TECHNICAL SPECIFICATION

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Reaction-to-fire tests — Calibration and use of radiometers and heat flux meters —

Part 1: General principles

Essais de réaction au feu — Étalonnage des appareils de mesure du flux rayonné et du flux thermique —

Partie 1: Principes généraux

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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

- an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

- an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 14934-1 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

ISO/TS 14934 consists of the following parts, under the general title *Reaction-to-fire tests — Calibration and use of radiometers and heat flux meters*:

- *Part 1: General principles*

- *Part 2: Primary calibration*

- *Part 3: Secondary calibration*

- *Part 4: Guidance on the use of heat flux meters in fire tests*

Introduction

Radiant heat transfer is an important mode of fire spread, particularly in large fires with flames and hot gas layer thickness larger than 1 m. To represent optimally realistic scenarios, many fire test methods specify the radiation level. Therefore, it is of great importance in fire safety engineering and in fire testing that the radiant heat flux be measured with sufficient accuracy (see 5.1).

In practice, radiant heat flux is usually measured with total heat flux meters of the Schmidt-Boelter (thermopile) or Gardon (foil) type. Such meters register the combined heat flux from radiation and convection. This introduces an uncertainty, as the measured heat flux will contain an unknown contribution from the convection heat transfer. The actual contribution due to convection, in calibrations and fire tests, will depend upon a number of factors such as the design of the heat flux meter, the orientation of the meter, the cooling water temperature, the temperature and flow conditions close to the meter, and the calibration method. In many practical situations, the uncertainty in the convection can amount to 25 % of the total heat flux measured.

To overcome the difficulties with the convection influence, a calibration procedure is outlined where primary calibration is performed on two different types of heat flux meters:

a) total hemispherical radiometer or a cavity radiometer which is sensitive only to radiation; and

b) total heat flux meter, as is typically used, which detects both modes of heat transfer.

Where possible, an effort should be made to minimize the convective influence. In all calibrations and measurements of radiative heat flux, the uncertainty calculations should include the uncertainty due to the residual convective component. For secondary calibration methods, a combined use of hemispherical radiometers and total heat flux meters makes it possible to estimate the convection contribution. The same arrangement can be used in calibration of fire test methods.

Primary calibration is performed in fully characterized blackbody facilities, with total combined expanded uncertainty of less than ± 3,0 % with a 95 % confidence level, in the measured heat flux. One such facility is an evacuated blackbody with the unique characteristic of negligible convection and conduction effects on calibration. Other non-evacuated blackbody facilities are also suitable to be primary radiative flux calibration sources, provided that they are fully characterized, including any convection effects, and the combined expanded uncertainty is less than ± 3,0 %.

It should be noted that the wavelength spectrum and angular distribution of the radiation from a fire may be different from that of a blackbody source. This may introduce extra sources of error to the combined expanded uncertainty when a heat flux meter is used.

In this Technical Specification, three different methods of calibrations using blackbody radiation sources are proposed for provisional evaluation. The objective of this evaluation phase, expected to last about three years, is to determine the relative merits and limitations of the methods and the associated total combined uncertainty. The results and the operational experience gained during the evaluation phase will be reviewed to recommend a suitable test standard.

Within the ongoing European project “Improving heat flux meter calibration for fire testing laboratories HFCAL” SMT4-CT98-2266, total heat flux meters of the Schmidt-Boelter or Gardon type and a total hemispherical radiometer of the Gunners type will be characterized with respect to wavelength, geometry and convection. Different types of emissivity coatings will be investigated. Calibration results of two of the primary calibration methods described in this Technical Specification, the LNE vacuum blackbody cavity (VBBC) [1], and the NT FIRE 050 [2], and of secondary calibration methods will be compared in a round robin test.

Reaction-to-fire tests — Calibration and use of radiometers and heat flux meters —

Part 1: General principles

1 Scope

This Technical Specification gives guidelines for calibration and use of radiometers and heat flux meters in fire testing and for correction of the sensitivity function due to convection effects.

It briefly describes the calibration methods, the most commonly used types of radiometers and heat flux meters, and the fire tests in which these transducers are used.

This Technical Specification is applicable to total hemispherical radiometers, total heat flux meters of Schmidt-Boelter (thermopile) and Gardon (foil) type. It applies only to instruments having plane receivers and does not apply to receivers in the form of wires, spheres, etc.

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 5657:1997, *Reaction to fire tests — Ignitability of building products using a radiant heat source*

ISO 5658-2:1996, *Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building products in vertical configuration*

ISO 5659-2:1994, *Plastics — Smoke generation — Part 2: Determination of optical density by a single-chamber test*

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

EN ISO 9239-1:2002, *Reaction to fire tests for floorings — Part 1: Determination of the burning behaviour using a radiant heat source*

EN ISO 13943:2000, *Fire safety — Vocabulary*

ISO/TR 14696:1999, *Reaction to fire tests — Determination of fire parameters of materials, products and assemblies using an intermediate-scale heat release calorimeter (ICAL)*

VIM, *International vocabulary of basic and general terms in metrology*, BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, ISBN 92-67-01075-1

GUM, *Guide to the expression of uncertainty in measurement*, BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, ISBN 92-67-10188-9

3 Terms and definitions

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

3.1
blackbody radiant source
radiating source which is designed to absorb all radiation incident upon it and not reflect any radiation

NOTE The emissivity of an ideal blackbody radiant source is unity.

3.2
calorimeter
apparatus that measures heat by detecting the change in its body temperature over time

3.3
convection
transmission of heat by a surrounding fluid involving movement of the fluid

3.4
emissivity
ratio of the radiation emitted by a surface to the radiation emitted by a perfect blackbody radiator at the same temperature

3.5
heat flow rate
energy per unit time

3.6
irradiance (at a point on a surface)
amount of radiant power per unit area that flows across or onto a surface

3.7
primary standard
absolute standard to which all other calibrated measuring instruments can be traced

3.8
radiant heat flux
power (energy per unit time) per unit area emitted, transferred or received in the form of heat radiation

3.9
radiative heat transfer
transmission of heat by electromagnetic radiation

3.10
radiation
emission and propagation of electromagnetic waves through space or some medium

3.11
radiometer
transducer (instrument) that converts radiant heat flux into an electrical signal

3.12
radiosity
rate at which radiant energy leaves a surface by combined emission and reflection of radiation

3.13
secondary standard
standard instrument with a calibration traceable to the primary standard

3.14
sensing surface
active part of the transducer which detects the heat flux through the surface

3.15
sensitivity (of a radiometer or a total heat flux meter)
ratio of the output voltage to the irradiance in the plane of the receiver

3.16
total heat flux
total amount of heat flow rate per unit area incident on a surface which includes both radiative and convective heat transfer

3.17
total heat flux meter
transducer (instrument) that responds to both radiative and convective heat transfer

3.18
total hemispherical radiometer
radiometer that responds only to radiative heat transfer with an acceptance angle approaching 180°

4 Principle

4.1 General

All heat flux meters for daily use in fire testing can be calibrated either by using a blackbody radiant source (primary calibration) or by using a transfer calibration method (secondary calibration), whichever provides the desired accuracy for the user.

4.2 Principles of measuring radiant heat flux

Either a total hemispherical radiometer or a total heat flux meter can be used to measure the radiant flux during a fire test.

Although the use of total hemispherical radiometers is not currently wide spread, their use in daily measurement or during calibration in fire test methods has the advantage of requiring no correction for convective effects to the measured radiant heat flux. Only the radiant heat flux is measured and a total hemispherical radiometer may be used in any of the methods mentioned below, without the need to apply a correction for any convective heat transfer. Caution is recommended to ensure that the angular response of the radiometer has near-true cosine dependence.

When a total heat flux meter is used, assessment of the convective contribution shall be documented in all stages of calibration and use. This assessment may result in modification of the procedure so as to reduce the convective component and/or increase the uncertainty of the incident radiant flux for the calibration or measurement. Documented characterization of the convective component using additional measurements (e.g. sensing element temperature, local velocities and ambient gas temperatures near the sensing element) and/or modelling may allow the isolation of the radiant component leading to reduced uncertainty in measurements. Total heat flux meters respond to any heat that is transferred to or from the sensing surface, and cannot distinguish between radiant or convective components of heat transfer. Hence, other means are necessary to quantify their relative importance.

However, it may not be necessary to measure the sensitivity of the meter to convection for every single specimen of heat flux meter. It is possible that corrections can be established for each separate type of meter for use in a particular calibration or fire test method. Thus, the output signal of a meter to total heat flux could be corrected to apply to only the radiant heat flux for every total heat flux meter used in that specific method.

4.3 Principles of primary calibration of a heat flux meter

4.3.1 General

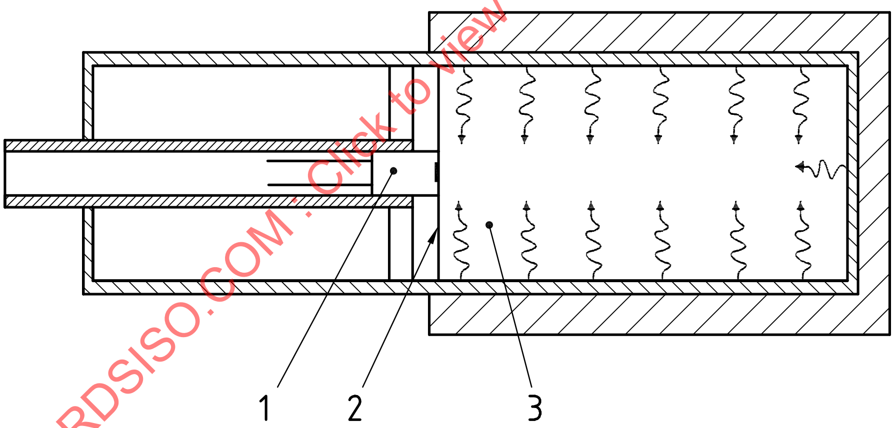
Primary calibration methods use a blackbody radiant source, such as the LNE vacuum blackbody cavity (VBBC) [1], and the NT FIRE 050 [2], shown in Figures 1 and 2, respectively. These are defined as primary calibration methods because the heat flux they emit can be calculated directly from their temperature, surface characteristics and geometry, and they do not require a calibrated heat flux meter to provide a transfer measurement. Another source used at the National Institute of Standard and Technology (NIST) is a variable temperature blackbody (VTBB) which is a heated graphite tube [3]. Figure 3 shows a schematic layout of the VTBB. The VTBB is used in a transfer mode to calibrate heat flux meters against an electrical substitution radiometer (ESR).

4.3.2 Principles of primary calibration apparatus “VBBC” of BNM-LNE

The primary standard consists of a cavity giving nearly blackbody radiation (see Figure 1). The cavity is a horizontally orientated cylinder with a diameter of 160 mm and a length of 410 mm. The blackbody cavity can be evacuated to about 0,5 Pa by a primary roughing pump and a molecular turbo-pump. The temperature at several positions in the cavity is measured and recorded continuously during calibration.

The blackbody cavity is electrically heated through the cylindrical wall. Four regulators, whose thermocouples are localized close to each heater, control the heating of the blackbody. Moreover, three reflecting diaphragms surround the heat flux meter in order to limit the losses generated by this opening. A water circuit cools the external wall to ensure safety. The moving enclosure fits into the blackbody enclosure and is used to convey all the measuring instruments to the blackbody cavity.

The LNE VBBC is described in 5.2.



Key

1 heat flux meter

2 reflecting diaphragms

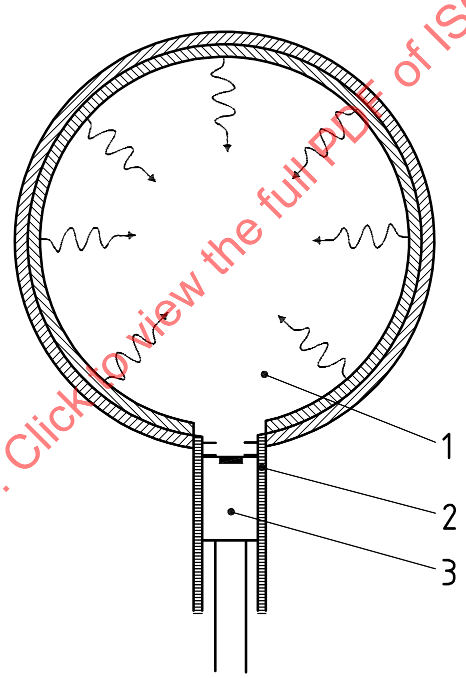
3 evacuated blackbody cavity

Figure 1 — Schematic drawing of inner part of LNE vacuum blackbody cavity (VBBC)

4.3.3 Principles of primary calibration apparatus NT FIRE 050 at SP

In NT FIRE 050, natural convection from the surface of the sensing element is minimized by mounting the meter vertically in an aperture at the bottom of the spherical furnace. This design encourages the cooler air just above the sensing element to remain stationary below the heated air in the furnace. The cooler insert has a number of shields, which protect the gauge from receiving radiation reflected from the cooler wall. They also help to conserve the stratification of air, which reduces the convective heat transfer between the gauge and the surroundings.

Although the convection is minimized in NT FIRE 050, it is necessary to quantify the uncertainty as a function of flux level due to any remaining convection and other factors for each type of total heat flux meter that is calibrated in the furnace (Gardon or Schmidt-Boelter). This uncertainty or correction is determined by measuring the radiant heat flux in the NT FIRE 050 using a total hemispherical radiometer and the typical total heat flux meter, that were both calibrated earlier in the LNE vacuum blackbody (VBBC). For the total heat flux meter, it is important that cooling water flow rate and temperature are maintained at the same level during tests in both the LNE and NT blackbody facilities. The difference in the radiant heat flux in NT FIRE 050 between the two meters, as a function of flux level, may be used to correct for the convective component when other heat flux meters of the same type are calibrated in NT FIRE 050. It should be noted that effects of the different view angles of the different shaped blackbodies and the different acceptance angles of the two types of meters also need to be accounted for. NT FIRE 050 is further described in 5.3.



Key

1 blackbody cavity

2 cooler insert with flanges

3 heat flux meter

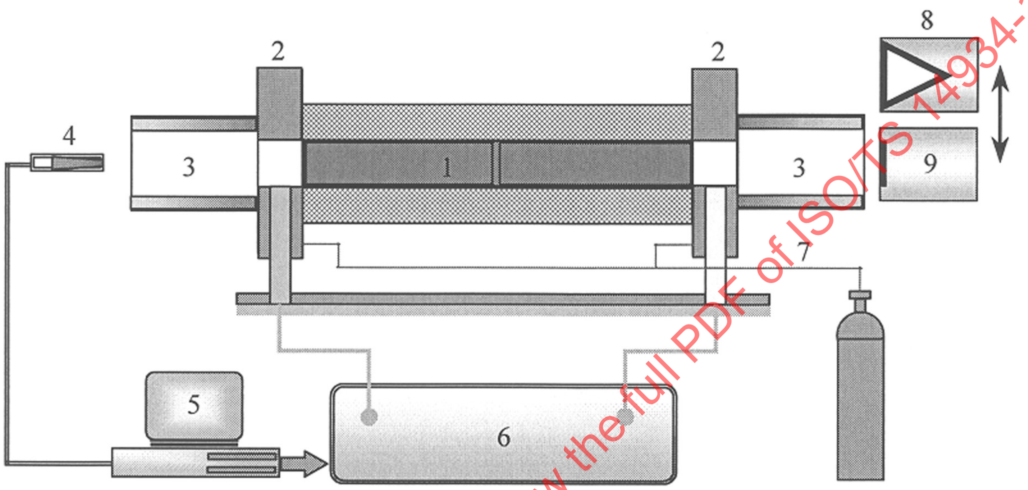
Figure 2 — Schematic drawing of NT FIRE 050

4.3.4 Principles of primary calibration apparatus VTBB at NIST

The 25 mm Variable-Temperature Blackbody is a primary facility used in radiance temperature calibrations. It has a large aperture and is particularly suitable for calibrating heat-flux sensors. The 25 mm VTBB (Figure 3) has been extensively used to calibrate sensors and to study problems related to calibration using blackbody radiation. It is a thermally insulated and electrically heated graphite tube cavity. The heated tube cavity diameter is 25 mm and the heated section is 28,2 cm long with a centre 3 mm thick partition.

The tube end caps are water-cooled and are directly connected to the heating electrodes. The design provides a sharp temperature gradient between the end cap and the graphite heater element. This helps in achieving a uniform temperature distribution along the cavity length of the graphite tube. Different lengths of graphite extension tubes can be attached to the end caps. The sensors are placed close to the blackbody exit to achieve the highest possible heat-flux levels.

An optical pyrometer measures the blackbody temperature by sensing radiation from one end of the furnace. A proportional-integral-differential (PID) controller regulates the power supply to maintain the furnace temperature to within ± 0,1 K of the set value. The maximum recommended operating temperature for the furnace is 2 973 K. The heat-flux sensors to be calibrated and the reference radiometer (ESR) are located at a fixed distance away from the exit of the blackbody. At a distance of 12 mm from the exit, the maximum heat-flux is approximately 50 kW/m^2 to 60 kW/m^2. When calibrating at lower heat-flux levels of up to about 10 kW/m^2, the sensor and the radiometer are located at a distance of about 60 mm from the exit.



Key

1 heated graphite tube dual-cavity
2 water-cooled copper end caps
3 graphite extension (not cooled)
4 control pyrometer
5 temperature controller/computer
6 power supply
7 purge gas lines (argon)
8 transfer standard radiometer
9 test heat flux meter

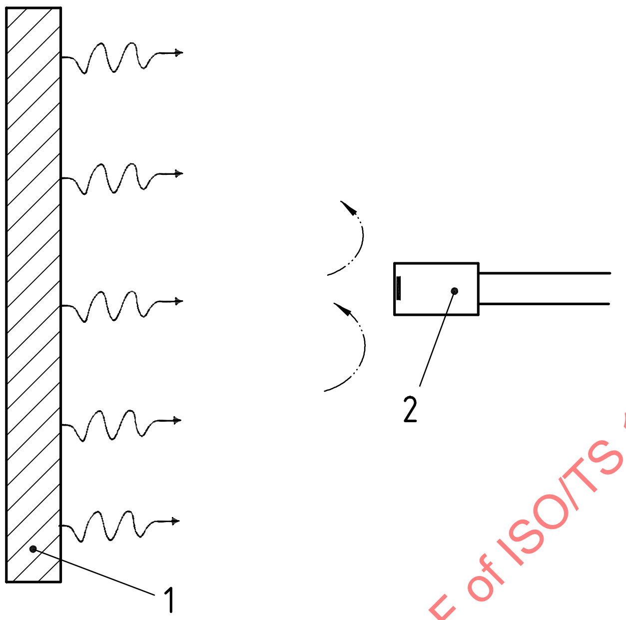
Figure 3 — Schematic layout of the NIST 25 mm Variable-Temperature Blackbody (VTBB)

4.4 Principles of secondary calibration of a heat flux meter

One transfer calibration method, shown schematically in Figure 4, is given in BS 6809 [4]. Also fire test methods such as ISO 5660 or ISO 5657 can be used as transfer calibration methods. In these methods, the heat flux meter under calibration is compared to a total hemispherical radiometer or total heat flux meter. Again, it is critical that convection effects be documented and minimized where possible.

In all transfer calibration methods, the total heat flux meters also measure convective heat transfer, which can be a substantial fraction of the total heat flux. This convective component comes from two principal sources. The first is the natural convection from the sensing surface of the total heat flux meter. This depends on the temperature of the meter relative to the local environment. When the meter is cooled below the room temperature, the convective component can be positive (heating). When the sensing surface of the meter is locally heated by the incident flux, the convective component can be negative (cooling). A second convective source can be crosscurrents that occur during the test. The local temperature of the face of the meter relative to the local air (as well as the velocities, mounting and orientation) will determine the direction and magnitude of the contribution. A comparison with a total hemispherical radiometer can help to establish the significance of the convection component for each type of total heat flux meter during the transfer calibration.

When calibration is performed, the total heat flux meter is replaced by the primary or transfer calibrated meter. The position of the heat flux meter and the transfer meter must be identical when the record is taken.



Key

1 radiant panel

2 heat flux meter or transfer meter

Figure 4 — Schematic drawing of a transfer calibration method (mounting rack is excluded)

4.5 Principles of using total heat flux meters to set the radiant heat flux in a fire test method

When a total heat flux meter is used in a fire test method, documented characterization of the convection component is always needed. The documented characterization shall be established for each fire test method used by the fire testing laboratory, and for the type of total heat flux meter that is to be used for that specific method. Further, it shall be re-established if the test conditions change due to use of a new type meter, rebuilding of the apparatus or changes in the test environment.

The significance of the convection component may be determined by comparing the heat flux recorded by a total hemispherical radiometer with the heat flux recorded by a total heat flux meter or it may be estimated from local temperature measurements.

5 Primary calibration methods for radiometers and total heat flux meters

5.1 Requirements of a primary radiation calibration

With the documented precision, a primary calibration bench should allow radiating calibrations up to 100 kW/m² to be conducted with an uncertainty equal to or less than ± 3,0 % with 95 % confidence. During the calibration, the calculation of the radiation consists of measuring the emissivity field of the blackbody, estimating the emissivity of the meter to be calibrated, and measuring the temperature field in the blackbody. All uncertainty components of the primary calibration shall be quantified or accounted for.

The primary calibration method is absolute. It consists of a direct calibration of the heat flux meter on a bench with a reference blackbody source.

5.2 Primary calibration apparatus "VBBC" of BNM-LNE — France [1]

5.2.1 General

The method is mainly intended for calibration of total heat flux meters of the Gardon, Schmidt-Boelter, and more general thermopile-type meters. Total hemispherical radiometers can also be calibrated in the blackbody.

The method enables calibration up to 100 kW/m^2. Heat flux meters with a housing diameter at the sensing surface of up to 48 mm and a sensitive area diameter up to 10 mm can be accommodated.

The calibration bench includes two essential parts: the gun which is the cylindrical tube carried by a carriage including the blackbody, the heat flux meter and its cooling tubes, and a second part composed of the furnace. The bench is able to provide radiating calibrations up to 100 kW/m^2 with an uncertainty equal to or less than ± 3,0 % with 95 % confidence.

5.2.2 Calibration procedure

The heat flux meter is put flush to the diaphragm in order to close the system consisting of the blackbody, the heat flux meter and the diaphragm assembly. When the VBCC is operating under low vacuum conditions, the heat transfer due to convection can be neglected to a first approximation, and the meter output is a measure of the radiant heat flux. However, the correction due to residual convection present is included as a component of the combined uncertainty.

Consequently, the sensitivity is the ratio of the heat flux meter output voltage divided by the incident irradiance. To calculate the irradiance received by a given surface, the method of the radiosities can be used. The radiosity formulation approach for the cavity enclosure is used to determine the incident heat flux at the sensitive surface of the flux meter placed on the primary bench, using the measured experimental parameters. The enclosure calculation procedure will be improved with experience from the current European project "HFCAL" SMT4-CT98-2266.

5.3 Primary calibration apparatus NT FIRE 050 at SP — Sweden [2]

The method is mainly intended for calibration of total heat flux meters of the Gardon and Schmidt-Boelter types. Total hemispherical radiometers can also be inserted in the furnace for establishing the correction factor for the convective component. The method enables calibration range (2 to 100) kW/m^2. Heat flux meters with a housing diameter of up to 50 mm and a sensitive area diameter of up to 10 mm can be accommodated. Note that effects of the different acceptance angles of the two types of meters also need to be accounted for.

The method consists of blackbody radiation source designed as a spherical furnace with an aperture at the bottom, shown in Figure 2. The temperature of the furnace is accurately controlled and is highly uniform inside the furnace assuring a high precision of the radiation level. The method has an uncertainty equal to or less than ± 3,0 % with 95 % confidence.

The inside diameter of the furnace is larger than 4,5 times the restricting aperture of the fixed cooler at the bottom of the furnace. Heat flux meters to be calibrated are inserted through the aperture with the sensing surface of the heat flux meter oriented horizontally. The influence of convection is thus highly reduced. The convection is further reduced to a minimum by a number of shields on the cooler insert where the meter is mounted during calibration. The shields help to maintain the stratification of air so that convective airflow is minimized. The heat flux meter sees nothing but the controlled environment of the blackbody emitter. The radiation level of this blackbody emitter depends solely on the measured temperature making it traceable to international thermal calibration standards.

5.4 Primary calibration apparatus "VTBB" at NIST — USA [3]

The 25 mm Variable-Temperature Blackbody is a primary facility used in radiance temperature calibrations. It has a large aperture and is particularly suitable for calibrating heat-flux sensors. The 25 mm VTBB (Figure 3) has been extensively used to calibrate sensors and to study problems related to calibration using blackbody radiation. It is a thermally insulated and electrically heated graphite tube cavity. The heated tube cavity diameter is 25 mm, and the heated section is 28,2 cm long with a centre 3 mm thick partition.

The tube end caps are water-cooled and are directly connected to the heating electrodes. The design provides a sharp temperature gradient between the end cap and the graphite heater element. This helps to achieve a uniform temperature distribution along the cavity length of the graphite tube. Different lengths of graphite extension tubes can be attached to the end caps. The sensors are placed close to the blackbody exit to achieve the highest possible heat-flux levels.

An optical pyrometer measures the blackbody temperature by sensing radiation from one end of the furnace. A proportional integral differential (PID) controller regulates the power supply to maintain the furnace temperature to within ± 0,1 K of the set value. The maximum recommended operating temperature for the furnace is 2 923 K.

The heat flux sensors to be calibrated and the reference radiometer (ESR) are located at a fixed distance away from the exit of the blackbody. At a distance of 12 mm from the exit, the maximum heat flux is approximately 50 kW/m^2 to 60 kW/m^2. When calibrating at lower heat flux levels of up to about 10 kW/m^2, the sensor and the radiometer are located at a distance of about 60 mm from the exit.

The transfer calibration methodology adapted in calibrating heat flux sensors at NIST is to use a room temperature electrical substitution radiometer (ESR) as a transfer standard. The ESR calibration is traceable to the High Accuracy Cryogenic Radiometer (HACR), the US standard for optical radiation, through a chain of calibrations. The ESR absorbs the incident photon flux almost completely because of the blackened walls and multiple reflections within the radiometer cavity. The equivalent electrical power required to produce the same temperature rise in the cavity as the incident flux is determined by heating the cavity by a precision heating element. Considering the effective absorptivity of the cavity and other factors involved in determining the equivalent electrical power, the measurements by these radiometers are likely to be within 0,5 % of the unknown value of the incident flux and can be considered absolute. However, in the NIST measurement chain, instead of using absolute calibration, the ESR is calibrated to provide traceability to the primary standard HACR.

The calibration of heat-flux sensors with reference to the calibrated ESR is performed using broadband radiation from the VTBB. The ESR and the sensor to be calibrated are exposed to the same level of radiant heat-flux by locating them at a fixed distance from the blackbody aperture. The blackbody is operated at different temperatures to obtain a range of heat-flux levels to calibrate the sensors.

6 Secondary calibration method for radiometers and total heat flux meters

The transfer calibration method of BS 6809 [4], shown in Figure 4, consists of a radiant panel and a platform for mounting heat flux meters. The platform is designed to bring the receiver of each heat flux meter quickly into a pre-set, locked position in front of the centre of the radiant panel. The radiant panel is gas fuelled and typically has the dimensions 0,3 m × 0,3 m. It is operated at an equivalent blackbody temperature of 1 100 K in such a way that no flames emerge from the surface. The measurements are made at different levels of heat flux by varying the distance between the radiant source and the heat flux meter. To achieve this, the mounting platform is capable of being moved towards or away from the radiator.

The heat flux meter to be calibrated and the primary standard calorimeter are most probably affected by convection. As BS 6809 is currently written, no measures are recommended to avoid natural convective influence on the face of the meter during calibration. Recommendations are included that discuss maintaining the test meter and transfer meter far enough from the panel to minimize the influence from the convection generated at the panel.

The method uses a primary standard calorimeter which is said to give an absolute value of radiation from a radiant source of up to 55 kW/m^2. The value is compared with a secondary standard subjected to the same source. The secondary standard is then used to compare the readings from the heat flux meter to be calibrated. For practical reasons, the primary standard is not used directly. A total hemispherical radiometer should be used as the secondary standard. This type of instrument is, however, not included in the current version of BS 6809.

There are thus three steps in which errors occur. The overall errors, from absolute value to a working total heat flux meter, add up and can be substantial if great care is not taken. The 95 % confidence limits for the calibration of the secondary-standard radiometer have been estimated as about ± 3 %.

7 Use of total heat flux meters to set/measure the radiant heat flux in fire test methods

7.1 General

When total heat flux meters are used in practice, they will measure a combination of radiant and convective heat. The convective component depends on the design of the heat flux meter, the orientation of the meter, local temperature and flow conditions, and on the temperature of the cooling water.

Where a total heat flux meter is cooled by circulation of water, the cooling water temperature should be high enough to avoid condensation on the sensing surface of the heat flux meter.

For each fire test scenario, the convective component shall be determined. By comparing the radiation flux received by the total hemispherical radiometer and the total heat flux received by the total heat flux meter in the fire test scenario in question, the correction factor can be established.

Correction factors shall be established for each fire test equipment and corresponding environment where the total heat flux meter is used. The factor is then used to correct the relationship of total heat flux to determine the radiant flux component only from the heat flux meter measurements when it is used in the fire test scenario in question.

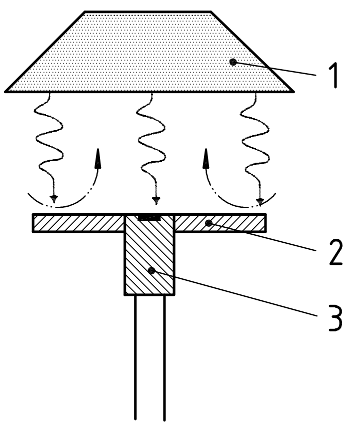
The correction factor should be re-established if alterations to the equipment that cause the convective influence to change are made.

The main principle for how to determine the convective influence is that the two instruments are mounted so that the receiver of each of them is at the same distance and viewing angle from the radiating surface in the fire test scenario. The mounting technique is kept the same for the two instruments, and the emitted radiant flux is set to the same level when the heat flux is recorded.

The mounting principles for some fire test methods are briefly described in 7.2 to 7.5. Calibration of heat flux should be done at steady state conditions. More detailed descriptions of setting up the radiation in fire tests are given in Annex B.

7.2 ISO 5657 ignitability test

The total heat flux meter and the total hemispherical radiometer are mounted in the normal ceramic fibreboard used for calibration of the heat flux (see Figure 5). The temperature of the heating coil is kept constant for each radiant flux level.



Key

1 conically shaped heater

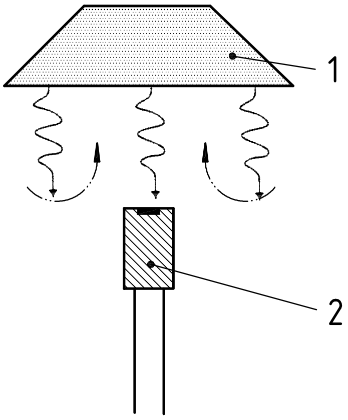
2 ceramic fibreboard (dummy specimen)

3 total heat flux meter

Figure 5 — Schematic drawing of the conically shaped heater and the total heat flux meter mounted in the ceramic fibreboard of ISO 5657 ignitability test

7.3 ISO 5659-2 smoke density chamber and ISO 5660-1 cone calorimeter test

The total heat flux meter and the total hemispherical radiometer are mounted in an open configuration under the cone, see Figure 6. The total heat flux meter should also be mounted in a dummy specimen with the same dimensions as the specimen holder to give information about the convective influence on the test specimen. The temperature of the heating coil is kept constant for each radiant flux level.



Key

1 conically shaped heater

2 total heat flux meter

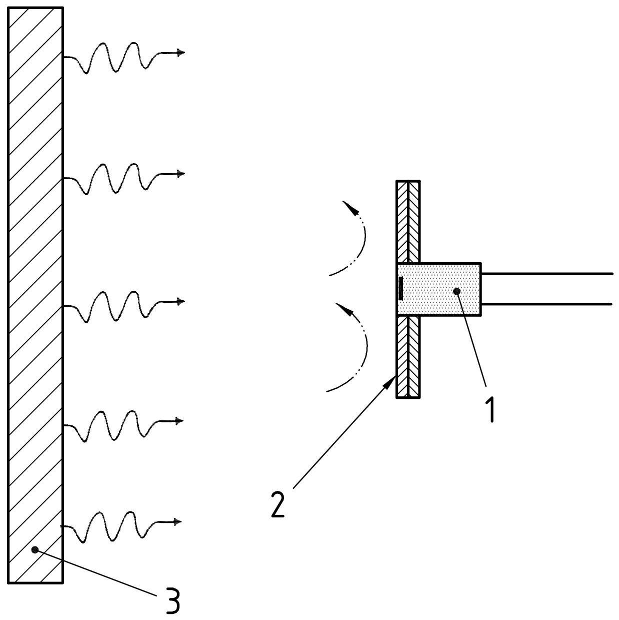
Figure 6 — Schematic drawing of the conically shaped heater and the total heat flux meter mounted in free flowing air of ISO 5659-2 smoke density chamber and ISO 5660-1 cone calorimeter

7.4 ISO 5658-2 and IMO Resolution A.653 spread of flame test and EN ISO 9239-1 radiant panel test for floorings

The total heat flux meter and the total hemispherical radiometer are mounted in the dummy specimen used for calibration (see Figures 7 and 8). The dummy specimen contains a number of holes to achieve a flux profile over the entire specimen. Both meters must be mounted one by one in each of the holes in the dummy specimen.

The heat output from the radiating panel must be controlled and kept constant when the meters are switched and moved from hole to hole in the dummy specimen.

If the total hemispherical radiometer has the same diameter as the total heat flux meter, the dummy specimen can be used. If the total hemispherical radiometer has a larger diameter than the total heat flux meter, a specially designed dummy specimen must be used. Rings made of the same material as the dummy specimen reducing the size of the holes for the total heat flux meter should be used.



Key

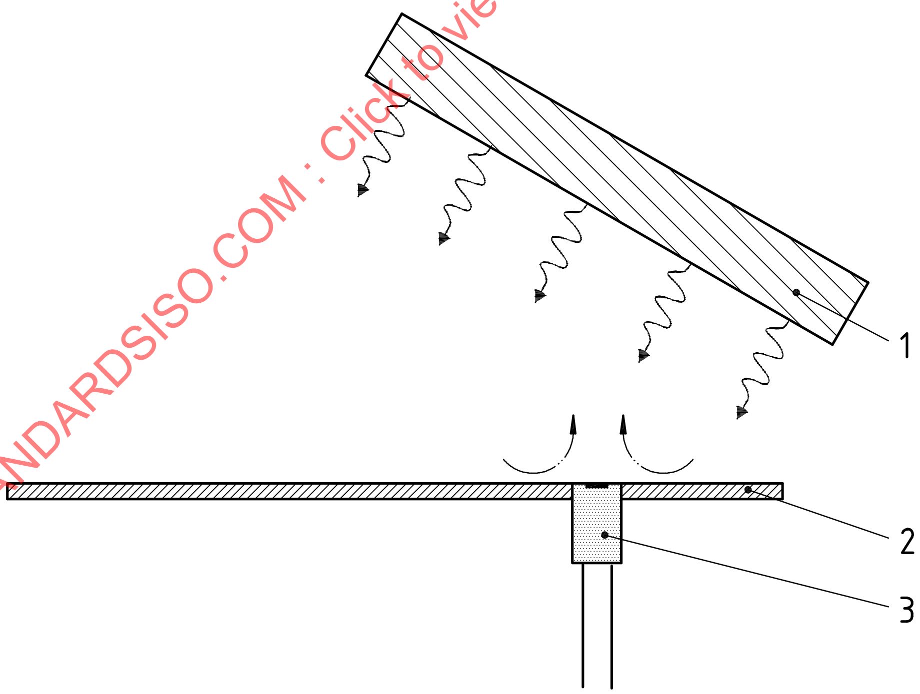
1 total heat flux meter

2 ceramic fibreboard (dummy specimen)

3 rectangular heater

NOTE The angle of 15° between panel and specimen is not shown in the figure.

Figure 7 — Schematic drawing of the rectangular heater and the total heat flux meter mounted in the dummy specimen of ISO 5658-2 and IMO Resolution A.653 spread of flame test



Key

1 rectangular heater

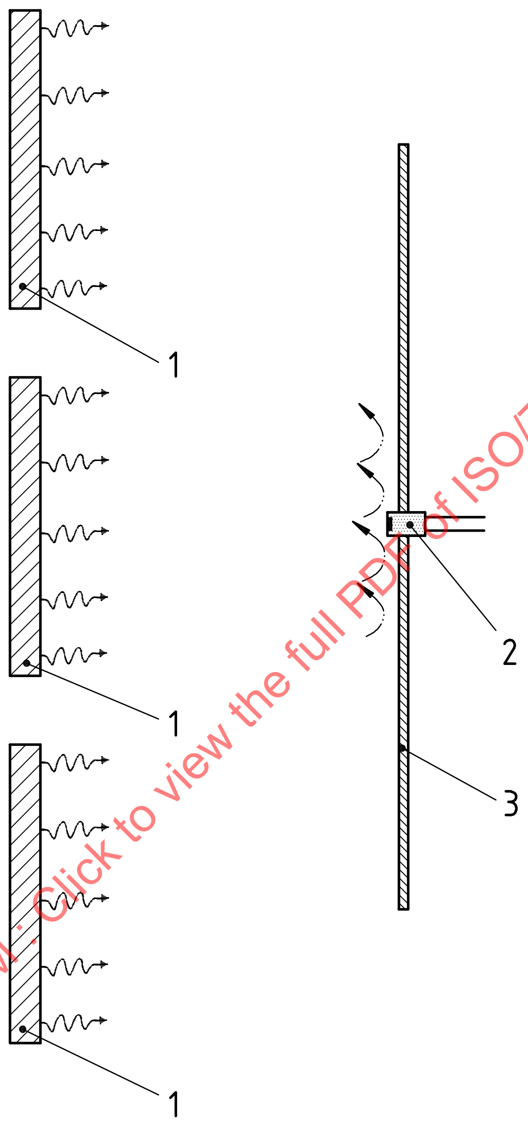
2 ceramic fibreboard (dummy specimen)

3 total heat flux meter

Figure 8 — Schematic drawing of the rectangular heater and the total heat flux meter mounted in the dummy specimen of EN ISO 9239-1 radiant panel test for floorings

7.5 ISO/TR 14696 intermediate scale calorimeter

The total heat flux meter and the total hemispherical radiometer are mounted in the normal dummy specimen used for calibration. The temperature of the dummy specimen is kept constant for each radiant flux level.



Key

1 rectangular heaters

2 total heat flux meter

3 ceramic fibreboard (dummy specimen)

Figure 9 — Schematic drawing of the rectangular heater and the total heat flux meter mounted in the dummy specimen of ISO/TR 14696 intermediate scale calorimeter (ICAL)

Annex A
(informative)

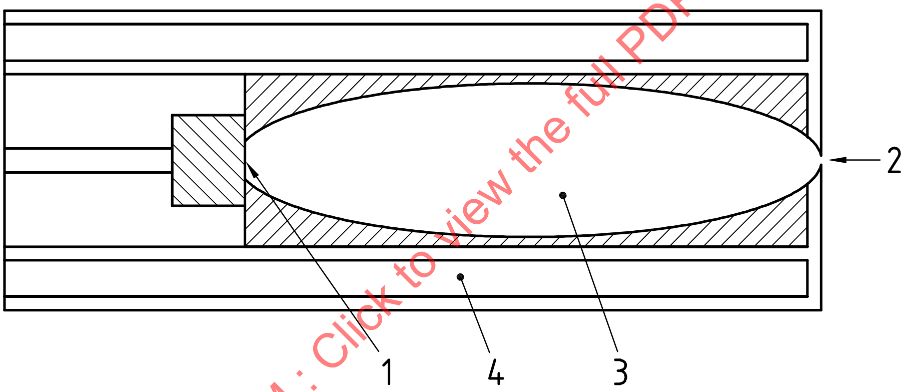
Description of radiometers and heat flux meters

A.1 Radiometers

A total hemispherical radiometer, shown in Figure A.1, is constructed to absorb only the incident radiation flux. The measured heat flux has a minor convective component.

The radiometer consists of an ellipsoidal cavity with a highly reflective, gold plated surface. The aperture opening is located at one focus and the sensing element, which is typically a Schmidt-Boelter thermopile sensor, is located at the other focus. The reflector cavity and the thermopile are housed in a water-cooled cylindrical jacket.

By the geometric property of an ellipsoid, a ray that passes through one focus in any arbitrary direction will be reflected from the surface of the ellipsoid and pass through the other focus.



Key

1 thermopile

2 aperture

3 gilded ellipsoidal reflector

4 water cooled jacket

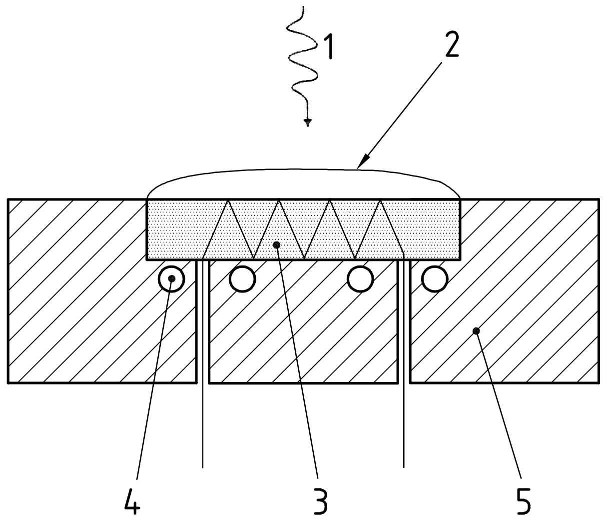
Figure A.1 — Schematic cross-section drawing of a total hemispherical radiometer (not to scale)

A.2 Total heat flux meters

The total heat flux meters most commonly used in fire research are based on two principles. The first type, called the Schmidt-Boelter gauge (SB gauge), operates on the basis of an axial heat flow, i.e. normal to the sensing surface. The principle of operation is depicted in Figure A.2.

The sensing element is a thermopile comprising a number of junctions. The number of junctions may depend on the range of heat flux, which the meter is designed to measure.

Since the receiver disk is cooled in both radial and axial directions, the sensing surface does not develop a high centre temperature as the Gardon gauge, described below. The temperature distribution over the disk is consequently more uniform.



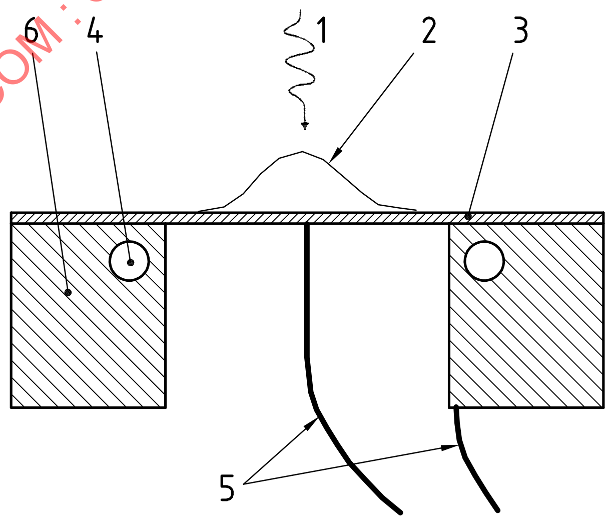
Key

1 incident radiation
2 temperature profile
3 thermopile
4 cooling water channels
5 copper body

Figure A.2 — Schematic cross-section drawing of a Schmidt-Boelter gauge (not to scale)

The second type, called the Gardon gauge, operates on the principle of radial flow of heat over its sensing surface, which is a thin constantan foil. Figure A.3 shows the typical layout of a Gardon gauge and the temperature distribution across the foil.

The sensing element is a single thermocouple, consisting of a copper lead attached to the constantan foil, which forms the receiving disk. The copper housing forms the second leg in the thermocouple circuit. As the disk is cooled only at its periphery, it develops a comparably high centre temperature. The radial temperature distribution is therefore parabolic, with a peak at the centre of the disk, as shown in Figure A.3.



Key

1 incident radiation
2 temperature profile
3 constantan foil
4 cooling water channels
5 copper leads
6 copper body

Figure A.3 — Schematic layout of a Gardon gauge (not to scale)

Both the Schmidt-Boelter and Gardon type gauges sense the total heat flux incident on the receiving surface. Thus, the gauges are not only responding to radiation, but also to convection. This sensitivity to convection poses certain problems when the gauges are used to measure radiation only.

The most obvious solution to the convection problem is to install a window in front of the receiving surface, but that method has certain drawbacks. The window will be selectively transparent to different wavelengths and will also affect the receiver's view factor.

Heat flux meters of the Schmidt-Boelter type can include built-in surface temperature thermocouples. This additional piece of information can greatly enhance the user's ability to characterize the convective component.

Both Gardon and Schmidt-Boelter type gauges often use cooling water to extend the meter's maximum flux range. The flow and temperature of the water may significantly affect the magnitude and direction of the convective component. Optimally, the conditions used during testing will be the same as those during calibration.

