TECHNICAL SPECIFICATION

ISO/TS 14934-4

First edition
2007-02-15

Fire tests — Calibration 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

Reference number
ISO/TS 14934-4:2007(E)

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Published in Switzerland

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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/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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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 14934-4 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 *Fire tests — Calibration of heat flux meters*:

— *Part 1: General principles* (Technical Specification)

— *Part 2: Primary calibration methods*

— *Part 3: Secondary calibration method*

— *Part 4: Guidance on the use of heat flux meters in fire tests* (Technical Specification)

Introduction

In practice, radiant 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 on 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 radiant 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:

— a total hemispherical radiometer sensitive to radiation only;

— a total heat flux meter (most frequently used) sensitive to both radiant heat transfer and to convective heat transfer.

When using heat flux meters, it is important to realize that 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 Technical Specification provides guidance on how this type of instrument is used and how the results are interpreted.

Fire tests — Calibration of heat flux meters —

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

1 Scope

This Technical Specification 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 Technical Specification 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 concerning fire research, it can also serve as a guide for other research applications, for example, research on 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 Technical Specification.

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 13943:2000, *Fire safety — Vocabulary*

ISO 14934-2:2006, *Fire tests — Calibration and use of heat flux meters — Primary calibration methods*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943:2000 and ISO 14934-2 apply.

4 General information on heat flux meters

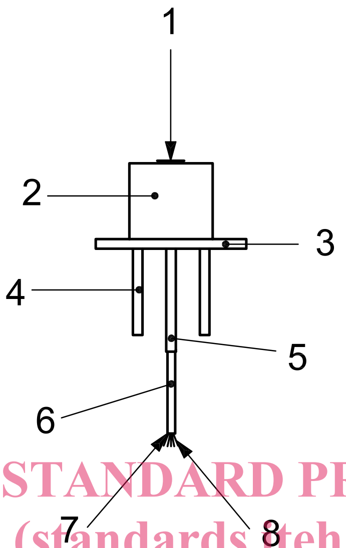
4.1 General

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 is 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 of which the 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 can normally also be disregarded.

In a normal situation, the field of view is assumed to be 180° and the surface is assumed to be a perfect black body, 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

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 collect 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 3.4.3).

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4.3 Design of heat flux meter

4.3.1 General

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.

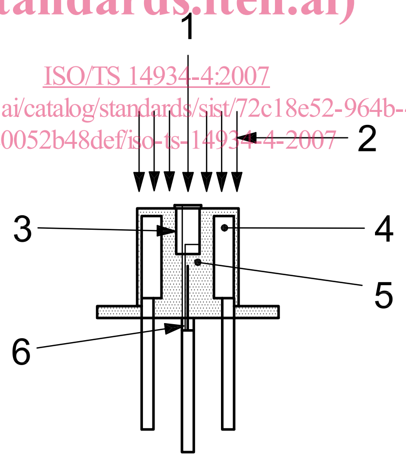
The Gardon-type heat flux meter has a very wide working range and a very fast response time. However, it has a low sensitivity and therefore does not work with low heat fluxes.

The Schmidt-Boelter-type heat flux meter generally has 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 the surrounding gas temperature and velocity, and is used for estimating the convective part of the heat transfer measured with total heat flux meters.

4.3.2 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. The 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.



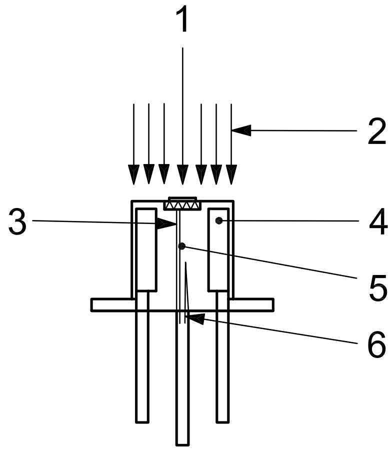
Key

1 Foil with black absorber (usually constantan)
2 Incident heat flux
3 Wire connected to the centre of the foil
4 Cooling water
5 Wire connected to the body (or edge of the foil)
6 Thermocouple for body temperature measurement

Figure 2 — Gardon-type heat flux meter

4.3.3 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. The temperature difference between the sensor and the body is measured by the multiple thermocouples connected in series in the thermopile. A schematic view of the Schmidt-Boelter-type heat flux meter is shown in Figure 3.



Key

1 Foil with black absorber (usually constantan)

2 Incident heat flux

3 Wire connected to the centre of the thermopile

4 Cooling water

5 Wire connected to the centre of the thermopile

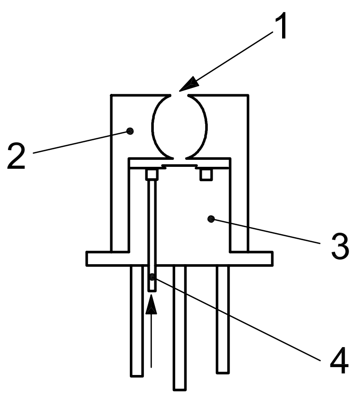
6 Thermocouple for body temperature measurement

Figure 3 — Schmidt-Boelter-type heat flux meter

4.3.4 Hemispherical radiometer

A 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, which is 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

2 Body with reflecting interior

3 Heat sink

4 Output wire

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, in the 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 Equation (1):

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

where

U_{out} is the output signal, in V;

S_1 is the primary sensitivity, in mV/W·m^{-2};

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 by Equation (2):

$$t_{\text{sen}} = \rho \cdot c_{\text{p}} \cdot D^2 / 16\lambda \tag{2}$$

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·K;

D is the foil diameter, in m;

λ is the foil thermal conductivity, in W/m·K.

For Schmidt-Boelter Gauges, based on a thermopile, the response time can be approximated according to Reference [7] by Equation (3):

$$t_{\text{sen}} = \left(4/\pi^2\right)\left(\rho \cdot c_{\text{p}} \cdot D^2 / \lambda\right) \tag{3}$$

where

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

ρ is the sensor density, in kg/m^3