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Fire tests — Calibration and use of heat flux meters —

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

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

Partie 4: Lignes directrices pour l'utilisation des fluxmètres thermiques dans les essais au feu

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Foreword

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

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

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

This first edition of ISO 14934-4 cancels and replaces ISO/TS 14934-4:2007, which has been technically revised.

ISO 14934 consists of the following parts, under the general title *Fire tests — Calibration and use of heat flux meters*:

- *Part 1: General principles*
- *Part 2: Primary calibration methods*
- *Part 3: Secondary calibration methods*
- *Part 4: Guidance on the use of heat flux meters in fire tests*

Introduction

In many fire test methods, the radiation level is specified and, therefore, it is of great importance that the radiative heat flux is well defined and measured with sufficient accuracy. Radiative heat transfer is also the dominant mode of heat transfer in most real fires.

In practice, radiative heat flux is usually measured with so-called total heat flux meters of the Schmidt-Boelter (thermopile) or Gardon (foil) type. Such meters register the combined heat flux by radiation and convection to a cooled surface. The contribution to the heat transfer by convection depends mainly on the temperature difference between the surrounding gases and the sensing surface and on the velocity of the surrounding gases. It will, however, also depend on the size and shape of the heat flux meter, its orientation, and its temperature level, which is near the cooling water temperature. In many practical situations in fire testing, the contribution due to convection to the sensing surface of the instrument can amount to 25 % of the heat flux. Therefore, it is always necessary to determine and control this part.

To determine the fraction of total heat flux due to radiation, a calibration scheme has been developed where primary calibration is performed on two different types of heat flux meters: (1) a total hemispherical radiometer sensitive to radiation only, and (2) a total heat flux meter (most frequently used) sensitive to both radiant heat transfer and convective heat transfer.

When using heat flux meters, it is important to realize that, provided that convective heat transfer is kept to a minimum, only incident radiant heat flux can be measured directly. The net radiant heat flux as well as the heat transfer by convection to a body depend on, among other things, the temperature of the receiving surface, while the instrument responds to heat transfer to a cooled surface.

This part of ISO 14934 provides guidance on how this type of instrument is used and how the results are interpreted.

Fire tests — Calibration and use of heat flux meters —

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

1 Scope

This part of ISO 14934 provides guidance on the use of heat flux meters in fire testing applications, including the description and working principles of common heat flux meters and methods for their selection and maintenance. The guidance can also be applied to measuring heat flux from radiant panels and other large heat sources used to simulate the heat flux from a fire. It is applicable for all common testing purposes when measuring heat flux from radiant sources.

This part of ISO 14934 also provides basic theory and working principles of heat flux meters and methods for selection, use, and maintenance of heat flux meters. Although it is particularly aimed at the application of heat flux meters in fire tests and experimental works of fire research, it can also serve as a guide for other research applications like research of boilers, combustion processes, etc.

Instruments, which measure the transient temperature of a solid body of known mass and heat capacity to infer the heat flux (slug calorimeter type), are not covered by this part of ISO 14934.

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 13943, *Fire safety — Vocabulary*

ISO 14934-1, *Fire tests — Calibration and use of heat flux meters — Part 1: General principles*

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

ISO 14934-3, *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 ISO 14934-1 apply.

4 General information on heat flux meters

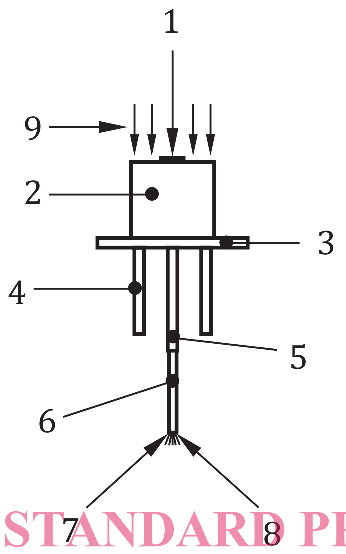
4.1 General

A heat flux meter is an instrument which measures the radiant and convective heat that is transferred from the fire environment to a sensing element. In practice, heat flux is most commonly measured with total heat flux meters of the Schmidt-Boelter (thermopile) or Gardon (foil) type. Although there are a wide variety of designs of heat flux meters, a typical design consists of a thermopile sensor, mounted on a metal body that is cooled by water. The body acts as a constant temperature heat sink. The thermopile sensor typically has a nearly black surface which is assumed to absorb all incident radiation, or which emissivity is given.

It is assumed that sensitivity does not depend on wavelength over the spectral range of the radiating sources. Deviations from the ideal directional response characteristics may normally be also disregarded.

In a normal situation, the field of view is assumed to be 2π sr and the surface is assumed to be a perfect blackbody, both regarding the spectral characteristics and the directional response.

In general, heat flux meters consist of an absorber of heat flux, body, water-cooling system, and wiring as shown in Figure 1. They often also have a flange for mounting purposes.



Key

1	absorber
2	body
3	flange
4	tube for water supply
5	tube for wiring
6	cable
7	heat flux meter signal
8	temperature sensor signal
9	incident heat flux

Figure 1 — General features of heat flux meters

The sensing surface shall remain free of deposition of soot or other particulates. It should be noted that soot may accumulate on the cool gauge surface and can affect the gauge output.

4.2 Principle of measurement

The incident heat flux onto the absorber creates a local temperature difference. This difference is measured, resulting in an output signal (voltage). As a first approximation, this voltage is linear with the heat flux received by the sensor. In most heat flux meters, the measurement of the temperature difference is based on thermocouples or thermopiles, which are passive and do not require any external power.

Within a limited working range, the relationship between the heat flux received by the sensor and the output signal can be assumed to be linear. However, it should be noted that the output signal is not always linear to the incident heat flux (see 4.4.3).

4.3 Design of heat flux meter

There are two types of heat flux meters that are widely used in fire tests: so-called Gardon (foil) type and Schmidt-Boelter (thermopile) type.

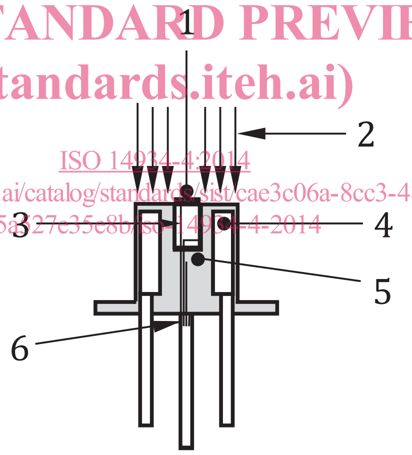
The Gardon type heat flux meters have a very wide working range and a very fast response time. However, they have a low sensitivity and therefore do not work with low heat fluxes.

The Schmidt-Boelter type heat flux meters generally have a much higher sensitivity than Gardon gauges.

Another type of heat flux meter is a hemispherical radiometer, sensitive to irradiance only, i.e. it is not sensitive to surrounding gas temperature and velocity and is used for estimating the convective part of the heat transfer measured with total heat flux meters.

4.3.1 Gardon type heat flux meter

The Gardon type heat flux meters have an absorber, which is deposited on a thin foil. The absorbed heat is conducted radially along the foil into the body, which is water-cooled. The absorber has an approximately parabolic temperature distribution. The temperature at the centre is high, varying with heat flux to the sensor, while the temperature at the edge is relatively low, remaining at the constant body temperature, i.e. the temperature of the cooling water. The temperature profile is no longer parabolic when a significant convective cross-flow is present. Temperature difference between the centre and the edge is measured by a thermocouple. A schematic view of the Gardon type heat flux meter is shown in Figure 2.



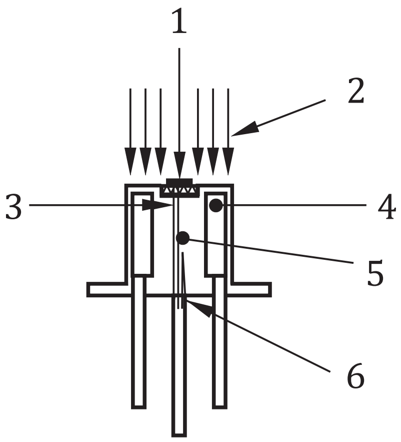
Key

1	foil with black absorber (usually constantan)	4	cooling water
2	incident heat flux	5	wire connected to the body (or edge of the foil)
3	wire connected to the centre of the foil	6	thermocouple for body temperature measurement

Figure 2 — Gardon type heat flux meter

4.3.2 Schmidt-Boelter type heat flux meter

A Schmidt-Boelter type heat flux meter has a relatively thick thermopile mounted on a heat sink, the water-cooled body of the gauge. The absorbed heat is conducted perpendicular to the absorber surface through the sensor into the heat sink. The absorber has a relatively uniform temperature distribution. Temperature difference between the sensor and the body is measured by the multiple thermocouples connected in series in the thermopile. The schematic view of the Schmidt-Boelter type heat flux meter is shown in Figure 3.



Key

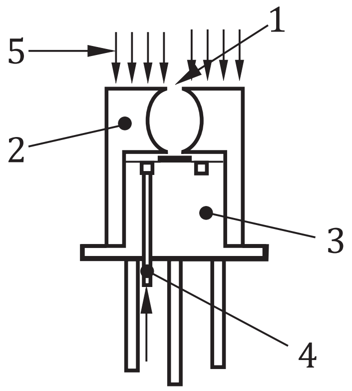
1	foil with black absorber (usually constantan)	4	cooling water
2	incident heat flux	5	wire connected to the centre of the thermopile
3	wire connected to the centre of the thermopile	6	thermocouple for body temperature measurement

Figure 3 — Schmidt-Boelter type heat flux meter

4.3.3 Hemispherical radiometer

Hemispherical radiometer is used for measuring irradiance. It is not sensitive to convective heat transfer conditions, i.e. surrounding gas temperature and velocity.

Hemispherical radiometers, as shown in Figure 4, have a reflecting interior (usually gold plated), which reflects the irradiance to the absorber, thus kept free of the influence of convection. Hemispherical radiometers are often used in flame research and are often equipped with air purging to keep the reflector free of soot.



Key

1	aperture	4	output wire
2	body with reflecting interior	5	incident heat flux
3	heat sink		

Figure 4 — Hemispherical radiometer

4.4 Measurement characteristics

4.4.1 Response time

Because the duration of many standardized tests is limited, a quick response is required from heat flux meters. In many cases, a full-scale response (99 %) of less than 10 s is required.

In general, application of the response time when a heat flux meter with a constant body temperature is exposed to an irradiance level starting from $t = 0$, the behaviour of signal output can be described by Formula (1):

$$U_{\mathrm{out}} = I \cdot S_1 \left(1 - \mathrm{e}^{\frac{-t}{t_{\mathrm{sen}}}} \right) \qquad (1)$$

where

U_{out} is the output signal in V;

S_1 is the primary sensitivity in mV (W m-2)−1;

I is the heat flux in W m−2;

t is the time in s;

t_{sen} is the sensor time constant in s.

The response time of a particular sensor is therefore usually indicated by its time constant. The time constant of a heat flux meter can also be seen as the time in which 63 % of the full scale (100 %) response is reached.

As a rule, the full-scale response (99 %) is reached within a timeframe of 5 times the time constant. In practice, this means that after 5 times the time constant the response time no longer is a significant source of error.

For Gardon gauges, based on a foil, the response time can be approximated as in Formula (2):

$$t_{\mathrm{sen}} = \frac{\rho \cdot c_{\mathrm{p}} d^2}{16\lambda} \qquad (2)$$

where

t_{sen} is the sensor time constant in s;

ρ is the foil density in kg m−3;

c_{p} is the foil specific heat capacity in J kg−1 K−1;

d is the foil diameter in m;

λ is the foil thermal conductivity in W m−1 K−1.