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

Part 2:
**Smoke production rate (dynamic
measurement)**

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

Partie 2: Taux de dégagement de fumée (mesure dynamique)

[ISO 5660-2:2002](https://standards.iso.org/standards/catalog/standards/sist/2bf61aaf-64b4-4221-bc80-3d62b1d85b68/iso-5660-2-2002)

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 5660 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5660-2 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

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)
- Part 2: Smoke production rate (dynamic measurement)
- Part 3: Guidance on heat and smoke release rate

Annexes A, B and C of this part of ISO 5660 are for information only.

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

Part 2:

Smoke production rate (dynamic measurement)

1 Scope

This part of ISO 5660 specifies a small-scale method for assessing the dynamic smoke production rate of essentially flat specimens exposed to controlled levels of radiant heating under well-ventilated conditions with or without an external igniter. The rate of smoke production 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.

The measurement system prescribed by this part of ISO 5660 is an extension of the apparatus described in ISO 5660-1. Therefore, this part of ISO 5660 is used in conjunction with ISO 5660-1.

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2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 5660. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 5660 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5660-1:2002, *Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method)*

ISO 13943:2000, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this part of ISO 5660, the terms and definitions given in ISO 5660-1 and ISO 13943 and the following apply.

3.1

smoke obscuration

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

3.2

extinction coefficient

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

3.3

smoke production

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

3.4

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 designation

Symbol	Designation	Units
A	Exposed surface area of specimen	m^2
D'	Optical density	1
\dot{m}_e	Mass flow rate in exhaust duct	$kg \cdot s^{-1}$
F	Calibration factor	m^{-1}
I_0/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_{ig}	Specimen mass at ignition (sustained flaming)	kg
m_f	Specimen mass at the end of the test	kg
\dot{m}	Mass loss rate of specimen	$kg \cdot s^{-1}$
Δm	Specimen mass loss	kg
M	Molecular mass of the gases flowing through the exhaust duct	$kg \cdot mol^{-1}$
S	Total smoke production	m^2
S_A	Total smoke production per unit area	$m^2 \cdot m^{-2}$
$S_{A,1}$	Total smoke production per unit area before ignition	$m^2 \cdot m^{-2}$
$S_{A,2}$	Total smoke production per unit area after ignition	$m^2 \cdot m^{-2}$
P_s	Smoke production rate	$m^2 \cdot s^{-1}$
$P_{s,A}$	Smoke production rate normalized to the specimen area	$s^{-1} [= (m^2 \cdot s^{-1}) / m^2]$
Δt	Sampling time interval	s
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	$m^3 \cdot s^{-1}$
ρ	Density	$kg \cdot m^{-3}$
σ	Specific extinction area	$m^2 \cdot kg^{-1}$

NOTE Detailed discussion of some of these parameters and their units is given in reference [12].

5 Principle

This test method 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 $0 \text{ kW} \cdot \text{m}^{-2}$ to $100 \text{ kW} \cdot \text{m}^{-2}$ 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 the exposed specimen surface area. Smoke production rate is calculated as the product of the extinction coefficient and the volume 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.

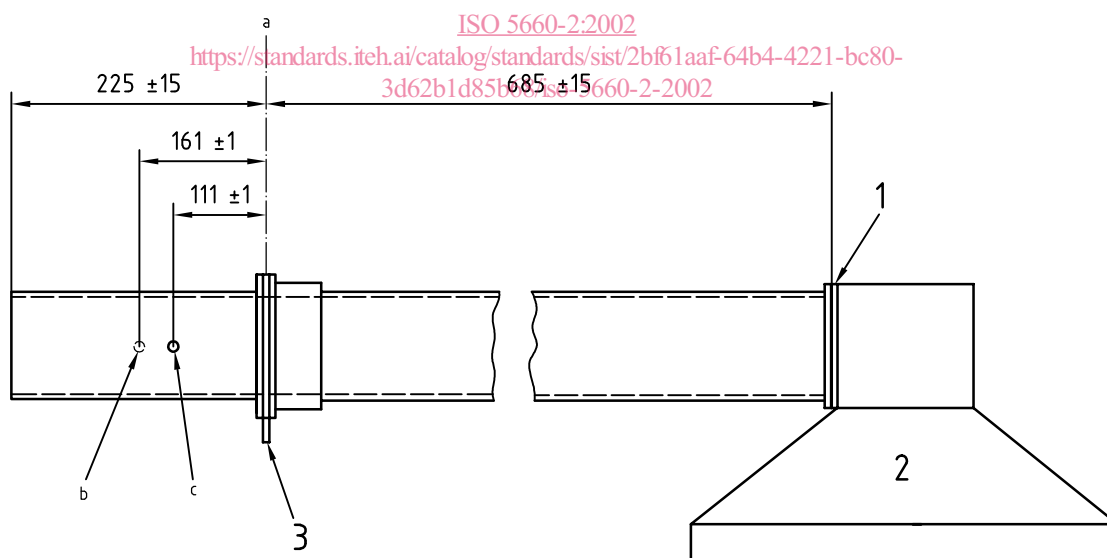
The test method is used to assess the contribution that the product under test can make to the rate of evolution of smoke and to the amount of smoke produced during its involvement in a well-ventilated fire. These properties are determined on small representative specimens.

6 Apparatus

The apparatus is identical to that specified in clause 6 of ISO 5660-1:2002, except for the additional equipment described below.

6.1 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 is located horizontally $111 \text{ mm} \pm 1 \text{ mm}$ downstream of the gas sampling ring, as shown in Figure 1. 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 2.

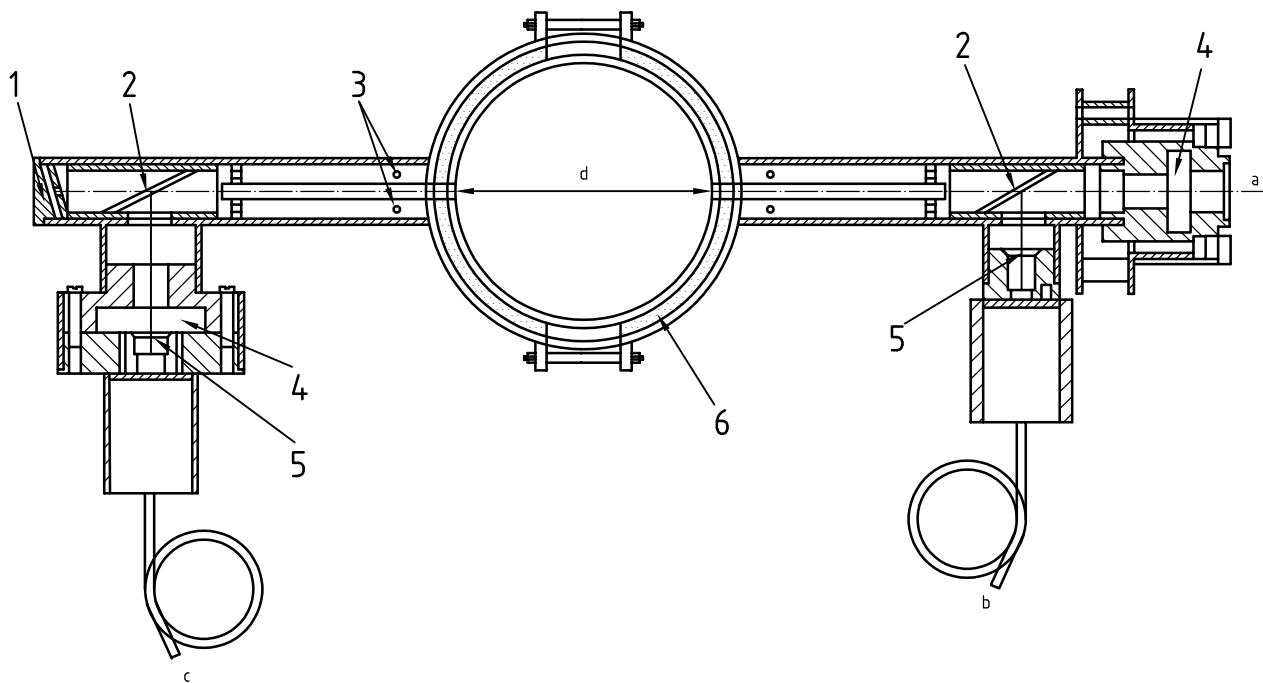
NOTE Experimental work has been performed with systems using a white light source with collimating optics^[1]. Such systems have been shown to yield generally similar results^{[2],[3],[4]} but not under all conditions^[5]. Theoretical predictions^[6] have been verified experimentally. White light systems may be used if shown to have an equivalent accuracy.



Key

- 1 Orifice plate
- 2 Hood
- 3 Gas sampling ring probe (sample holes face downstream)
- a Centre
- b Smoke thermocouple location
- c Smoke meter location

Figure 1 — Schematic representation of the smoke meter and smoke thermocouple locations



- Key**
- 1 Cap
 - 2 Beam splitter
 - 3 Purge air orifices
 - 4 Filter slot
 - 5 Opal glass
 - 6 Ceramic fibre packing
 - a He-Ne laser beam (0,5 mW)
 - b To compensation detector
 - c To main detector
 - d Optical path

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Figure 2 — Cross-section of a typical smoke measuring system arrangement

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

6.3 Optical filters, to calibrate the smoke obscuration measuring system. Two glass neutral density dispersion filters [7], 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:

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

7 Suitability of a product for testing

Identical provisions apply as in clause 7 of ISO 5660-1:2002.

8 Specimen construction and preparation

Identical provisions apply as in clause 8 of ISO 5660-1:2002.

9 Test environment

Identical provisions apply as in clause 9 of ISO 5660-1:2002.

10 Calibration

10.1 General

The heater, oxygen analyser and weighing device systems shall be calibrated as specified in clause 10 of ISO 5660-1:2002. The calibration for the smoke obscuration measuring system shall be performed as described below.

Alternative means of calibrating the weighing device system may be employed if it can be shown that an equivalent accuracy is obtained.

10.2 Smoke meter calibration

10.2.1 Calibration with neutral density filters

The smoke meter shall be calibrated to read correctly (k to within $0,1 \text{ m}^{-1}$) for the two neutral density filters specified in 6.3, and also at 100 % transmission. This neutral density filter calibration shall be performed at least every 100 working hours or upon reassembling of the optics after cleaning and maintenance.

10.2.2 Calibration before test

Immediately before each test, the zero value of the extinction coefficient (100 % transmission) shall be set by hardware or software as appropriate.

11 Test procedure

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

The test procedures involve high temperatures and combustion processes. Therefore, hazards can exist such as burns or the ignition of extraneous objects or clothing. The operator shall use protective gloves for insertion and removal of test specimens. Neither the cone heater nor the associated fixtures shall be touched while hot except with the use of protective gloves. Care shall be taken never to touch the spark igniter which carries a substantial potential (10 kV). The exhaust system of the apparatus shall be checked for proper operation before testing and shall discharge into a building exhaust system with adequate capacity. The possibility of the violent ejection of molten hot material or sharp fragments from some kinds of specimens when irradiated cannot totally be discounted and it is therefore essential that eye protection be worn.

The test procedure is identical to that described in clause 11 of ISO 5660-1:2002. However, the test data shall not be discarded if piloted ignition does not occur, because the smoke production rate data may have relevance under non-flaming conditions. The zero value of the extinction coefficient shall be verified prior to every test as part of the procedures specified in 11.2 of ISO 5660-1:2002.

NOTE The heat release rate measurements described in ISO 5660-1 normally utilize piloted ignition. Separate non-standard tests may be conducted for research purposes without piloted ignition to evaluate smoke production rates under non-flaming conditions.

12 Calculations

12.1 General

The mass loss rate calculations are described in 12.5 of ISO 5660-1:2002. The calculation of the smoke obscuration is given below.

12.2 Smoke obscuration

12.2.1 The extinction coefficient, k , is determined by the smoke meter electronics as follows:

$$k = \ln(I_0/I) L^{-1} \quad (2)$$

12.2.2 Smoke production rate per unit area of exposed specimen is given by:

$$P_{s,A} = A^{-1} k \dot{V}_s \quad (3)$$

The volumetric flow rate at the smoke meter, \dot{V}_s , is calculated from the mass flow rate measured with the orifice plate, \dot{m}_e via:

$$\dot{V}_s = \left(\dot{m}_e T_s \right) \left(12,2 \times 10^3 M \right)^{-1} \quad (4)$$

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The value of T_s is obtained from the thermocouple described in 6.2 and not from the thermocouple associated with the orifice plate mass flow measurement.

If O_2 , CO_2 , CO and H_2O analysers are present, \dot{m}_e and M are obtained from equations (F.8) and (F.9) respectively in annex F of ISO 5660-1:2002. For other analyser configurations discussed in ISO 5660-1, the mass flow rate shall be calculated from equation (9) in ISO 5660-1:2002, and M shall be estimated as $0,029 \text{ kg mol}^{-1}$ (the value for air).

12.2.3 The total smoke production per unit area of exposed specimen obtained during the non-flaming (pre-ignition) period of the test shall be calculated from:

$$S_{A,1} = A^{-1} \sum_{i=s}^{i=f} \dot{V}_s k \Delta t \quad (5)$$

and the smoke production per unit area of exposed specimen obtained during the flaming (post-ignition) period of the test shall be similarly calculated from:

$$S_{A,2} = A^{-1} \sum_{i=s}^{i=f} \dot{V}_s k \Delta t \quad (6)$$

where the values s and f for i refer to the start and the end of the time period over which the average is calculated. Thus, for the non-flaming phase, s refers to the start of the test and f to the time of the start of sustained flaming. For the flaming phase (if any), s corresponds to the time of the start of sustained flaming and f corresponds to the end of the flaming phase.

13 Test report

The test report shall be as comprehensive as possible and shall include any observations made during the test and comments on any difficulties experienced during testing. The units for all measurements shall be clearly stated in the report. Recommended units convenient for reporting are given in Table 1.

In addition to the items listed in clause 13 of ISO 5660-1:2002, the following essential information shall also be given in the test report:

- a) total smoke production per unit area of exposed specimen over the non-flaming phase for every specimen ($S_{A,1}$);
- b) total smoke production per unit area of exposed specimen over the flaming phase for every specimen ($S_{A,2}$);
- c) total smoke production per unit area of exposed specimen for every specimen ($S_A = S_{A,1} + S_{A,2}$);
- d) a graph showing the rate of smoke production per unit area as a function of time for every specimen ($P_{s,A}$ versus time), showing the time at first ignition;
- e) the exposed surface area of the test specimen (A).

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