INTERNATIONAL STANDARD

ISO 5660-1

Third edition
2015-03-15

Corrected version
2021-01

Reaction-to-fire tests — Heat release, smoke production and mass loss rate —

Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)

Essais de réaction au feu — Débit calorifique, taux de dégagement de fumée et taux de perte de masse —

Partie 1: Débit calorifique (méthode au calorimètre à cône) et taux de dégagement de fumée (mesurage dynamique)

Reference number
ISO 5660-1:2015(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **v**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Symbols **3**

5 Principle **4**

6 Apparatus **5**
6.1 General 5
6.2 Cone-shaped radiant electrical heater 5
6.3 Radiation shield 5
6.4 Irradiance control 5
6.5 Weighing device 5
6.6 Specimen holder 6
6.7 Retainer frame 6
6.8 Exhaust gas system with flow measuring instrumentation 6
6.9 Gas sampling apparatus 6
6.10 Ignition circuit 7
6.11 Ignition timer 7
6.12 Oxygen analyser 7
6.13 Heat flux meters 7
6.14 Calibration burner 7
6.15 Data collection and analysis system 8
6.16 Optional side screens 8
6.17 Smoke obscuration measuring system 8
6.18 Smoke system thermocouple 8
6.19 Optical filters 8

7 Suitability of a product for testing **9**
7.1 Surface characteristics 9
7.2 Asymmetrical products 9
7.3 Materials of short burning time 9
7.4 Composite specimens 9
7.5 Dimensionally unstable materials 9
7.6 Materials that require testing under compression 10

8 Specimen construction and preparation **10**
8.1 Specimens 10
8.2 Conditioning of specimens 11
8.3 Preparation 11
8.3.1 Specimen wrapping 11
8.3.2 Specimen preparation 11
8.3.3 Preparing specimens of materials that require testing under compression 11

9 Test environment **12**

10 Calibration **12**
10.1 Preliminary calibrations 12
10.1.1 General 12
10.1.2 Irradiance control system response characteristics 12
10.1.3 Weighing device response time 12
10.1.4 Weighing device output drift 12
10.1.5 Oxygen analyser delay and response times 12
10.1.6 Oxygen analyser output noise and drift 13
10.1.7 Effect of side screens 13
10.2 Operating calibrations 14

10.2.1 General ... 14
10.2.2 Weighing device accuracy ... 14
10.2.3 Oxygen analyser ... 14
10.2.4 Heat release rate calibration ... 15
10.2.5 Heater calibration ... 15
10.3 Smoke meter calibration ... 15
10.3.1 Calibration with neutral density filters ... 15
10.3.2 Calibration before test ... 15
10.4 Less frequent calibrations ... 15
10.4.1 Operating heat flux meter calibration ... 15
10.4.2 Linearity of heat release rate measurements ... 15
10.4.3 Accuracy of calibration burner flow meter ... 16

11 Test procedure ... 16
11.1 General precautions ... 16
11.2 Initial preparation ... 16
11.3 Procedure ... 17

12 Calculations ... 18
12.1 General ... 18
12.2 Calibration constant for oxygen consumption analysis ... 18
12.3 Heat release rate ... 18
12.4 Exhaust duct flow rate ... 19
12.5 Mass loss rate ... 19
12.6 Smoke obscuration ... 20

13 Test report ... 20

Annex A (informative) **Commentary and guidance notes for operators ... 31**

Annex B (informative) **Supplementary calculations — Normalization to the mass loss rate of the specific extinction area of specimen ... 36**

Annex C (informative) **Resolution, precision and bias ... 38**

Annex D (informative) **Mass loss rate and effective heat of combustion ... 44**

Annex E (informative) **Testing in the vertical orientation ... 45**

Annex F (informative) **Calibration of the working heat flux meter ... 48**

Annex G (informative) **Calculation of heat release with additional gas analysis ... 49**

Annex H (informative) **Calculation of Effective Critical Heat Flux for Ignition ... 53**

Bibliography ... 54

Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

This third edition of ISO 5660-1 cancels and replaces ISO 5660-1:2002 (second edition) and ISO 5660-2:2002 (first edition), which have been technically revised and merged.

ISO 5660 consists of the following parts, under the general title *Reaction-to-fire tests — Heat release, smoke production and mass loss rate*:

— *Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)*

— *Part 3: Guidance on measurement* [Technical Specification]

The following part is under preparation:

— *Part 4: Measurement of heat release for determination of low levels of combustibility.*

This corrected version of ISO 5660-1:2015 incorporates the following correction:

— Formula (4) has been corrected.

Reaction-to-fire tests — Heat release, smoke production and mass loss rate —

Part 1:
Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)

1 Scope

This part of ISO 5660 specifies a method for assessing the heat release rate and dynamic smoke production rate of specimens exposed in the horizontal orientation to controlled levels of irradiance with an external igniter. The heat release rate is determined by measurement of the oxygen consumption derived from the oxygen concentration and the flow rate in the combustion product stream. The time to ignition (sustained flaming) is also measured in this test.

The dynamic smoke production rate is calculated from measurement of the attenuation of a laser light beam by the combustion product stream. Smoke obscuration is recorded for the entire test, regardless of whether the specimen is flaming or not.

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 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 13943, *Fire safety — Vocabulary*

ISO 14697, *Fire tests — Guidance on the choice of substrates for building products*

3 Terms and definitions

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

3.1
essentially flat surface
surface whose irregularity from a plane does not exceed ± 1 mm

3.2
flashing
existence of flame on or over the surface of the specimen for periods of less than 1 s

3.3
ignition
onset of sustained flaming as defined in 3.10

3.4
irradiance
(at a point of a surface) quotient of the radiant flux incident on an infinitesimal element of surface containing the point, and the area of that element

Note 1 to entry: Convective heating is negligible in the horizontal specimen orientation. For this reason, the term "irradiance" is used instead of "heat flux" throughout this part of ISO 5660 as it best indicates the essentially radiative mode of heat transfer.

3.5
material
single substance or uniformly dispersed mixture

EXAMPLE Metal, stone, timber, concrete, mineral fibre and polymers

3.6
orientation
plane in which the exposed face of the specimen is located during testing, with either the vertical or horizontally face upwards

3.7
oxygen consumption principle
proportional relationship between the mass of oxygen consumed during combustion and the heat released

3.8
product
material, composite or assembly about which information is required

3.9
specimen
representative piece of the product which is to be tested together with any substrate or treatment

Note 1 to entry: For certain types of product, for example products that contain an air gap or joints, it may not be possible to prepare specimens that are representative of the end-use conditions (see Clause 7).

3.10
sustained flaming
existence of flame on or over the surface of the specimen for periods of over 10 s

3.11
transitory flaming
existence of flame on or over the surface of the specimen for periods of between 1 and 10 s

3.12
smoke obscuration
reduction, usually expressed as a percentage, in the intensity of light due to its passage through smoke

3.13
extinction coefficient
natural logarithm of the ratio of incident light intensity to transmitted light intensity, per unit light path length

3.14
smoke production
integral of the smoke production rate over the time interval being considered

3.15
smoke production rate
product of the volumetric flow rate of smoke and the extinction coefficient of the smoke at the point of measurement

4 Symbols

See Table 1.

Table 1 — Symbols and their designations and units

Symbol	Designations	Unit
A	exposed surface area of specimen	m^2
A_s	initially exposed surface area of the specimen	m^2
C	orifice flow meter calibration constant	$m^{1/2}$ $g^{1/2}$ $K^{1/2}$
D'	optical density	1
F	optical density calibration factor	m^{-1}
Δh_c	net heat of combustion	$K J\ g^{-1}$
$\Delta h_{c,eff}$	effective net heat of combustion	$M J\ kg^{-1}$
I_o/I	ratio of incident light to transmitted light	1
k	linear Napierian absorption coefficient (commonly called extinction coefficient)	m^{-1}
k_1	measured calibration extinction coefficient	m^{-1}
k_2	calculated calibration extinction coefficient	m^{-1}
k_m	measured extinction coefficient	m^{-1}
L	light path length through smoke	m
m	mass of the specimen	g
Δm	total mass loss	g
m_f	mass of the specimen at the end of the test	g
m_s	mass of the specimen at sustained flaming	g
$\dot{m}_{A,10-90}$	average mass loss rate per unit area between 10 % and 90 % of mass loss	$g\ m^{-2}\ s^{-1}$
m_{10}	mass of the specimen at 10 % of total mass loss	g
m_{90}	mass of the specimen at 90 % of total mass loss	g
$\dot{m}$	mass loss rate of the specimen	$g\ s^{-1}$
$\dot{m}_e$	mass flow rate in exhaust duct	$kg\ s^{-1}$
M	molecular weight of the gases flowing through the exhaust duct	$kg\ mol^{-1}$
Δp	orifice meter pressure differential	Pa
P_s	smoke production rate	$m^2\ s^{-1}$
$P_{s,A}$	smoke production rate normalized to the specimen area	s^{-1}
$\dot{q}$	heat release rate	kW
$\dot{q}_A$	heat release rate per unit area	$kW\ m^{-2}$
$\dot{q}_{A,max}$	maximum value of the heat release rate per unit area	$kW\ m^{-2}$
$\dot{q}_{A,180}$	average heat release rate per unit area over the period starting at t_{ig} and ending 180 s later	$kW\ m^{-2}$
$\dot{q}_{A,300}$	average heat release rate per unit area over the period starting at t_{ig} and ending 300 s later	$kW\ m^{-2}$
$Q_{A,tot}$	total heat released per unit area during the entire test	$MJ\ m^{-2}$
r_o	stoichiometric oxygen/fuel mass ratio	1
S	total smoke production	m^2
S_A	total smoke production per unit area	$m^2\ m^{-2}$
$S_{A,1}$	total smoke production per unit area before ignition	$m^2\ m^{-2}$
$S_{A,2}$	total smoke production per unit area after ignition	$m^2\ m^{-2}$
t	time	s

Table 1 *(continued)*

Symbol	Designations	Unit
t_d	delay time of the oxygen analyser	s
t_{ig}	time to ignition (onset of sustained flaming)	s
Δt	sampling time interval	s
t_{10}	time at 10 % of total mass loss	s
t_{90}	time at 90 % of total mass loss	s
T_e	absolute temperature of gas at the orifice meter	K
T_s	temperature of the smoke at the point of measurement	K
$\dot{V}_s$	volume flow rate of smoke at the point of measurement	$m^3\ s^{-1}$
X_{O2}	oxygen analyser reading, mole fraction of oxygen	1
X^0_{O2}	initial value of oxygen analyser reading	1
X^1_{O2}	oxygen analyser reading, before delay time correction	1
ρ	density	$kg\ m^{-3}$
σ	specific extinction area	$m^2\ kg^{-1}$

NOTE Detailed discussion of some of these parameters and their units is given in reference[11].

5 Principle

The test method is based on the observation that, generally, the net heat of combustion is proportional to the amount of oxygen required for combustion. The relationship is that approximately $13{,}1 \times 10^3$ kJ of heat are released per kilogram of oxygen consumed. Specimens in the test are burned under ambient air conditions, while being subjected to a predetermined external irradiance within the range of 0 kW m^{-2} to 75 kW m^{-2} and measurements are made of oxygen concentrations and exhaust gas flow rates.

This test method is used to assess the contribution that the product under test can make to the rate of evolution of heat during its involvement in fire. These properties are determined on small representative specimens.

The principle of the smoke measurement is based on the observation that, generally, the intensity of light that is transmitted through a volume of combustion products is an exponentially decreasing function of distance. This is commonly referred to as Bouguer's law. Specimens in the test are burned in ambient air conditions, while being subjected to a predetermined external irradiance within the range 0 kW m^{-2} to 75 kW m^{-2} and measurements are made of smoke obscuration, exhaust gas flow rate, and mass loss rate of the specimen. Smoke obscuration is measured as the fraction of laser light intensity that is transmitted through the smoke in the exhaust duct. This fraction is used to calculate the extinction coefficient according to Bouguer's law. The test results are reported in terms of smoke production and smoke production rate-both normalized to exposed specimen surface area. Smoke production rate is calculated as the product of the extinction coefficient and the volumetric flow rate of the smoke in the exhaust duct. Smoke production is calculated by numerical integration of the smoke production rate over the time interval being considered. The variables reported are normalized to area because smoke production is proportional to area.

The test method is used to assess the contribution that the product under test can make to the rate of evolution of smoke and to the amount of smoke produced during its involvement in a well-ventilated fire. These properties are once again determined on small representative specimens.

6 Apparatus

6.1 General

A schematic representation of the apparatus required for this part of ISO 5660 is given in Figure 1. The individual components are described in detail in 6.2 to 6.19.

Carbon Monoxide and Carbon dioxide measurements can optionally, and additionally, be made and used in the calculation of the heat release rate. The apparatus, procedures and calculation methods described in Annex G are then applicable.

With minor modifications to the apparatus, specimens may be tested in the vertical orientation. Annex E gives guidance on these modifications.

6.2 Cone-shaped radiant electrical heater

The active element of the heater shall consist of an electrical heater rod, capable of delivering 5 000 W at the operating voltage, tightly wound into the shape of a truncated cone (see Figure 2). The heater shall be encased on the outside with a double-wall stainless steel cone, filled with a refractory fibre blanket of nominal thickness 13 mm and nominal density 100 kg m^{-3}. The irradiance from the heater shall be maintained at a preset level by controlling the average temperature of three thermocouples (type K stainless steel sheathed thermocouples have proved suitable but Inconel or other high performance materials are also acceptable), symmetrically disposed and in contact with, but not welded to, the heater element (see Figure 2). Either 3,0 mm outside diameter sheathed thermocouples with exposed hot junction or 1,0 mm to 1,6 mm outside diameter sheathed thermocouples with unexposed hot junction shall be used. The heater shall be capable of producing irradiance on the surface of the specimen of up to 75 kW m^{-2}. The irradiance shall be uniform within the central 50 mm x 50 mm area of the exposed specimen surface, to within ± 2 %. for an irradiance of 50 kW m^{-2}

6.3 Radiation shield

The cone heater shall be provided with a removable radiation shield to protect the specimen from the irradiance prior to the start of a test. The shield shall be made of non-combustible material, with a total thickness not exceeding 12 mm. The shield shall be one of the following, either:

a) water cooled and coated with a durable matt black finish of surface emissivity ε = 0,95 ± 0,05; or

b) not water-cooled, which may be either metal with a reflective top surface, or metal with a ceramic top surface, or ceramic, in order to minimize radiation transfer.

The shield shall be equipped with a handle or other suitable means for quick insertion and removal. The cone heater base plate shall be equipped with a mechanism for moving the shield into position.

6.4 Irradiance control

The irradiance control system shall be properly tuned so that it maintains the average temperature of the heater thermocouples during the calibration described in 10.1.2 at the preset level to within ± 10 °C.

6.5 Weighing device

The weighing device shall have a resolution of 0,1 g and an accuracy of ± 0,3 g or better, measured according to the calibration procedure described in Clause 10.2.2. The weighing device shall be capable of measuring the mass of specimens of at least 500 g. The weighing device shall have a 10 % to 90 % response time of 4 s or less, as determined according to the calibration described in 10.1.3. The output of the weighing device shall not drift by more than 1 g over a 30 min period, as determined with the calibration described in Clause 10.1.4.

6.6 Specimen holder

The specimen holder is shown in Figure 3. The specimen holder shall have the shape of a square pan with an opening of (106 ± 1) mm x (106 ± 1) mm at the top, and a depth of (25 ± 1) mm. The holder shall be constructed of stainless steel with a thickness of (2,4 ± 0,15) mm. It shall include a handle to facilitate insertion and removal, and a mechanism to ensure central location of the specimen under the heater and proper alignment with the weighing device. The bottom of the holder shall be lined with a layer of low density (nominal density 65 kg m^{-3}) ceramic fibre blanket with a thickness of at least 13 mm. The distance between the bottom surface of the cone heater and the top of the specimen shall be adjusted to be (25 ± 1) mm, except for dimensionally unstable materials for which the distance shall be (60 ± 1) mm (see Clause 7.5).

6.7 Retainer frame

The frame shall be constructed of stainless steel with a thickness of (1,9 ± 0,1) mm in the shape of a box with an inside dimension of each side (111 ± 1) mm and a height of (54 ± 1) mm. The opening for the specimen face shall be (94,0 ± 0,5) mm square as shown in Figure 4. The retainer frame shall have an appropriate means to secure it to the specimen holder with a specimen in position.

6.8 Exhaust gas system with flow measuring instrumentation

The exhaust gas system shall consist of a centrifugal exhaust fan rated for the operating temperatures, a hood, intake and exhaust ducts for the fan, and an orifice plate flow meter (see Figure 5). The distance between the bottom of the hood and the specimen surface shall be (210 ± 50mm). The exhaust system shall be capable of developing flows up to 0,035 $m^3 s^{-1}$ under standard conditions of temperature and pressure. The recommended location of the fan is indicated in Figure 5. As an alternative, it is acceptable to locate the fan further downstream and to have the measuring orifice before the fan, provided that the requirements described in the remainder of this clause are fulfilled.

A restrictive orifice with an internal diameter of (57 ± 3) mm shall be located between the hood and the duct to promote mixing.

A gas sampling ring probe shall be located in the fan intake duct for gas sampling, (685 ± 15) mm from the hood (see Figure 5). The gas sampling ring probe shall contain 12 small holes with a diameter of (2,2 ± 0,1) mm, to average the stream composition, with the holes facing away from the flow to avoid clogging with soot.

The temperature of the gas stream shall be measured using a 1,0 mm to 1,6 mm outside diameter sheathed-junction thermocouple or a 3 mm outside diameter exposed-junction thermocouple positioned in the exhaust stack on the centreline and (100 ± 5) mm upstream from the measuring orifice plate.

The flow rate shall be determined by measuring the differential pressure across a sharp edge orifice [internal diameter (57 ± 3) mm, thickness (1,6 ± 0,3) mm] in the exhaust stack, at least 350 mm downstream from the fan, if the latter is located as shown in Figure 5. If the fan is located further downstream than indicated in Figure 5, it is acceptable to locate the orifice plate between the gas sampling ring probe and the fan. However, in that case the length of the straight duct section on both sides of the orifice plate shall be at least 350 mm.

6.9 Gas sampling apparatus

Gas sampling apparatus incorporates a pump, filters to prevent entry of soot, facilities for removal of the moisture, a by-pass system set to divert all flow except that required for the gas analysers, a further moisture trap and a trap for CO_2 removal.

A schematic view of an example of the gas sampling apparatus is shown in Figure 6. Other arrangements which satisfy the requirements may be used. The transport delay time of the oxygen analyser, t_d, shall be determined according to 10.1.5, and shall not exceed 60s.

NOTE If an (optional) CO_2 analyser is used, the formulae used to calculate the heat release rate can be different from those for the standard case (see Clause 12 and Annex G).

6.10 Ignition circuit

External ignition is accomplished by a spark plug powered from a 10 kV transformer or spark igniter. The spark plug shall have a gap of (3,0 ± 0,5) mm. The electrode length and location of the spark plug shall be such that the spark gap is located (13 ± 2) mm above the centre of the specimen, except for dimensionally unstable materials for which the distance is (48 ± 2) mm (see Clause 7.5).

6.11 Ignition timer

The ignition timer shall be capable of recording elapsed time to the nearest second and shall be accurate to within 1 s in one hour.

6.12 Oxygen analyser

The oxygen analyser shall be of the paramagnetic type, with a range of at least 0 % oxygen to 25 % oxygen. The analyser shall exhibit a drift of not more than 50 µl/l of oxygen over a period of 30 minutes, and a noise of not more than 50 µl/l of oxygen during this 30-min period, as measured according to 10.1.6. Since oxygen analysers are sensitive to stream pressures, the stream pressure shall be regulated (upstream of the analyser) to minimize flow fluctuations, and the readings from the analyser compensated with an absolute pressure transducer to allow for atmospheric pressure variations. The analyser and the absolute pressure transducer shall be located in an isothermal environment. The temperature of the environment shall be maintained to within 2 °C of a preset value between 30 °C and 70 °C. The oxygen analyser shall have a 10 % to 90 % of full-scale response time of less than 12 s, as measured according to 10.1.5.

6.13 Heat flux meters

The working heat flux meter shall be used to calibrate the heater (see 10.2.5). It shall be positioned at a location equivalent to the centre of the specimen face during this calibration.

This heat flux meter shall be of the Schmidt-Boelter (thermopile) type with a design range of (100 ± 10) kW m^{-2} . The target receiving the heat shall be flat, circular, of approximately 12,5 mm in diameter and coated with a durable matt black finish of surface emissivity ε = 0,95 ± 0,05. The body of the heat flux meter shall be water-cooled. A cooling temperature which would cause condensation of water on the target surface of the heat flux meter shall not be used.

Radiation shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, and stable in calibration. The instrument shall have a repeatability to within ± 0,5 %.

The calibration of the working heat flux meter shall be checked according to 10.4.1, by comparison with two instruments of the same type as the working heat flux meter and of similar range held as reference standards and not used for any other purpose (see Annex F). One of the reference standards shall be fully calibrated at a standardizing laboratory at yearly intervals.

6.14 Calibration burner

The calibration burner shall be constructed from tube with a square or circular orifice with an area of (500 ± 100) mm^2 covered with wire gauze through which the methane diffuses. The tube is packed with refractory fibre to improve uniformity of flow. The calibration burner is suitably connected to a metered supply of methane of at least 99,5 % purity. The accuracy of the flow meter or controller shall

be ± 3 % of the readout corresponding to a heat release rate of 5 kW. The accuracy verification shall be performed according to Clause 10.4.3.

6.15 Data collection and analysis system

The data collection and analysis system shall have facilities for recording the output from the oxygen analyser, the orifice meter, the thermocouples and the weighing device. The data collection system shall have an accuracy corresponding to at least 50 µl/l of oxygen for the oxygen channel, 0,5 °C for the temperature measuring channels, 0,01 % of full-scale instrument output for all other instrument channels, and at least 0,1 % for time. The system shall be capable of recording data every second. The system shall be capable of storing a minimum of 720 data points per parameter. The raw data recorded for each test shall be stored so that it can be recovered and used to check the accuracy of the software.

6.16 Optional side screens

For operational or safety reasons, it is permitted to guard the heater and sample holder with side screens. However, it shall be demonstrated that the presence of the screens does not affect the ignition time and heat release rate measurements according to the procedure described in 10.1.7.

If the screens form an enclosure, the attention is drawn to the fact that there is a possible explosion hazard when the instrument is not operated under conditions prescribed by this part of ISO 5660, in particular for experiments in oxygen enriched atmosphere. If an explosion hazard exists, proper precautions shall be taken to protect the operator, e.g. by installing an explosion vent facing away from the operator.

6.17 Smoke obscuration measuring system

For measuring the attenuation of laser light in the exhaust duct; the system comprises a helium-neon laser (between 0,5 mW and 2 mW, polarized), silicon photodiodes as main beam and reference detectors, and appropriate electronics to derive the extinction coefficient and to set the zero reading. The meter shall be located horizontally (111 ± 1) mm downstream of the gas sampling ring. Two small diameter tubes welded onto each side of the exhaust duct serve as part of the light baffling for the purging air and also allow for any smoke that may enter, despite the purge flow, to be deposited on the tube walls before reaching the optical elements. One acceptable arrangement of a smoke measuring system is shown in Figure 7.

NOTE Experimental work has been performed with systems using a white light source with collimating optics[12]. Such systems have been shown to yield generally similar results [17-19] but not under all conditions[20]. Theoretical predictions [21] have been verified experimentally. White light systems may be used if shown to have an equivalent accuracy.

6.18 Smoke system thermocouple

To measure the temperature of the gas stream near the smoke meter. This temperature shall be measured using a 1,0mm to 1,6mm outside diameter unearthed sheathed-junction thermocouple or a 3 mm outside diameter exposed-junction thermocouple positioned in the exhaust stack on the centre line and 50 mm downstream from the smoke meter, as shown in Figure 5.

6.19 Optical filters

To calibrate the smoke obscuration measuring system. Two glass neutral density dispersion filters[22], accurately calibrated at the laser wavelength of 632,8 nm, are required. The filters used shall not be of the coated type because these filters can give rise to interference effects with laser light and can deteriorate with time. The filters shall have nominal optical densities of 0,3 and 0,8. Corresponding values of extinction coefficient, k, are obtained from the formula:

$$k = (2{,}303\ D')\ L^{-1}$$

7 Suitability of a product for testing

7.1 Surface characteristics

A product having one of the following properties is suitable for testing:

a) an essentially flat exposed surface;

b) a surface irregularity which is evenly distributed over the exposed surface provided that

1) at least 50 % of the surface of a representative 100mm square area lies within a depth of 10 mm from a plane taken across the highest points on the exposed surface,

or

2) for surfaces containing cracks, fissures or holes not exceeding 8mm in width nor 10mm in depth, the total area of such cracks, fissures or holes at the surface does not exceed 30 % of a representative 100mm square area of the exposed surface.

When an exposed surface does not meet the requirements of either 7.1 a) or 7.1 b), the product shall be tested in a modified form complying as nearly as possible with the requirements given in 7.1. The test report shall state that the product has been tested in a modified form, and clearly describe the modification.

7.2 Asymmetrical products

A product submitted for this test can have faces which differ or can contain laminations of different materials arranged in a different order in relation to the two faces. If either of the faces can be exposed in use within a room, cavity or void, then both faces shall be tested.

7.3 Materials of short burning time

For specimens of short burning time (3 min or less), the heat release rate measurements shall be taken at not more than 2 s intervals. For longer burning times, 5 s intervals may be used.

7.4 Composite specimens

Composite specimens are suitable for testing, provided they are prepared as specified in 8.3 and are exposed in a manner typical of end use conditions.

7.5 Dimensionally unstable materials

Samples that intumesce or deform so that they contact the spark plug prior to ignition, or the underside of the cone heater after ignition, shall be tested with the separation of 60 mm between the base plate of the cone heater and the upper surface of the specimen. In this case the heater calibration (see 10.2.5) shall be performed with the heat flux meter positioned 60 mm below the cone heater base plate. It shall be stressed that the time to ignition measured with this separation is not comparable to that measured with the separation of 25 mm.

Other dimensionally unstable products, for example products that warp or shrink during testing, shall be restrained against excessive movement. This shall be accomplished with 4 tie wires, as described below. Metal wires of (1,0 ± 0,1) mm diameter and at least 350 mm long shall be used. The sample shall be prepared in the standard way as described in Clause 8. A tie wire is then looped around the sample holder and retainer frame assembly, so that it is parallel to and approximately 20 mm away from one of the 4 sides of the assembly. The ends of the wire are twisted together such that the wire is pulled firmly against the retainer frame. Excess wire is trimmed from the twisted section before testing. The 3 remaining wires shall be fitted around the specimen holder and retainer frame assembly in a similar manner, parallel to the three remaining sides.