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

Part 4:

**Measurement of heat release for
determination of low levels of
combustibility**

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

*Partie 4: Mesurage du débit calorifique pour la détermination des bas
niveaux de combustibilité*



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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.

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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.

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ISO 5660-4 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 measurement* [Technical Report]
- *Part 4: Measurement of heat release for determination of low levels of combustibility*

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

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

WARNING — The test procedures involve high temperatures and combustion processes. Therefore, hazards can exist for burns, ignition of extraneous objects or clothing, and for the inhalation of combustion products. The operator should use protective gloves for insertion and removal of test specimens. Neither the cone heater nor the associated fixtures should be touched while hot except with the use of protective gloves.

Materials containing volatile organic substances, decomposition products or large amounts of moisture can produce violent releases of combustible gases or water vapour during testing.

1 Scope

This part of ISO 5660 specifies a method for evaluating materials and products that produce low levels of heat release when exposed to high heat flux (i.e. irradiance levels) typical of fully developed fires. It differs from ISO 5660-1^[15] by prescribing items such as specific specimen size, specimen holder, specimen orientation, volumetric flow rate for O₂ analyses and irradiance levels at which testing is conducted.

This test method is intended for use on products and materials that contain only small amounts of combustible elements, e.g. test specimens that yield a total heat release of < 15 MJ m⁻².

NOTE The test method for specimens that yield moderate to high total heat release is described in ISO 5660-1.

The information obtained from the test method in this part of ISO 5660 can also be used for fire safety engineering purposes.

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, *Reaction-to-fire tests — Guidance on the choice of substrates for building and transport products*

ISO 14934-2, *Fire tests — Calibration and use of heat flux meters — Part 2: Primary calibration methods*

ISO 14934-3:2006, *Fire tests — Calibration and use of heat flux meters — Part 3: Secondary calibration method*

3 Terms and definitions

For the purposes of this document, 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** (3.10)

3.4

irradiance

〈at a point on a surface〉 quotient of the radiant flux incident on an infinitesimal element of surface containing the point and the area of that element

NOTE Convective heating is minimized 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

EXAMPLES 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 horizontal 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 that is tested together with any substrate or treatment

NOTE For certain types of product, for example products that contain an air gap or joints, it might not be possible to prepare a specimen that is 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 s and 10 s

3.12**heat flux**

heat passing through a surface per unit area and unit time

NOTE Heat flux is expressed in kilowatt per square metre.

3.13**emissivity**

ratio of the radiant heat flux emitted by a surface to the radiant heat flux emitted by a blackbody radiator at the same temperature

NOTE Emissivity is dimensionless.

4 Symbols and units

For the purposes of this document, the following symbols apply.

Symbol	Designations	Unit
A_s	initially exposed surface area of the specimen, 0,020 7 m ²	m ²
C	orifice flow meter calibration constant	m ^{1/2} ·g ^{1/2} ·K ^{1/2}
Δh_c	net heat of combustion	kJ·g ⁻¹
$\Delta h_{c,eff}$	effective net heat of combustion	MJ·kg ⁻¹
m	mass of the specimen	g
Δm	total mass change	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 change rate per unit area between 10 % and 90 % of mass change	g·m ⁻² ·s ⁻¹
m_{10}	mass of the specimen at 10 % of total mass change	g
m_{90}	mass of the specimen at 90 % of total mass change	g
$\dot{m}$	mass change rate of the specimen	g·s ⁻¹
$\dot{m}_e$	mass flow rate in exhaust duct	kg·s ⁻¹
Δp	orifice meter pressure differential	Pa
$\dot{q}$	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

Symbol	Designations	Unit
t	time	s
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
X_{O_2}	oxygen analyser reading, mole fraction of oxygen	1
X_{0,O_2}	initial value of oxygen analyser reading	1
$X_{(-1),O_2}$	oxygen analyser reading, before delay time correction	1
ε	emissivity	—

5 Principle

The measurement of the heat release rate and total heat release is used to quantify the test specimen's ability to ignite and contribute heat to the fire. It is based on the observation that, generally, the net heat of combustion of a material is directly related to the quantity of oxygen required for its combustion. This relationship is such that approximately $13,1 \times 10^3$ kJ of heat are released per 1,0 kg of oxygen consumed.

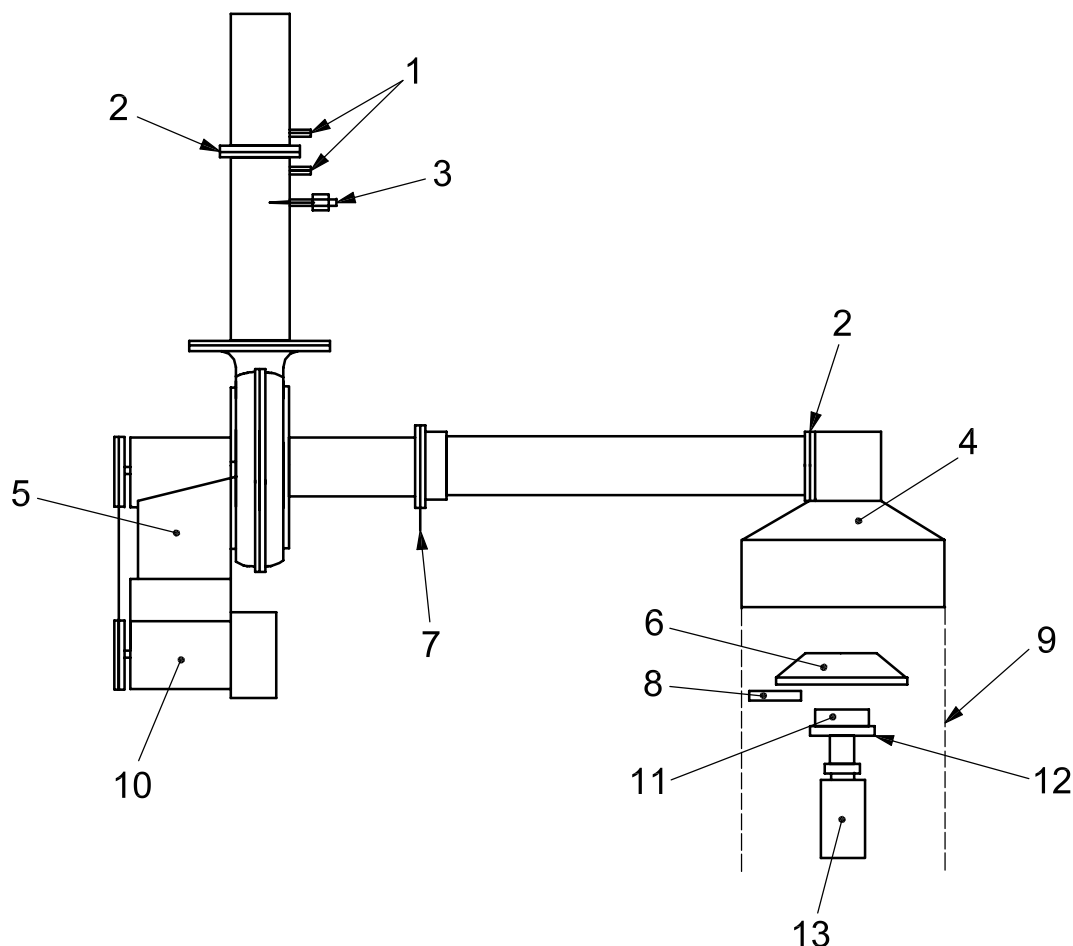
Specimens are exposed in ambient air conditions, while being subjected to an irradiance of 75 kW/m^2 in the presence of a spark ignition source. Alternatively, testing may be conducted at an exposure of 50 kW/m^2 provided there is ignition of the specimen at the 50 kW/m^2 irradiance level, and there is no evidence of continued combustion after the 20 min test duration. The changes in oxygen, O_2 , concentration of gases and exhaust gas flow rate are monitored and, from these data, the heat release is calculated. Additionally, the time to sustained flaming is observed and mass-loss rate is measured.

In this part of ISO 5660, the heat release is measured from the moment the specimen is subjected to the radiant thermal exposure of a conical heater and is continued for 20 min. The primary measurements are oxygen concentration and exhaust-gas flow rate. Provision is also made for the time to sustained flaming. This test method is used to evaluate specimens in a horizontal orientation under an external heat flux.

6 Apparatus

6.1 General

The apparatus shall be set up as shown in Figure 1, with the individual components as described in detail in 6.2 to 6.6.



Key

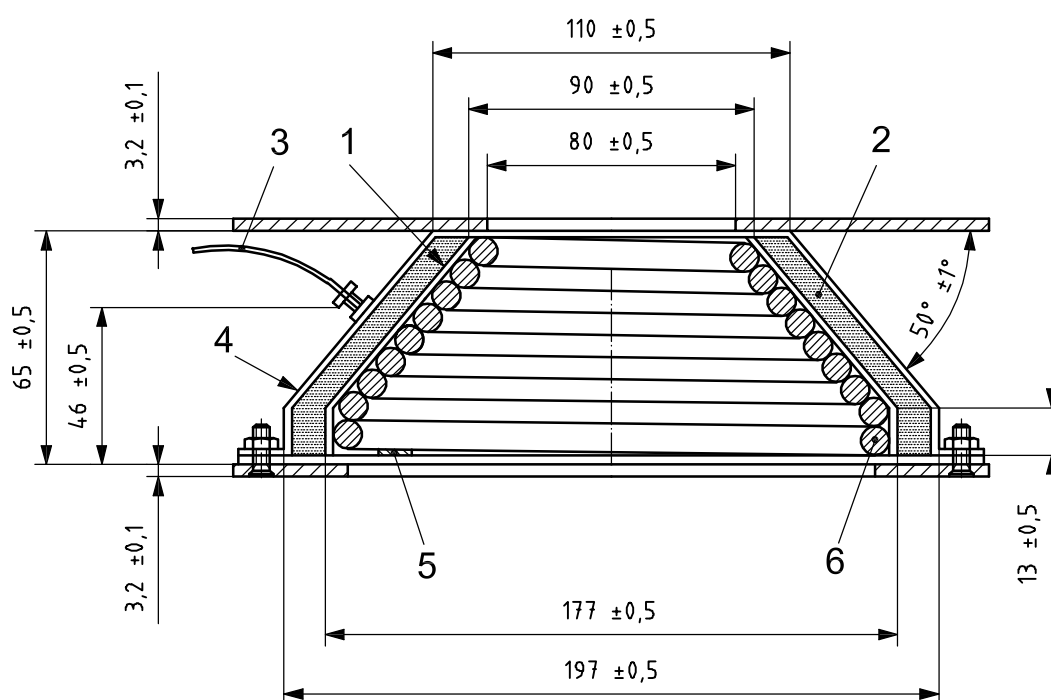
- | | | | |
|---|--|----|-----------------------------|
| 1 | pressure ports | 8 | spark plug |
| 2 | orifice plate | 9 | optional screen |
| 3 | thermocouple (located on stack centreline) | 10 | blower motor |
| 4 | hood | 11 | retainer frame and specimen |
| 5 | blower | 12 | specimen holder |
| 6 | heater | 13 | weighing device |
| 7 | gas sampling ring probe | | |

Figure 1 — Apparatus

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/m³. 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 Inconel¹) 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 an exposed hot junction or a 1,0 mm to 1,6 mm outside-diameter, sheathed thermocouples with an unexposed hot junction shall be used. The heater shall be capable of producing irradiance on the surface of the specimen of up to 100 kW/m². The irradiance shall be uniform within the central 50 mm × 50 mm area of the exposed specimen surface, to within ± 2 %.

Dimensions in millimetres



Key

- | | | | |
|---|--------------------------|---|-----------------|
| 1 | inner shell | 4 | outer shell |
| 2 | refractory fibre packing | 5 | spacer block |
| 3 | thermocouple | 6 | heating element |

Figure 2 — Cone heater

1) Inconel is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 5660 and does not constitute an endorsement by ISO of this product.

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:

- a) water-cooled and coated with a durable matt black finish of surface emissivity, ε , equal to $0,95 \pm 0,05$;
- b) not water-cooled, either metal with a reflective 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 10.2.5 at the preset level to within ± 10 °C.

6.5 Weighing device

The weighing device shall have an accuracy of $\pm 0,1$ g or better, measured according to the calibration procedure described in 10.2.2. The weighing device shall be capable of measuring the mass of specimens of at least 2,0 kg. The weighing device shall have a 10 % to 90 % response time of 4 s or less, as determined according to the calibration described in 10.1.2. 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 10.1.3.