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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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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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

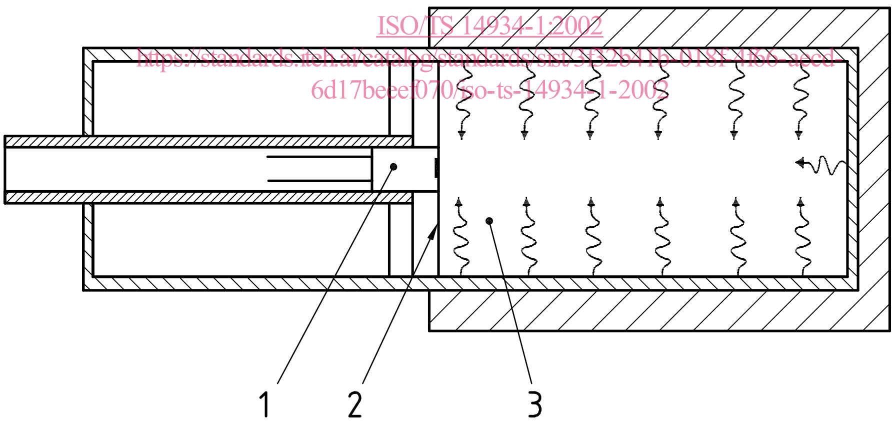
Primary calibration methods use a blackbody radiant source, such as the LNE vacuum blackbody cavity (VBBC) [1], and the NT FIRE 050 [2], shown in Figures 1 and 2, respectively. These are defined as primary calibration methods because the heat flux they emit can be calculated directly from their temperature, 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

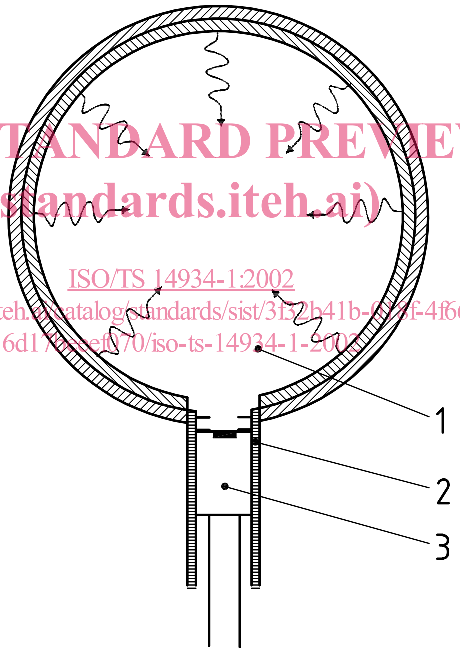
3 evacuated blackbody cavity

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.