture and a photocell (see Figure 2). The system shall be constructed in such a way as to ensure that soot deposits during the test do not reduce the light transmission by more than 5 %.

8.3.2 Lamp

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

8.3.3 Lenses

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

8.3.4 Aperture

The aperture shall be placed at the focus of the lens L2 as shown in Figure 2 and it shall have a diameter, d, chosen with regard to the focal length, f, of L2 so that d/f is less than 0,04.

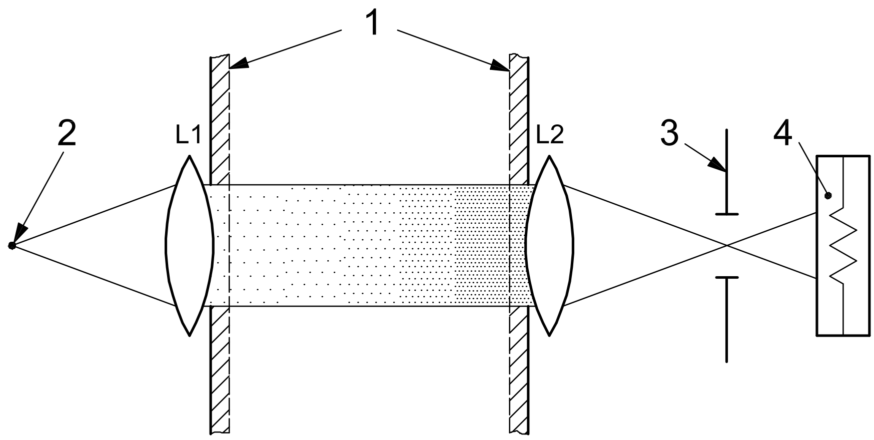
8.3.5 Detector

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

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

8.3.6 Location

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



Key

1 wall of exhaust duct

2 lamp

3 aperture

4 detector

L1 and L2: lenses of focal length f

Figure 2 — Optical system

1) Commission internationale d'éclairage (International Commission on Illumination).

9 System performance

9.1 Calibration

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

NOTE Equations for calculations are given in Annex B.

The calibration shall be performed at the burner heat outputs given in Table 1, with the burner positioned directly under the hood. Measurements shall be taken every 3 s and shall be started 1 min prior to ignition of the burner. At steady state conditions, the difference between the mean heat release rate over 1 min calculated from the measured oxygen consumption and that calculated from the metered gas input shall not exceed 5 % for each level of heat output.

Table 1 — Burner heat output profile

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

9.2 System response

The time delay for a stepwise change of the heat output from the burner, when placed centrally 1 m below the hood, shall not exceed 20 s and shall be corrected for in-test data. The time delay for each step shall be determined by measuring the time taken to reach agreement to within 10 % of the difference between the initial and final measured heat release value, when going through the stepwise procedure given in Table 1, taking measurements at 3 s intervals.

9.3 Precision

The precision of the system at various volume flow rates shall be checked by increasing the volume flow in the exhaust duct in four equal steps, starting from 2 $m^3 s^{-1}$ (at 0,1 MPa and 25 °C) up to maximum. The heat output from the burner shall be 300 kW. The error in the mean heat release rate, calculated over 1 min, shall be no more than 10 % of the actual heat output from the burner.

10 Preparation of test specimens

10.1 Test specimen configuration

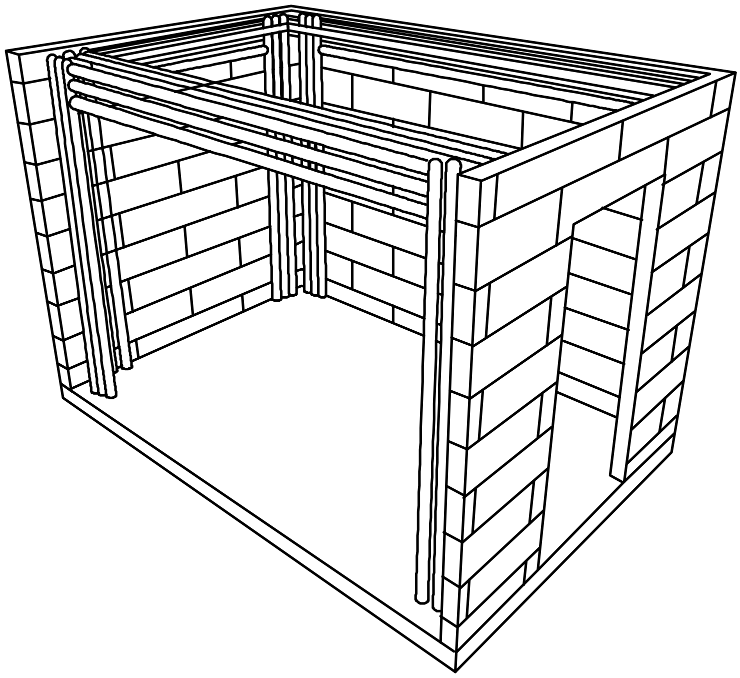
The pipe insulation product shall be mounted as closely as possible to the end use application conditions. It shall be mounted and fixed as pipe sections with a (25 ± 1) mm gap maintained between each of the insulated pipe runs according to the configuration given in Annex A. A three-dimensional view is given in Figure 3.

10.2 Mounting of insulation on pipes

Pipe insulation shall be mounted and fixed on steel pipes. The steel pipes shall have an outside diameter of (21,3 ± 0,1) mm and a thickness of (2,55 ± 0,05) mm.

NOTE 1 Steel pipes produced according to ISO 65[1], medium series, fulfil these criteria.

NOTE 2 The standard configuration is steel pipes, but other types of pipe can be tested if required.



NOTE The roof and left wall of the room corner have been removed for better view.

Figure 3 — Three-dimensional view of the test specimen configuration

10.3 Dimensions of test specimen

Pipe insulation shall be tested with an inner diameter of (22,0 ± 0,5) mm and an insulation thickness of between 25 mm and 50 mm.

NOTE 1 Some rules can be considered when examining the reaction to fire performance of ranges of pipe insulation, e.g.:

a) test data on pipe insulation with an inner diameter of 22 mm might be applicable for other inner diameters; however, intermediate bore diameters, i.e. greater than 50 mm, might not be covered by this test and ad hoc testing is recommended;

b) test data on pipe insulation with 25 mm thickness can also be valid for smaller thicknesses.

c) test data on pipe insulation with 50 mm thickness can be valid for larger thicknesses.

NOTE 2 Lower thicknesses can be tested but in this case the result is only valid for that specific thickness.

11 Testing

11.1 Initial conditions

11.1.1 The temperature in the test room from the start of the installation of the specimens until the start of the test shall be between 10 °C and 30 °C.

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

11.1.2 The horizontal wind speed measured to an accuracy of 0,12 m s^{-1} at a horizontal distance of 1 m external from the centre of the doorway shall not exceed 0,5 m s^{-1}.

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

11.1.4 The pipe insulation assembly shall be photographed or video recorded before testing.

11.2 Test procedure

11.2.1 Start all recording and measuring devices and record data at least 2 min prior to the burner being ignited. Use a 3 s interval.

11.2.2 Adjust the burner to the output level given in Clause 6 (see last paragraph) within 10 s of ignition. Continuously adjust the exhaust capacity so that all combustion products are collected.

11.2.3 Make a photographic and/or video recording of the test, with a timer appearing in all photographic records, giving time to the nearest second.

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

a) ignition of the test specimen, and any glowing or smouldering that might occur;

b) the surface spread of flame on the test specimen through measurement of the distance of damaged length;

c) occurrence and location of flaming droplets/particles that fall outside a zone measuring 1,2 m from the corner line of the corner where the burner is placed;

d) flames emerging through the doorway and whether these are transient flames or sustained flames;

e) flashover (corresponding to a heat release rate in the exhaust duct of 1 000 kW, including the contribution of the burner).

11.2.5 Stop the test if flashover occurs, or after 20 min from ignition of the burner, whichever occurs first. Continue observations until visual signs of combustion have ceased.

NOTE Safety considerations can dictate an earlier termination.

11.2.6 Note the extent and type of damage of the product after the test.

11.2.7 Record any other unusual performance.

12 Sensitivity analysis

Variation of fire load by either changing the number of pipes or by changing the insulation thickness from 25 mm to 50 mm is not expected to change the ranking order according to the fire performance of the products.

NOTE See, for example, Bibliography [4].

13 Precision data

The precision of this test method has not been determined. Results of a planned inter-laboratory test series will be included when available.

NOTE Repeatability has been studied in a European project and data are available. See Bibliography [4].

14 Test report

The test report shall contain the following information:

a) name and address of the testing laboratory;

b) date and identification number of the report;

c) name and address of the sponsor;

d) purpose of the test;

e) method of sampling;

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

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

h) density and thickness of the product;

i) date of supply of the product;

j) description of the test specimens and detailed mounting technique, i.e. clamps, fixing, etc.;

k) conditioning of the test specimens;

l) date of test;

m) test method and reference to this International Standard, i.e. ISO 20632:2007;

n) test results (see Annex B):

   1) time to flashover (see Clause B.5);

   2) time/heat release rate, $\dot{q}$, and, if the burner is included, time/heat release rate from the burner, $\dot{q}_b$;

   3) time/smoke production rate, R_{inst}, at actual duct flow temperature;

   4) description of the fire development (including photographs taken during the test);

   5) total smoke production, R_{tot}, calculated according to B.4.2 and specifying the time of integration;

   6) total heat released, Q_{tot}, calculated according to B.2.3 and specifying the time of integration;

   7) visual observations of flame spread and any flaming droplets/particles;

o) optional test results:

   1) time/volume flow in the exhaust duct;

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

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

p) on request of the sponsor, data file with data recorded automatically according to Clause 9 and/or latest calibration reports;

q) the statement “The test results relate only to the performance 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 material in use”.

Annex A
(normative)

Test specimen configuration

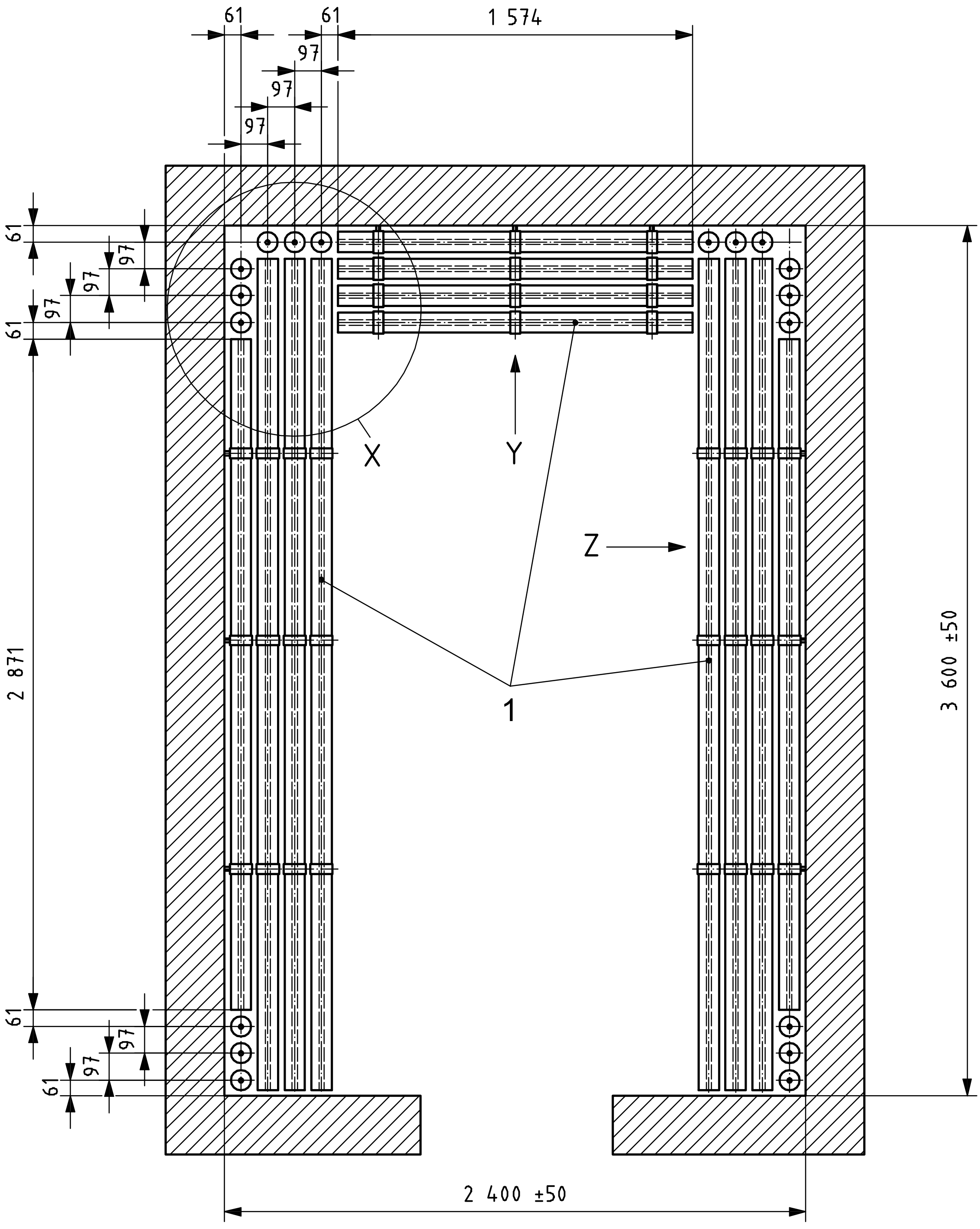
The pipe insulation shall be mounted on the ceiling and along the walls as schematically illustrated in Figures A.1 to A.4.

NOTE 1 The drawings in this annex assume a 25 mm insulation thickness but the same principles can be applied for thicknesses up to 50 mm, keeping the spacing between insulation surfaces and with the wall to 25 mm.

Tolerances given in the main body shall apply to these figures. For those dimensions where no specific tolerances are given in the figures or main body, standard technical tolerances shall apply.

NOTE 2 The mounting of the pipe insulation should follow end-use mounting and details of clamps, fixing, joints, etc., should be reported in detail.

Dimensions in millimetres



Key

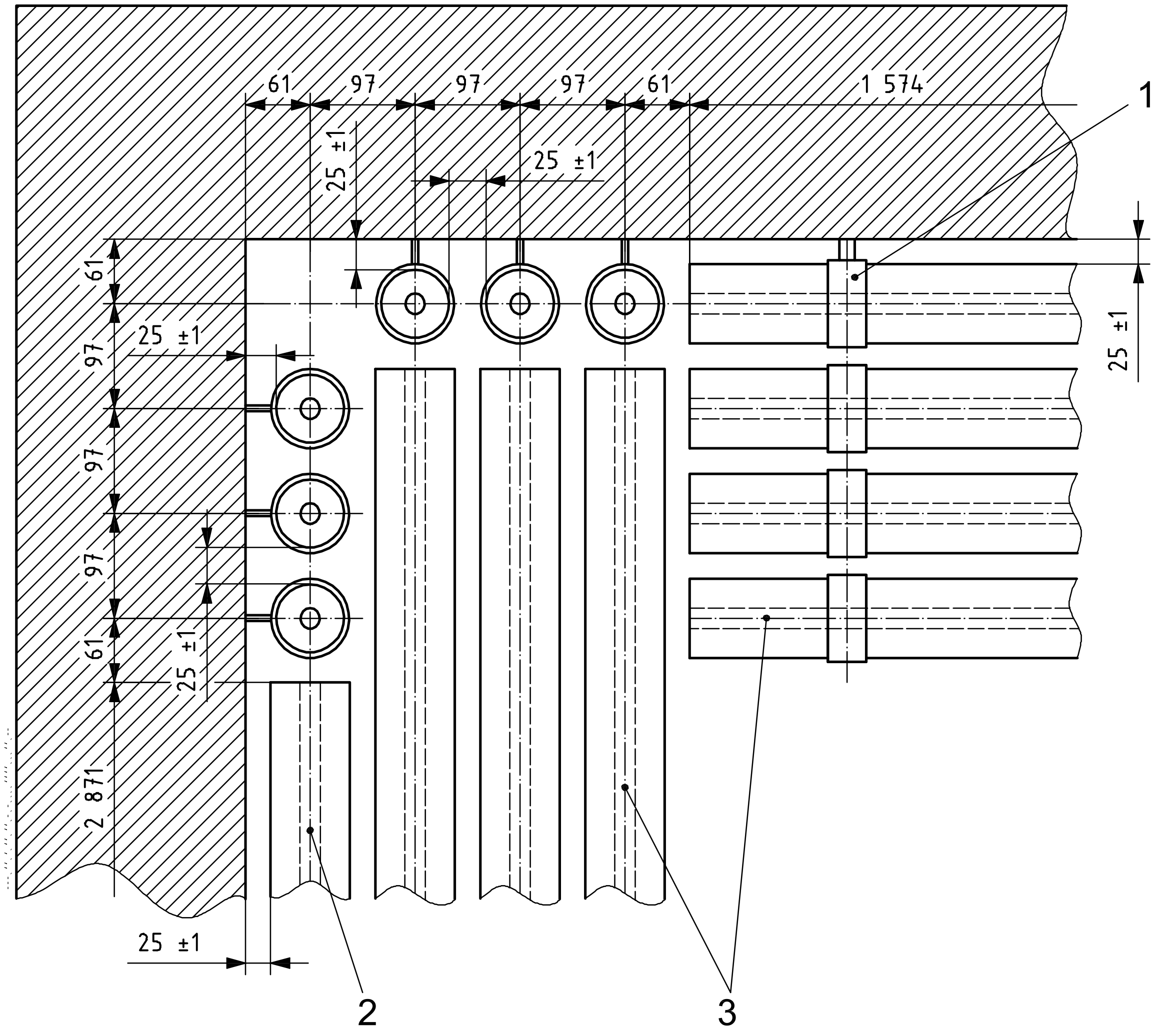
1 tubes

X detail of corner, given in Figure A.2

Y view of the end wall, given in Figure A.3

Z view of the side wall, given in Figure A.4

Figure A.1 — Example of test specimen configuration, plan view of top of room



Key

1 pipe hanger

2 tube R-022 (ISO 65)

3 tubes installed on ceiling

Figure A.2 — Example of test specimen configuration, elevation of corner detail
(detail X from Figure A.1)

Dimensions in millimetres

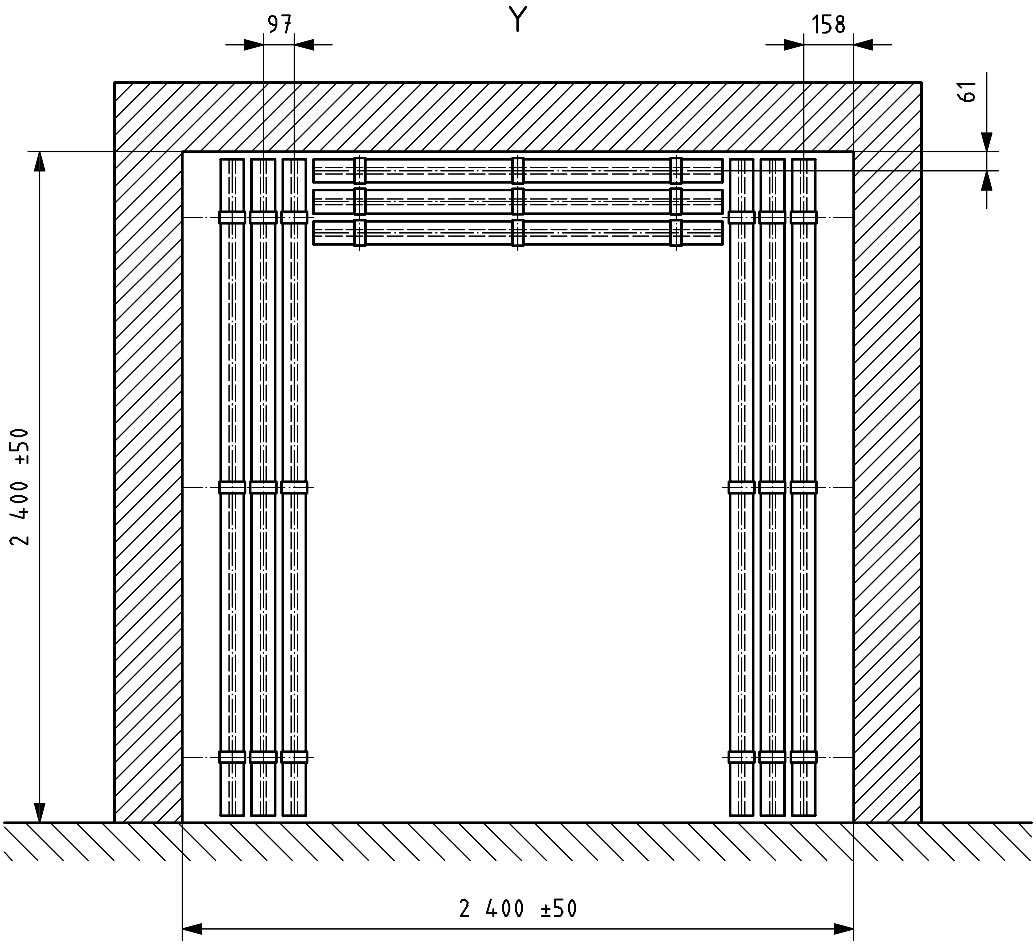
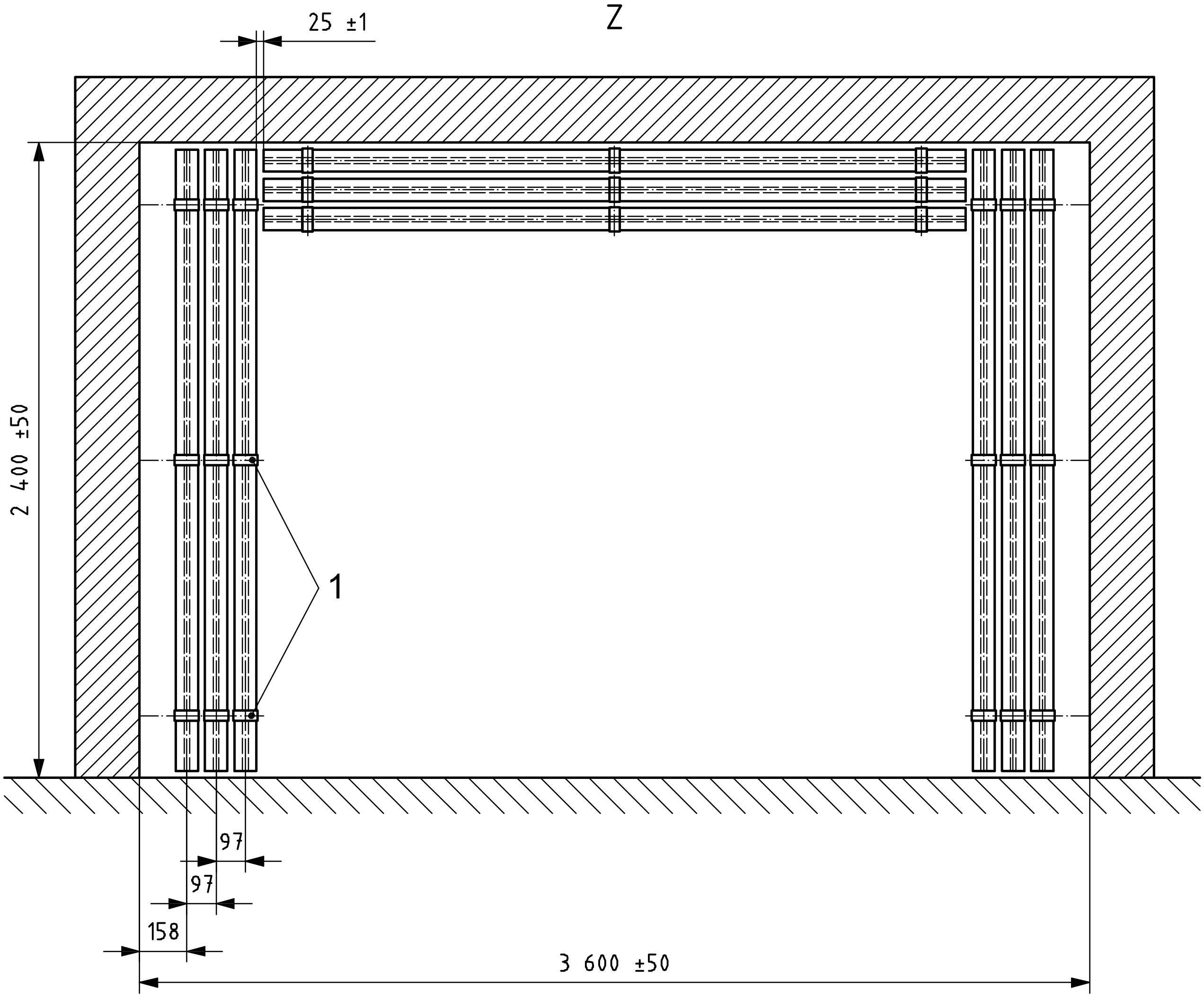


Figure A.3 — Example of test specimen configuration, elevation of end wall



Key

1 pipe hanger

Figure A.4 — Example of test specimen configuration, side elevation near side wall

Annex B
(normative)

Calculations

B.1 Volume flow

The volume flow in the exhaust duct, $\dot{V}_{298}$, expressed in cubic metres per second, related to atmospheric pressure and an ambient temperature of 25 °C, shall be calculated by the equation

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

where

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

T_o = 273,15 K;

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

ρ_{298} is the air density at 25 °C and atmospheric pressure, expressed in kilograms per cubic metre;

ρ_o is the air density at 0 °C and 0,1 MPa, expressed in kilograms per cubic metre;

A is the cross-sectional area of exhaust duct, expressed in square metres;

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

k_p is the Reynolds number correction for the bi-directional probe, taken as constant and equal to 1,08.

Equation (B.1) assumes that density changes in the combustion gases (related to air) are caused solely by the temperature increase. The calibration constant k_t is determined by measuring the temperature and flow profile inside the exhaust duct along a cross-sectional diameter. Several series of measurements should be made with representative mass flows and with both warm and cold gas flows. The error when determining the k_t factor should not exceed ± 3 %.

NOTE Corrections due to a changed chemical composition or humidity content can be ignored except in studies of the extinguishment process with water.

B.2 Generated heat effect, calibration and test process

B.2.1 Calibration process

During the calibration process, heat release rate from the ignition source, $\dot{q}_b$, expressed in kilowatts, shall be calculated from the consumption of propane gas from Equation B.2:

$$\dot{q}_b = \dot{m}_b \Delta h_{c,eff} \quad \text{(B.2)}$$

where

$\dot{m}_b$ is the mass flow rate of propane to the burner, expressed in grams per second;

$\Delta h_{c,eff}$ is the effective lower heat combustion of propane, expressed in kilojoules per gram.

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

B.2.2 Heat release rate

Heat release rate from a tested product, $\dot{q}$, expressed in kilowatts, shall be calculated from Equation B.3:

$$\dot{q} = E^1 \dot{V}_{298} x_{O_2}^{a} \left(\frac{\phi}{\phi(\alpha - 1) + 1} \right) - \frac{E^1}{E_{C_3H_8}} \dot{q}_b \quad \text{(B.3)}$$

with ϕ, the oxygen depletion factor, given by

$$\phi = \frac{x_{O_2}^{0}(1 - x_{CO_2}) - x_{O_2}(1 - x_{CO_2}^{0})}{x_{O_2}^{0}(1 - x_{CO_2} - x_{O_2})} \quad \text{(B.4)}$$

and $x_{O_2}^{a}$, the ambient mole fraction of oxygen, given by

$$x_{O_2}^{a} = x_{O_2}^{0}(1 - x_{H_2O}^{a}) \quad \text{(B.5)}$$

where

E is the heat release per volume of oxygen consumed, expressed in kilojoules per cubic metre;

E^1 = 17,2 × 10^3 kJ m^{-3} (25 °C) for combustion of tested product;

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

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

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

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

NOTE $x_{O_2}^{a}$ should be measured prior to the test without trapping of water.

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

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

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

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

$x_{H_2O}^{a}$ is the ambient mole fraction of water vapour.

NOTE Subtracting the heat release from the burner at the very beginning of a test will produce negative values of $\dot{q}$. This is due to combustion gas fill-up times in the room, transportation times to the hood, etc., and can be corrected for by making measurements of the burner only when placed in the room and then subtracting the time-dependent response that was measured.

B.2.3 Calculation of total heat release

The total heat release from a tested product, Q_{tot}, shall be calculated as:

$$Q_{tot}(t) = \frac{1}{1\,000}\sum_{0s}^{t}\dot{q}(t) \times 3s \quad \text{(B.6)}$$

where

$Q_{tot}(t)$ = total heat release during 0 s to t s in megajoules;

$\dot{q}(t)$ = heat release rate, in kilowatts = $\dot{q}$, according to Equation (B.3).

The time t is selected according to requirements. The time t shall be the end of test (in case of no flashover) or one record before the time to flashover as defined in B.5 in case of flashover.

Equations (B.2) to (B.5) are based on certain approximations leading to the following limitations.

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

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

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

These accumulated errors should normally be less than 10 %.

B.3 Combustion gases

By measuring the mole fraction of a specified gas, it is possible to calculate the instantaneous rate of gas production $\dot{V}_{gas}$, expressed in cubic metres per second at 0,1 MPa and 25 °C and the total amount of gas production V_{gas}, expressed in cubic metres at 0,1 MPa and 25 °C. The following equations shall be used:

Error! Objects cannot be created from editing field codes. (B.7)

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

where

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

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

t is the time from ignition, expressed in seconds.

B.4 Light obscuration

B.4.1 Light intensity

The optical density is represented by the extinction coefficient, k, expressed in reciprocal metres and shall be calculated as follows:

$$k = \frac{1}{L}\ln\left(\frac{I_o}{I}\right) \tag{B.9}$$

where

I_o is the light intensity for a beam of parallel light rays measured in a smoke free environment with a detector having the same spectral sensitivity as the human eye;

I is the light intensity for a parallel light beam having traversed a certain length of smoky environment;

L is the length of beam through the smoky environment, expressed in metres.

The instantaneous rate of light-obscuring smoke R_{inst}, expressed in square metres per second, and the total amount of smoke R_{tot} (see B.4.3) expressed in square metres shall then be calculated from

$$R_{inst} = k\dot{V}_s \tag{B.10}$$

where $\dot{V}_s$ is the volume flow in the exhaust duct at actual duct gas temperature, expressed in cubic metres per second.

B.4.2 Calculation of smoke production rate, $R_{inst,smooth}$

$R_{inst,smooth}(t)$ is the average of $R_{inst}(t)$ over 60 s, shall be calculated as in equation (B.11).

$$R_{inst,smooth}(t) = \frac{R_{inst}(t-30s) + R_{inst}(t-27s) + ... + R_{inst}(t+27s) + R_{inst}(t+30s)}{21} \tag{B.11}$$

During flashover, in the first and the last minute of a test, the calculation of $R_{inst,smooth}$ according to equation (B.11) does not apply, as the required 21 records are not available. For those cases the procedures given below apply.

Beginning of test:

For $t = 0$ s: $R_{inst,smooth} = 0$ m^2/s

For $t = 3$ s: $R_{inst,smooth} = R_{inst}$ average over the period (0s…6s)

For $t = 6$ s: $R_{inst,smooth} = R_{inst}$ average over the period (0s…12s)

For $t = 27$ s: $R_{inst,smooth} = R_{inst}$ average over the period (0s…54s)

For $t = 30$ s $R_{inst,smooth}$ is calculated according to Equation (B.11)

End of test:

$R_{inst,smooth}$ is calculated according to equation (B.11) until the data point SPR (t + 30s) is one record from the flashover point or, if there is no flashover, until SPR (t + 30s) = 19 min 57s. This means that there are no values of $R_{inst,smooth}$ given for the last 10 records, 30 s, of a test.

Flashover faster than 60 s:

In cases of flashover in shorter time than 60 s, $R_{inst,smooth}$ is calculated as the time average over the entire actual time interval. The corresponding value of t is taken at the middle of the time interval.

B.4.3 Calculation of R_{tot}

The total smoke production $R_{tot}(t)$ shall be calculated as:

$$R_{tot}(t) = \sum_{0s}^{t} R_{inst}(t) \times 3\text{s} \tag{B12}$$

where

$R_{tot}(t)$ = total smoke production during 0 s to t s in square metres;

$R_{inst}(t)$ = smoke production rate in square metres per second.

The time t is selected according to requirements. The time t may be the time at the end of the test or one record before flashover as defined in B.5.

B.5 Time to flashover

Time to flashover is the time when the total HRR is 1 000 kW. It is found by linear interpolation between the nearest two measured data points.

Annex C
(informative)

Design of exhaust system

C.1 General

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

C.2 Hood

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

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

The hood should be designed and manufactured so that leakage is not possible.

C.3 Duct

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

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

The exhaust duct is connected to an evacuation system.

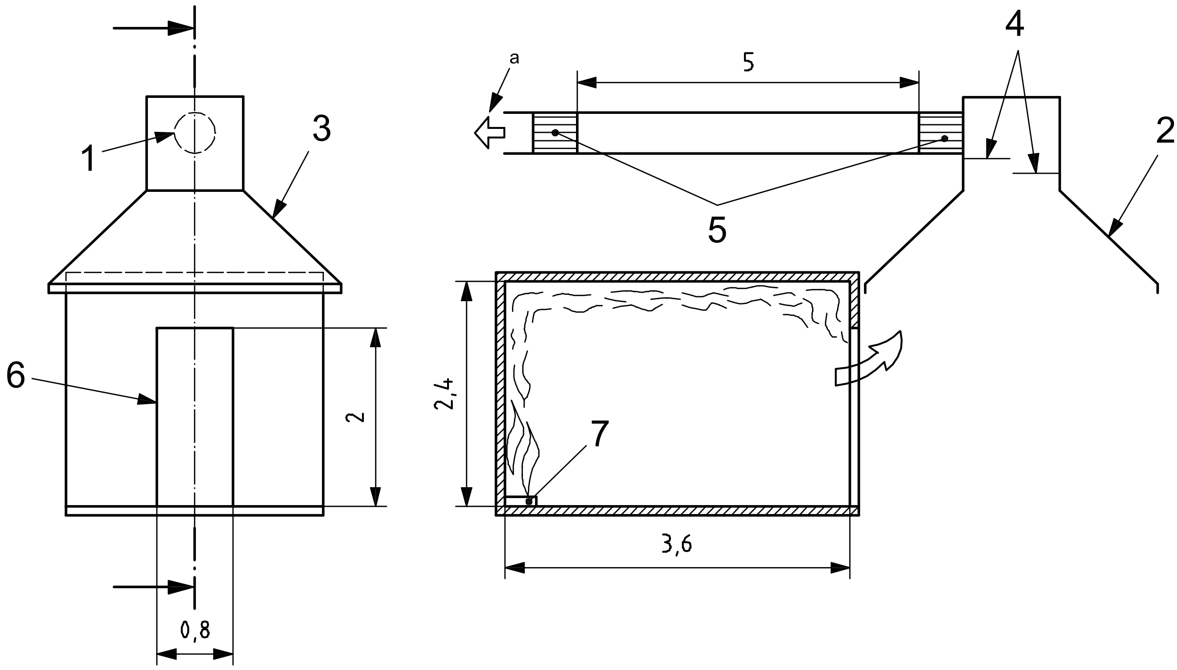
C.4 Capacity

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

C.5 Alternative systems

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

Dimensions in metres



Key

1 exhaust duct Ø 0,4 m

2 hood 3 m × 3 m

3 hood 3 m × 3 m

4 baffles

5 guide vanes

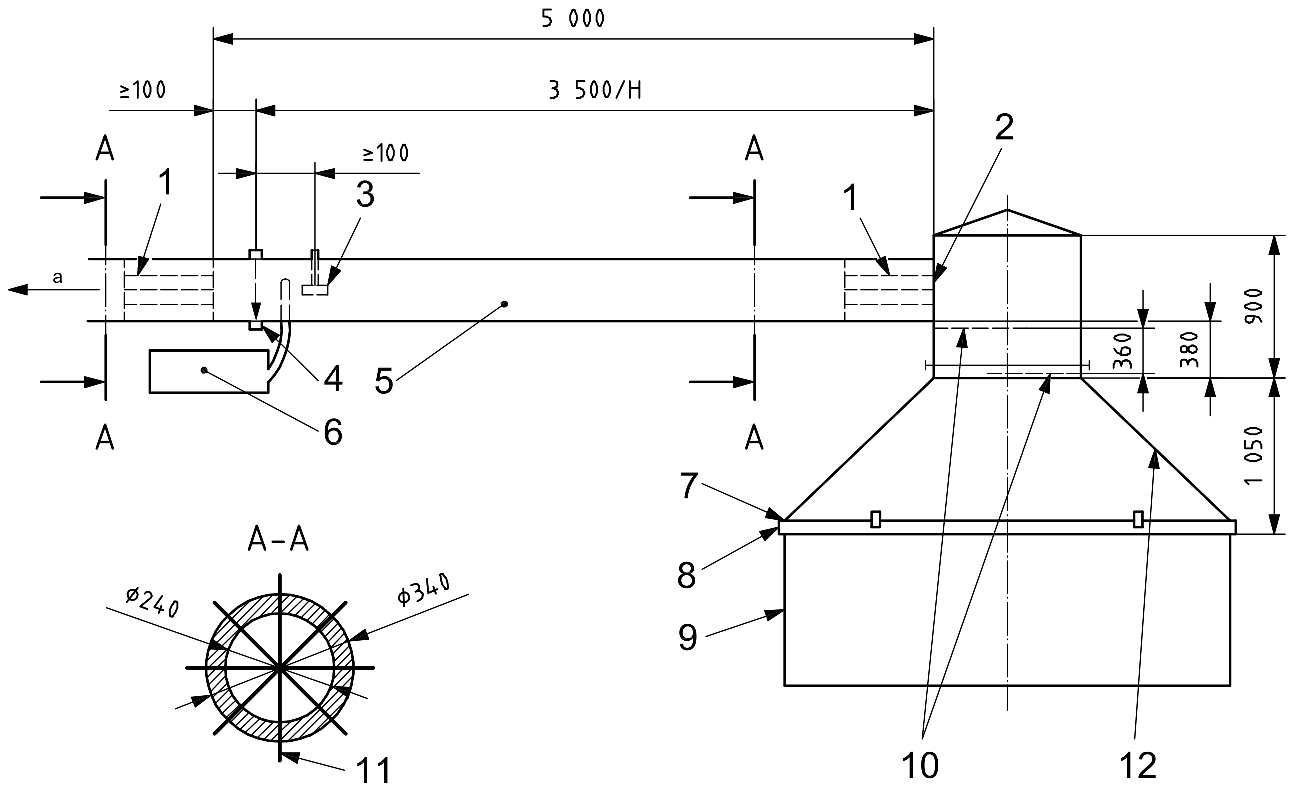
6 doorway

7 gas burner

[a] To exhaust gas cleaning.

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

Dimensions in millimetres



Key

1 guide vanes

2 opening Ø 400 mm

3 pitot tube

4 lamp, photocell system

5 exhaust duct Ø 400 mm

6 gas analysis

7 opening 3 000 mm × 3 000 mm

8 frame of steel profile 50 mm × 100 mm × 3,2 mm

9 steel plates 1 000 mm × 3 000 mm

10 steel plates 2 mm × 500 mm × 900 mm

11 four steel plates 395 mm × 400 mm

12 hood of 2 mm thick steel plate

[a] To exhaust gas cleaning.

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

Annex D
(informative)

Instrumentation in exhaust duct

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

D.1 Volume flow

D.1.1 The flow may be measured by a bidirectional probe located at the centre line of the duct. The probe shown in Figure D.1 consists of a stainless steel cylinder, 32 mm long and with an inner diameter of 14 mm. The cylinder is divided into two equal chambers. The pressure difference between the two chambers is measured by a pressure transducer. The plot of the probe response versus the Reynolds number is shown in Figure D.2.

D.1.2 The pressure transducer should have a measuring precision better than ± 5 Pa and be of the capacitance type. A suitable range of measurement is 0 Pa to 2 000 Pa.

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

D.2 Sampling line

D.2.1 The sampling probe should be located where the exhaust duct flow is well mixed. The probe should have a cylindrical form so that disturbance of flow is minimized. The gas samples should be taken along the whole diameter of the exhaust duct.

D.2.2 The sampling line (see Figure D.3) should be manufactured from a non-corrosive material, e.g. PTFE. The combustion gases should be filtered with inert filters to the degree of particle concentration required by the gas analysis equipment. The filtering procedure should be carried out in more than one step. The gas mixture should be cooled to a maximum of 10 °C.

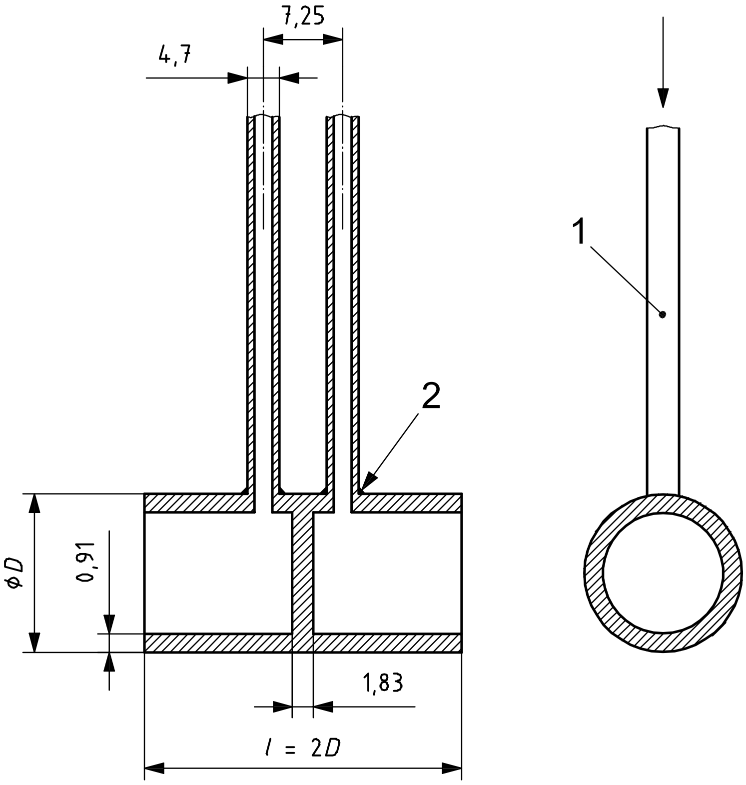
For gases other than CO, CO_2 and O_2, heated sampling lines (150 °C to 175 °C) should be used. The sampling lines should be as short as possible and the gases should not be filtered (see also D.3.3 and D.3.4).

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

D.2.4 The sampling line should end in an open container at atmospheric pressure. The volume of the container should not be so large that concentration gradients or time lags are generated. Transport time in the sampling line should not exceed 1 s.

D.2.5 A suitable sampling probe is shown in Figure D.4. A suitable pump should have the capacity of 10 l min^{-1} to 50 l min^{-1}, as each gas analysis instrument requires about 1 l min^{-1}. The pump should generate a pressure differential of at least 10 kPa to reduce the risk of smoke clogging of the filters. The intake of the sampling probe is turned downstream in order to avoid soot clogging in the probe.

Dimensions in millimetres



Key

1 variable length support tubes (to Δp instrument)

2 weld

NOTE 1 Source: see Bibliography [5].

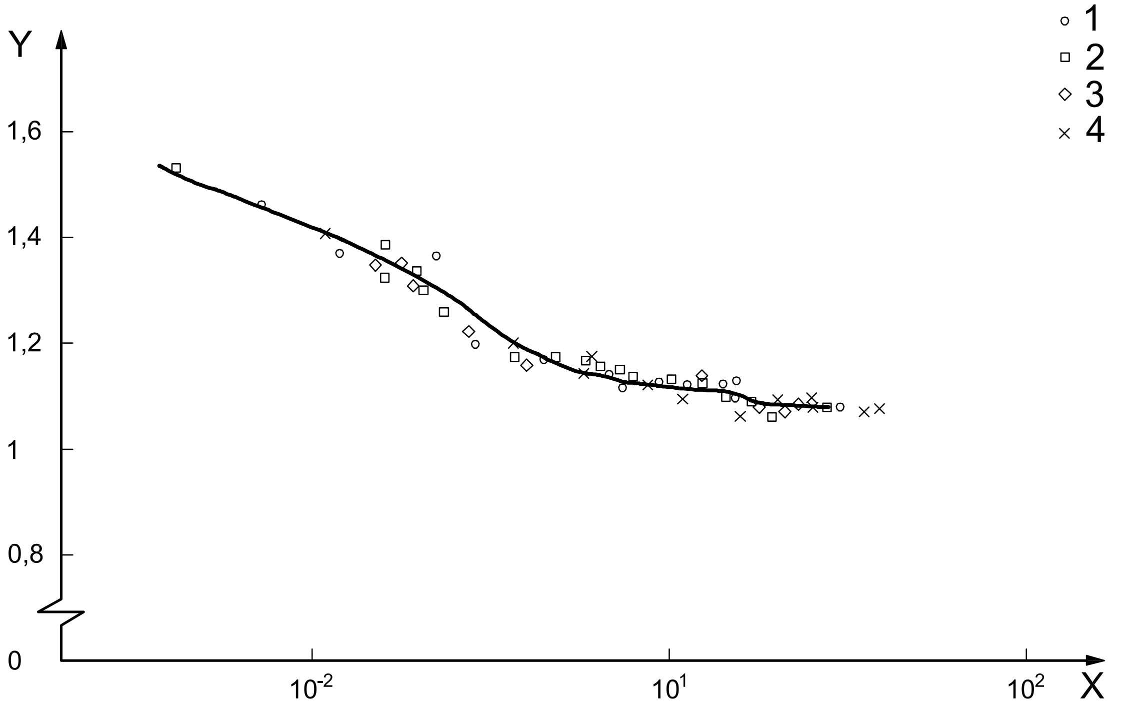
NOTE 2 The pressure differences were measured using a sensitive electronic manometer; the uniform low velocity flows were provided by two independent facilities described in McCaffrey and Heskestad[5]. Basically, a hot wire anemometer and pitot-static tube, where appropriate, were used to determine the stream velocity. For data reduction via computer, the polynomial curve fit obtained for the points shown in Figure D.2 is

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

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

NOTE 3 A suitable value of D (the outer diameter of the probe) is 16 mm.

Figure D.1 — Bi-directional probe



Key

X Reynolds number (non-dimensional)

Y probe response (non-dimensional)

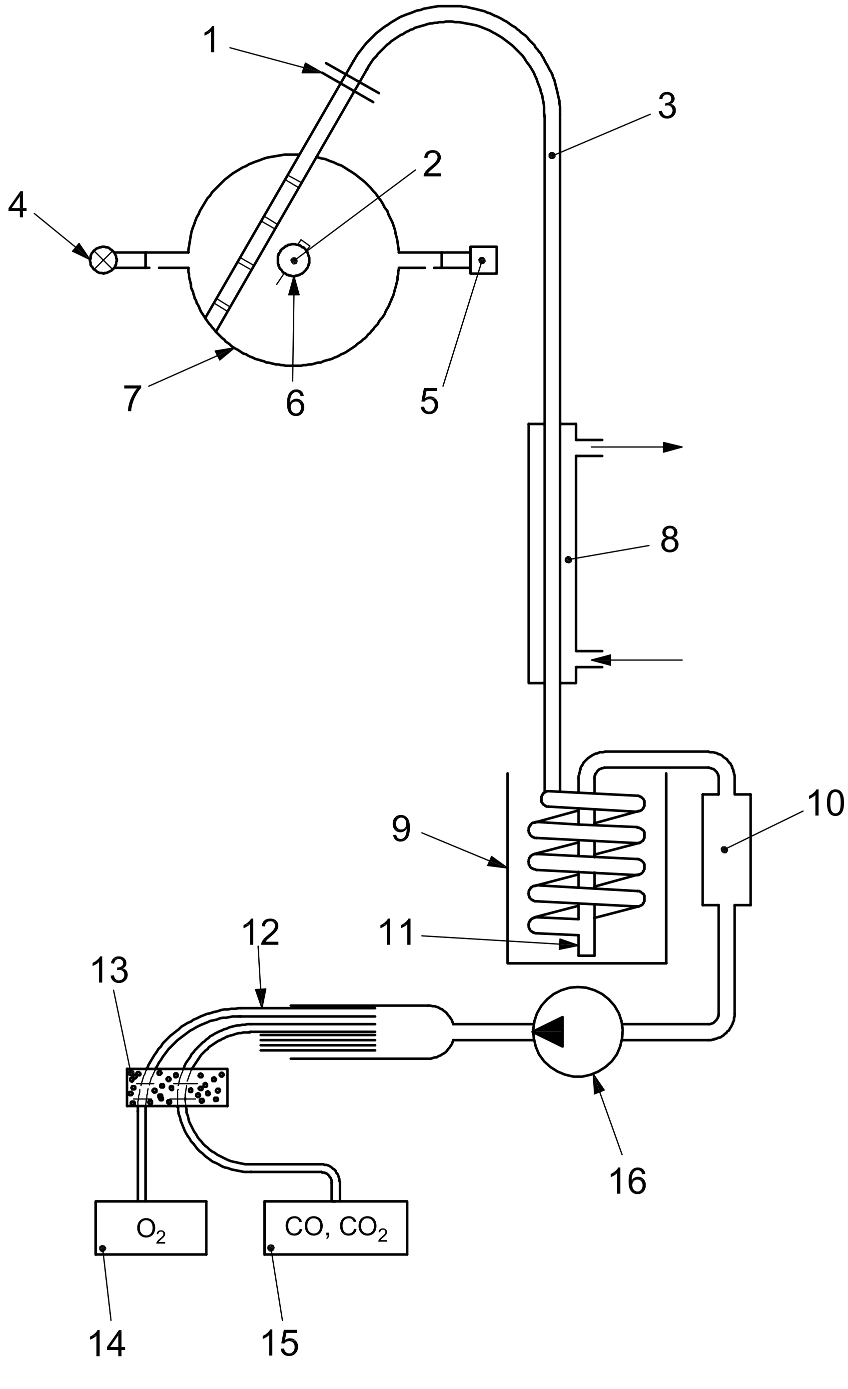
1 $D = 12{,}7$ mm

2 $D = 15{,}9$ mm

3 $D = 25{,}4$ mm

4 $D = 22{,}2$ mm

Figure D.2 — Probe response versus Reynolds number



Key

1 glass filters 150 µm to 200 µm

2 thermocouple

3 stainless steel sampling line Ø 10 mm

4 lamp

5 photocell

6 pitot tube

7 exhaust duct

8 water cooler

9 ice box

10 membrane filter 3 µm

11 water drainage

12 surplus gas

13 filter for water absorption

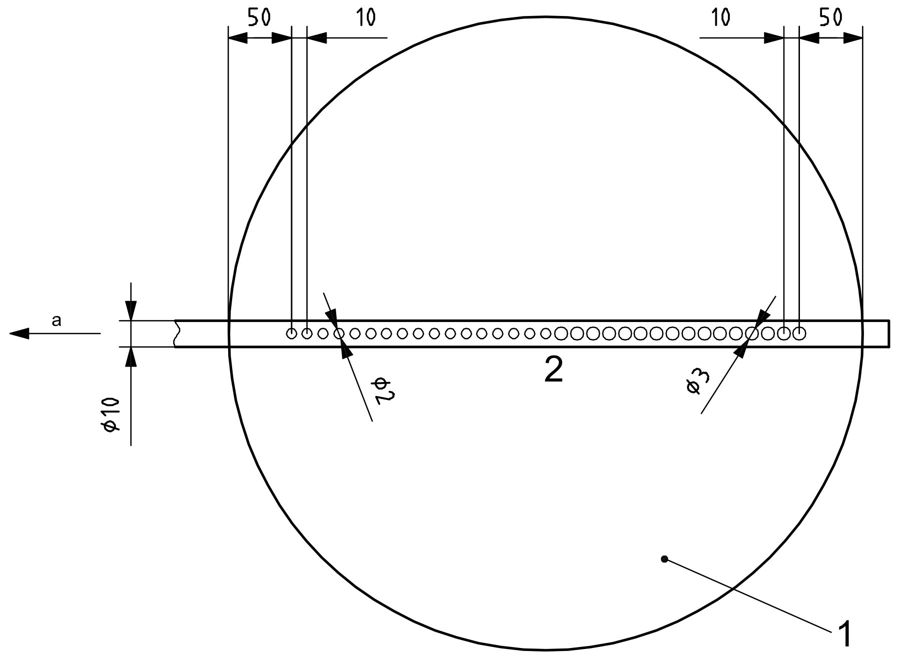
14 paramagnetic analyser (O_2)

15 infrared spectrophotometer (CO, CO_2)

16 membrane pump

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

Dimensions in millimetres



Key

1 exhaust duct

2 holes on downstream side of flow (16 holes Ø 2 mm and 15 holes Ø 3 mm)

a Sample flow.

Figure D.4 — Sampling probe

D.3 Combustion gas analysis

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

D.3.1 General

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

D.3.2 Oxygen concentration

The oxygen analyser should comply with the requirements specified in 8.2.2 and should be of the paramagnetic type.

D.3.3 Carbon monoxide and dioxide concentration

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

D.3.4 Hydrocarbons

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

D.3.5 Nitrogen oxide concentration

The concentration of NO and NO_2 can be measured together in total and with an analyser of the chemiluminescence type. The total maximum error of the analyser should be 2 % and a suitable range of measurement is 0 to 0,025 %. Response times are specified in D.3.4. A heated sampling line should be used.

D.4 Optical density

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

— lenses: plane convex; diameter 40 mm, focal length 50 mm;

— lamp: halogen type; 6 V, 10 W;

— photocell: silicon photodiode with a coloured glass subtractive filter that produces a spectral response equivalent to that of the human eye.

The photocell is connected to an appropriate resistance or amplifier that gives a minimum resolution of 3,5 decades. Lenses, lamp and photocell are mounted inside two housings, located on the exhaust duct diametrically opposite each other.

The system should be self-cleansing with respect to soot deposits, which may be achieved by having holes in the periphery of the two housings with the system under pressure so that air flows in through the periphery of the housings.

NOTE A suitable light measuring system is given in ISO/TR 5924[2].

Bibliography

[1] ISO 65, *Carbon steel tubes suitable for screwing in accordance with ISO 7-1*

[2] ISO/TR 5924, *Fire tests — Reaction to fire — Smoke generated by building products (dual-chamber test)*

[3] ISO/TR 9122-3, *Toxicity testing of fire effluents — Part 3: Methods for the analysis of gases and vapours in fire effluents*

[4] SUNDSTROM, B. and AXELSSON, J. *Development of a common European system for fire testing of pipe insulation based on EN 13823 (SBI) and ISO 9705 (Room/Corner Test)*, SP report 2002:21

[5] MCCAFFREY and HESKESTAD, *Combustion and Flame*, **26**, 1976

ICS 13.220.50

Price based on 29 pages