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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

Reference number
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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

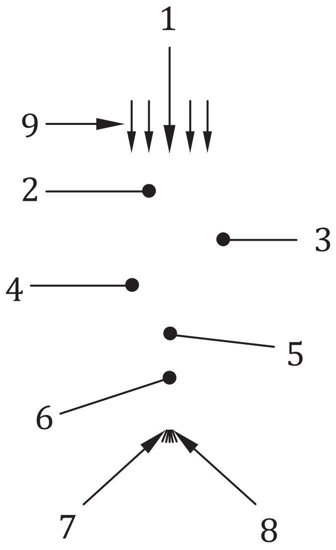
4.1 General

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.

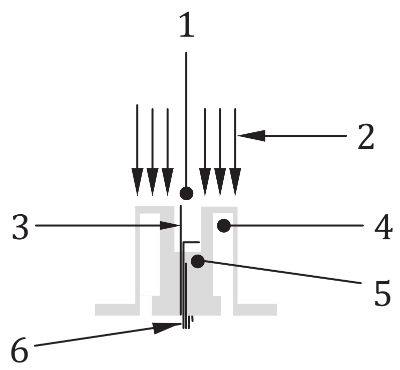
The Gardon type heat flux meters have a very wide working range and a very fast response time. However, they have a low sensitivity and therefore do not work with low heat fluxes.

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.



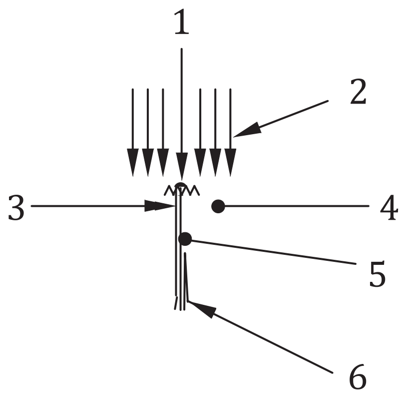
Key

1 foil with black absorber (usually constantan)
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

4.3.2 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

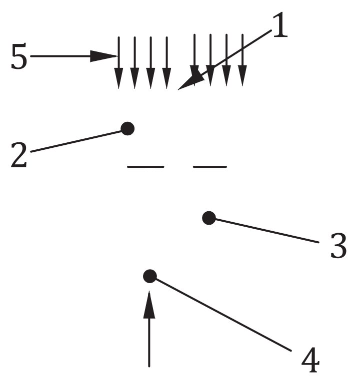
1 foil with black absorber (usually constantan)
2 incident heat flux
3 wire connected to the centre of the thermopile
4 cooling water
5 wire connected to the centre of the thermopile
6 thermocouple for body temperature measurement

Figure 3 — Schmidt-Boelter type heat flux meter

4.3.3 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
2 body with reflecting interior
3 heat sink
4 output wire
5 incident heat flux

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):

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

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):

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

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.

For Schmidt-Boelter Gauges, based on a thermopile, the response time can be approximated as in Formula (3):[7]

$$t_{sen} = \left(\frac{4}{\pi^2}\right)\left(\frac{\rho c_p d^2}{\lambda}\right) \quad (3)$$

where

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

ρ is the sensor density in kg m^{-3};

c_p is the sensor specific heat capacity in J kg^{-1} K^{-1};

d is the sensor thickness in m;

λ is the sensor thermal conductivity in W m^{-1} K^{-1}.

Most heat flux meters currently used for fire tests have a time constant around 1 s or less. Therefore, measured results of heat flux in nearly steady-state condition in fire tests can be deemed as instantaneous.

If heat flux is measured in a very fast phenomenon such as flashover stage or explosion, measured results of heat flux might be needed to correct using the time constant.

4.4.2 Working range

In general, a heat flux meter of a particular type is designed to measure within a certain heat flux range (its working range). Also, the sensor has certain sensitivity and a certain response time to reach a certain output signal level. The main restriction is that the absorber temperature is kept within acceptable limits, in which the paint and sensor will not be destroyed.

The absorber temperature rise is a result of incident heat flux, sensor construction, and cooling system.

4.4.3 Sensitivity of heat flux meters

The sensitivity of heat flux meters is primarily determined by the physical composition of the sensor itself. The combined properties of the absorber, surrounding geometry (limiting the field of view), window, and thermopile will result in a certain output at a certain level of incident radiation.

The incident radiation level as a function of the output voltage signal is assumed as a second-degree polynomial as in Formula (4):

$$I = A_0 + A_1 U_{out} + A_2 U_{out}^2 \quad (4)$$

where, I is the incident radiation as defined by the calibration method (Clause 7, 8, and 9).

The view angle dependence is then considered by the calculation procedure of the method.

A_0, A_1, and A_2 are constants to be determined by the calibration procedure.

U_{out} is the output voltage signal.

A_0 can be identified as in Formula (5):

$$A_0 = \eta \sigma T_{\mathrm{wc}}{}^4 \tag{5}$$

where

η is a coefficient to consider influence of convection in the calibration situation;

T_{wc} is the absolute temperature of the cooling water during calibration;

σ is the Stefan-Boltzmann constant given as 5,67051 × 10^{-8} W·m^{-2}·K^{-4}.

When the heat transfer by convection during calibration may be neglected, the coefficient η is equal to 1,0 and A_0 may be calculated directly. Otherwise, A_0 has to be determined together with A_1 and A_2 in a best-fit procedure as described in ISO 14934-2 and ISO 14934-3. The coefficient η can then be calculated as in Formula (6):

$$\eta = \frac{A_0}{\left(\sigma T_{\mathrm{wc}}{}^4\right)} \tag{6}$$

When used in practice, the incident radiation, *I,* is calculated for various water temperatures, T_{w}, as in Formula (7):

$$I = I_{\mathrm{W}} + A_1 U_{\mathrm{out}} + A_2 U_{\mathrm{out}}{}^2 \tag{7}$$

where

$$I_{\mathrm{W}} = \eta \sigma T_{\mathrm{W}}{}^4 \tag{8}$$

and

T_{w} is the in use temperature of the cooling water. The first and third terms are, in most cases, small in comparison to the second term.

In many cases, manufacturers only provide a linearized sensitivity coefficient (A_0 and A_1 in Formula (4)). In such cases, they assume A_0 and A_2 are zero.

4.4.4 Spectral and directional response

The values measured by the heat flux meters described in this part of ISO 14934, i.e. the Gardon type, the Schmidt-Boelter type, and the hemispherical radiometers, can be affected by their distance from the fire and the orientation of the sensing surface in relation to the fire. These meters also respond differently to radiation in different spectral ranges. However, they are designed to have a close to hemispherical view angle and the sensing elements are coated to achieve spectral absorptivities in excess of 0.9. Therefore, for many common fire tests for which they are used, the uncertainty caused by directional and spectral variations in the fires themselves can be assumed to be small.

There are two situations that need particular care when using these heat flux meters that could cause them to deviate significantly from the ideal. First, if a window is fitted to the heat flux meter to eliminate convection, both the view angle and the spectral response of the heat flux meter can be significantly affected. Second, if the coating on the sensing element becomes contaminated, the spectral response of the heat flux meter can change. The manufacturer’s recommendations should be followed for recoating the sensing element to minimize uncertainties due to spectral response.

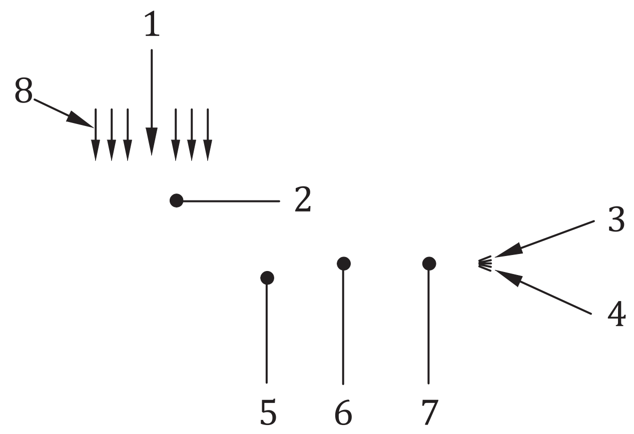
4.4.5 Sensitivity to convective heat transfer

The Gardon and Schmidt-Boelter type heat flux meters described in 4.3.1 and 4.3.2 are sensitive to both incident radiant heat flux and convective heat transfer. The convective heat transfer is normally reduced to a minimum during calibration in a calibration furnace while in a fire test situation the convective heat transfer can be significant. Furthermore, it should be noted that the convective heat transfer in an arbitrary situation could give either a positive contribution (heating the sensor) or a negative contribution (cooling the sensor), depending on the gas temperature adjacent to the sensor in comparison to the sensor surface temperature.

4.5 Physical shape of heat flux meter

The shape of a heat flux meter is usually cylindrical. The absorber is usually directly attached to the body: a water-cooled heat sink. There is a wide variety of sizes (diameter as well as height) of the cylindrical body.

Tubes for water inlet and outlet as well as lead wires from the thermocouple or thermopile are attached to the body. Heat flux meters can be categorized by the way of tube attachment: the horizontal type as shown in Figure 5 with tubes and wiring attached to the side wall of the body, and the vertical type as shown in Figure 1 with tubes and wiring attached to the bottom of the body.



Key

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

Figure 5 — Horizontal type heat flux meter

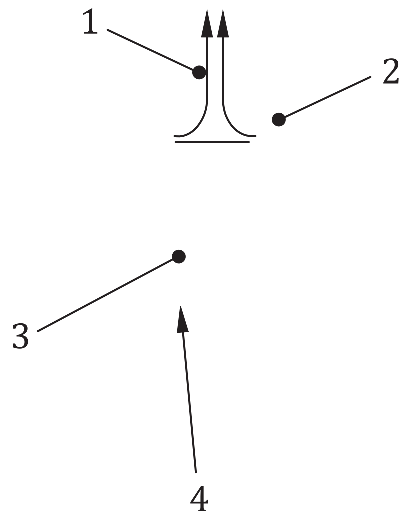
In order to facilitate installation, a flange may be attached to the body of the heat flux meter (see Figure 6). The side of the body may have a threaded hole or female thread for installation (see Figure 6).

Figure 6 — Flanged heat flux meter (left) and flanged and threaded heat flux meter (right)

5 Attachments to heat flux meters

5.1 Air purging

Air purging (see Figure 7) may be used in combination with a heat flux meter. This is particularly useful when extensive amount of smoke or soot is expected during the experiment. Air purge systems are used to prevent the smoke particles from accumulating onto the absorber of the heat flux meter. It should be noted that purged air can affect the combustion and heat transfer, in particular convection, around the heat flux meter. Air purged sensors will require dedicated calibration (see also Clause 6.).



Key

1 air outflow

2 cover for guiding air-flow

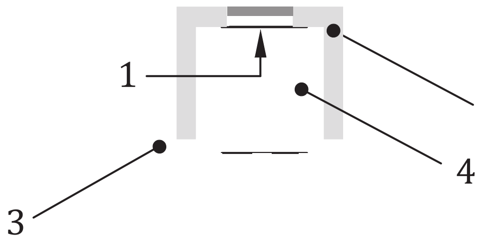
3 air pipe

4 purging air

Figure 7 — Heat flux meter with an air purge system

5.2 Windows

In order to measure radiation only and thus, avoid the contribution of convection, a window may be attached in front of the absorber of a heat flux meter (see Figure 8). It should be noted that the window can absorb a significant part of the radiation, and also that the mounting of a window will change the field of view. Therefore, the choice of window material as well as mechanical mounting will affect the measurement. This will require dedicated calibration (see also Clause 6). Figure 9 shows examples of transmission of some types of window materials.



Key

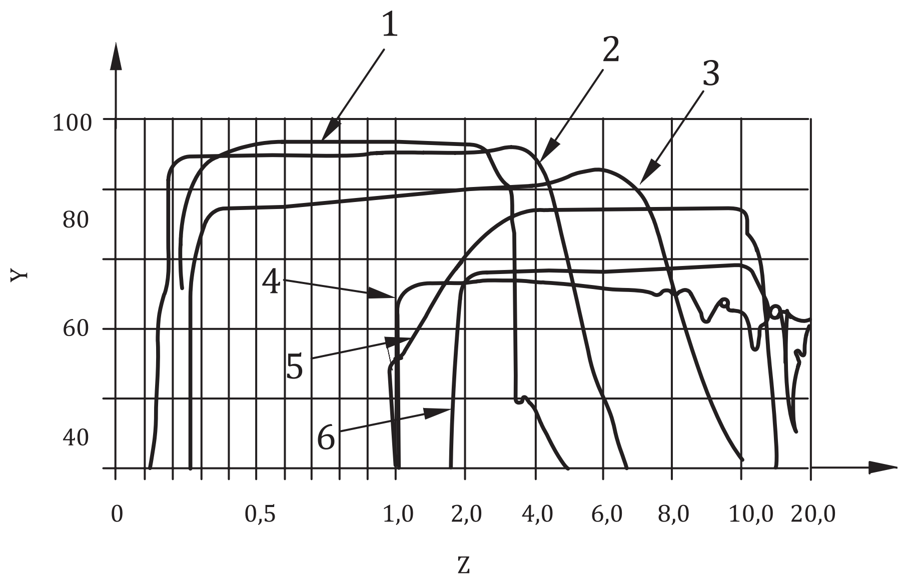
1 sensing surface of the heat flux meter

2 holder for window with a window facing to 1

3 flange

4 heat flux meter body

Figure 8 — Heat flux meter with a window



(Unit: nm)

Key

Y transmittance (%)

Z wavelength (nm)

1 crystal, quartz

2 sapphire

3 YTTRALOX

4 silicon

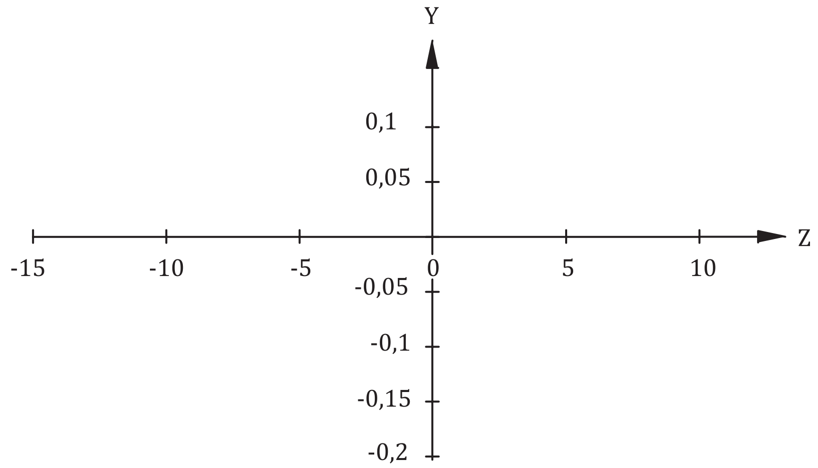
5 IRTRAN2

6 Germanium

Figure 9 — Transmittance curve by each window material

5.3 Cooling system

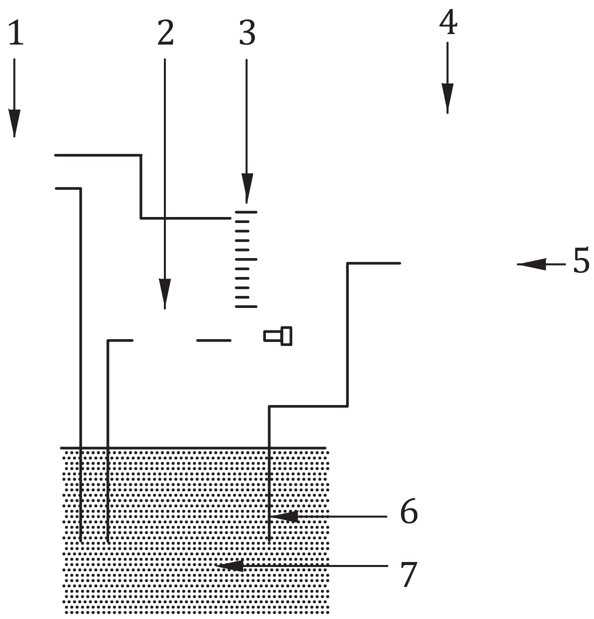
For both the Gardon type and the Schmidt-Boelter type heat flux meters, the body is usually cooled and stabilized by circulating water. Care should be taken that the water temperature remains as constant as possible, and that it remains above the local dew point temperature. If the cooling water temperature is below the dew point of ambient air, water condenses on the exposed surface of the heat flux meter and gives an incorrect measurement. In case of measurement of very low level of heat flux, temperature change of cooling water might affect the measurement considerably. Figure 10 shows signal output of a heat flux meter, which exposed to no irradiance when cooling water temperature is different from ambient temperature. Use of a cooling water circulation system, as shown in Figure 11, is recommended. The cooling capacity of the water should be large enough to avoid temperature change due to the heat received by the heat flux meter. Flow rate of water from 0,5 l to 1 l per min is usually sufficient for this purpose.



Y output (kWm⁻²)

Z temperature difference (°C)

Figure 10 — Output of heat flux meter against cooling water temperature difference from ambient temperature (when no irradiance is given)



Key

1	heat flux meter	4	signal analyser (voltmeter)
2	pump	5 and 6	water temperature controller
3	flow meter	7	cooling water

Figure 11 — Cooling water circulation system

6 Selection of a suitable heat flux meter

6.1 General

There are several criteria for the selection of a suitable heat flux meter for use in a fire test, such as:

— range of measurement;

— dimensions and weight;

— orientation of sensor surface against wiring and piping system;

— view angle;

— assessment of level of convection heat transfer. [8]

6.2 Range of measurement

6.2.1 Evaluating the working and calibration range

Excessive incident heat flux to a heat flux meter beyond its working range can cause destruction of the heat flux meter. On the other hand, the use of heat flux meters to measure at very low levels of heat flux (in relation to the working/calibration range of a heat flux meter) can cause large inaccuracies and errors. Therefore, the working range as well as the calibration range of the heat flux meter should match the conditions of the intended measurement.

6.2.2 Looking at the required test method

When selecting a heat flux meter, it is important to estimate the heat flux level to be measured. In case of standardized tests, the heat flux level is defined in the standards covering these tests.

6.2.3 Estimation of the expected heat flux

When a heat flux meter is used in a real scale fire test or in a test where combustion cannot be controlled, the following assumption might help to choose a suitable heat flux meter. Table 1 gives typical levels of heat flux at various fire conditions. Note that time is involved for the occurrence of a certain phenomenon, but Table 1 provides general information for the selection of appropriate heat flux meters.

Table 1 — Typical levels of heat flux (kW m^{-2})

Heat flux (kW m^{-2})	**Phenomenon**
100 to 200	Incident heat flux on the wall in a developed fire enclosure
30 to 100	Radiation from burning house
around 30	Causing ignition of tree
20 to 10	Causing ignition of timber
around 7 or 8	Lowest level for causing ignition of timber wall under a pilot flame
around 4	Level for causing second-degree skin burning
around 1,4	Highest level for people to endure without serious pain
under 1,3	Solar radiation to the earth’s surface

6.2.3.1 When heat flux from a fire plume is measured, the level depends upon the size of fire plume and distance from it.

6.2.3.2 When measuring heat flux along an escape route, a low level of heat flux such as below 5 kW m^{-2}, should be measurable.

6.2.3.3 When heat flux is measured in a developing stage of fire with single flame, the heat flux from the flame can be up to 100 kW m^{-2}, if the measurement is made in contact with the flame.

6.2.3.4 When heat flux is measured in a fully developed fire or in a fire resistance test for structural members, approximately a maximum level of 300 kW m^{-2} can be reached.

6.3 Type, dimensions and orientation

The type, dimensions, and orientation (horizontal or vertical) of the heat flux meter used in a fire test should be specified in the test method. If such specification is not given by the standard, the manufacturer of the test equipment might recommend the type, dimensions, and orientation of heat flux meter to be used in the test equipment.

When a heat flux meter is installed into a specimen, the water cooling system of the heat flux meter might have a cooling effect on the specimen. This can cause a drop in the temperature of the specimen around the heat flux meter and result in a delay or failure of ignition and/or flame spread. In this case, use of a small size heat flux meter is recommended.

Where a heat flux meter is installed in a large-scale test specimen, care should be taken that the heat flux meter as well as wiring and piping system are robust enough for the purpose.

NOTE It is suggested that a piece of insulation material, such as ceramic fibre can be inserted between the heat flux meter and the test rig or the specimen, and that the wires and pipes of the gauge should be also protected with a piece of insulation material.

6.4 View angle

If a window or air purge system is installed into a heat flux meter, the view angle will be limited, and care should be taken that targeted heat source is within the view angle. Where the size of the heat source cannot be defined, heat flux meters which have a limited view angle should not be used.[9]

6.5 Response time

Most of the Gardon type and Schmidt-Boelter type heat flux meters have a short time constant of less than 1 s. Therefore, there is no need to consider the response time for the application to standardized fire tests, where heat condition is relatively constant. However, if heat flux is measured in a very fast phenomenon such as a flashover or explosion, the response time should be taken into account for the selection of the heat flux meter.

6.6 Sensitivity to convective heat transfer

The Gardon and Schmidt-Boelter type heat flux meters are not equally sensitive to convective heat transfer. The surface temperature is lower on the Schmidt-Boelter type, which should be taken into account.

7 Performing a measurement

7.1 Installation

7.1.1 Installation of heat flux meter to test equipment

The method of installing a heat flux meter into test equipment is usually specified in the test standard.

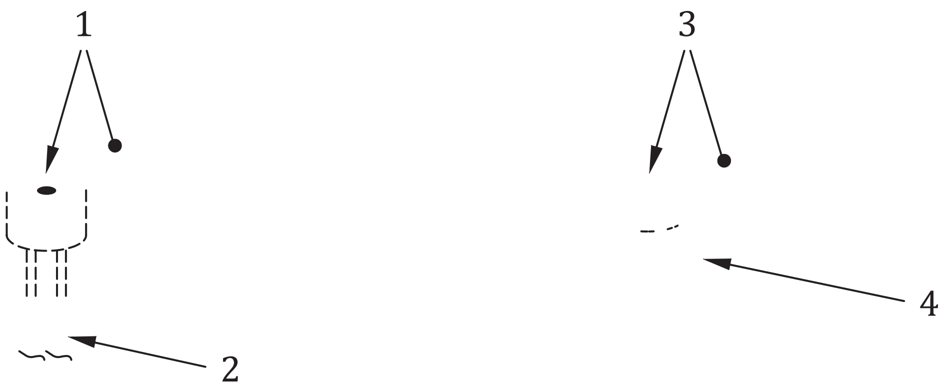
7.1.2 Installation of heat flux meter to specimen

When a heat flux meter is installed into a specimen or a dummy specimen, holes are drilled in the specimen to accommodate the body of the heat flux meter. In general, it is recommended to have the surface of the heat flux meter at the same level as the surface of the specimen.

When the surface of a heat flux meter is on the same level as the surface of the specimen, both convective and irradiative heat transfer to the cooled absorber are measured. It should be noted that the heat flux meter measures heat transfer to the cooled surface of the absorber and is dependent on its temperature. The heat transfer from the environment to the specimen surface is, in general, much smaller as the specimen surface temperature rises. When the surface of heat flux meter protrudes from the surface of the specimen, in particular when orientated vertically, the convective heat is altered. If the heat flux meter recesses from the surface of the specimen, the edge and side wall of the hole of the specimen limit the field of view to the heat source. Recessed as well as protruded mounting should be used in exceptional cases only, and should be well documented.

In a large-scale fire test, the heat flux to a heat flux meter mounted in the specimen is sometimes measured. In order to install a vertical type heat flux meter into a specimen, a hole may be made in the specimen through which the heat flux meter is inserted (see Figure 12). In this case, the tubes for water supply and lead wires can be protected by the specimen. However, care should be taken to avoid damage or mechanical stress to the sensor by collapse or deformation of the specimen. It is recommended to insert an insulation material, such as ceramic wool, between the side of the heat flux meter and the wall of the hole of the specimen. This insulation material can protect the heat flux meter from any deformation of the specimen, and also reduce the cooling effect of water-cooling system of the heat flux meter to the specimen.

Horizontal type heat flux meters can be mounted on the surface of the specimen in large-scale tests without any treatment of the specimen (see Figure 12). In this case, the heat flux meter protrudes from the surface of specimen. The tubes for water supply and lead wires are now exposed to the heat source, and should be protected by appropriate means.



Heat flux meter is installed to the specimen through a hole.

Heat flux meter is installed on the surface of the specimen

Key

1 surface of the heat flux meter is on the same level of the surface of the specimen

2 tube for cooling water

3 heat flux meter protrudes from the surface of the specimen

4 tube for cooling water

Figure 12 — Installation of heat flux meter to specimen

7.2 Target surface

Heat flux meters are usually supplied with a plastic cover to protect the sensing surface that is intended to be removed before testing. The plastic cover easily melts in high temperature and adheres to the target, and it is difficult to remove.

7.3 Electronics

Electronic device connecting to the output of the heat flux meter should have an input impedance of at least 1 000 times the impedance of the sensor of the heat flux meter.

After installation, a check of the electronic circuit should be carried out. The check consists of replacement of the sensors by the following:

— a resistor of similar resistance value to the sensor, to verify that there are no significant offsets;

— a voltage source to verify the voltage measurements.

7.4 Relationship between output voltage and total heat flux

The sensitivity of heat flux meters is primarily determined by the physical composition of the sensor itself. The combined properties of the absorber, surrounding geometry (limiting the field of view), window, and thermopile will result in a certain output at a certain level of incident radiation. (See ISO 14934-1).

8 Calibration

8.1 Secondary standard heat flux meter

Secondary-standard heat flux meters as described in ISO 14934-3, should be calibrated according to one of the primary methods described in ISO 14934-2.

8.2 Working standard heat flux meters

Working heat flux meters to be used in fire tests should be calibrated by comparison with the secondary standard heat flux meters following the method specified in ISO 14934-2 and ISO 14934-3.

8.3 Frequency of calibration

The interval of calibration of the working heat flux meter shall be as specified in the fire standards that are being used.

NOTE If there is no specification in the intended fire test standard, it is recommended to use ISO 5660-1, 10.3.1 for this purpose.

9 Maintenance

9.1 Absorber

During the use of heat flux meters, the colour of the absorber surface might change. This might be caused by overheating, deposition of soot, ash and/or other particles, reaction of the coating with gasses, etc. In case of minor colour change, the heat flux meter may be used after cleaning the surface and recalibration. If the extent of colour change is large, or in case of the coating letting loose, the surface shall be repainted in accordance with the manufacturer's recommendations. When the absorber of a heat flux meter is repainted or substantially cleaned, the heat flux meter shall be re-calibrated.

9.2 Wiring

The output lead wire shall be examined. Large noise in the output suggests a defect or snapping in the wiring. No signal change when facing the sensor to a heat source might mean a short in the wiring or an open circuit.

9.3 Water supply

The water supply system for cooling the heat flux meter shall be checked and it is important to make sure that there is no leakage of water and that water flow is according to the manufacturer's specifications and constant. Filtering the water supply may be appropriate to keep particulates from blocking the water passages inside the gauge.

10 Use of heat flux meters in fire tests

10.1 General

This clause gives examples of the application of heat flux meters in ISO standardized fire tests. In any fire test standard where heat flux meters are used, ISO 14934-3 shall be referred to for calibration of heat flux meters and ISO 14934-4 should be mentioned for correct use of heat flux meters. The following text serves as an illustration only and for detailed test procedures, the individual standards shall be used.

When heat flux meters are exposed to hot gases or flames, the surface of the heat flux meters shall be checked for damage and calibration confirmed after the test.

Prior to describing the detailed information of the use of heat flux meters in each ISO standard, Table 2 gives classification by purpose of using heat flux meters for each fire test.

Table 2 — Classification by purpose of using heat flux meters in fire tests

Major purpose of using heat flux meters	Fire Test in ISO	Test sample size	Range of heat flux meter	Accuracy	Repeatability
P1	5657: Ignitability of building products 5658–2: Spread of flame (lateral) 5658–4: Spread of flame (vertical) 5660–1: Cone Calorimeter 9239–1: Floorings 12136: Measurement of material properties 17554: Mass loss measurement 14696: ICAL	165 × 165 mm 155 × 800 mm 1 025 × 1 525 mm 100 × 100 mm 1 050 × 230 mm e.g. 102 × 102 mm 100 × 100 mm 1 × 1 m	0–70 kW m^{-2} 0–50 kW m^{-2} 0–50 kW m^{-2} 0–100 kW m^{-2} 0–15 kW m^{-2} 0–100 kW m^{-2} 0–100 kW m^{-2} 0–50 kW m^{-2}	±3 % ±6 % ±3 % ±3 % ±3 % ±9 % ±3 % ±3 %	0,5 % ±0,5 % ±0,5 % ±0,5 % — 0,5 % ±0,5 % ±0,5 %
P2	13785–1: Facades 24473: Open calorimetry	1,2 × 2,4 m None specified	0–50 kW m^{-2} 0–50 kW m^{-2}	±3 % ±3 %	0,5 % 0,5 %
P3	9705: Room corner test 13784–1: Room test for sandwich panels 24473: Open calorimetry	3,6 × 2,4 × 2,4 m (LWH) 3,6 × 2,4 × 2,4 m (LWH) None specified	0–50 kW m^{-2} 0–50 kW m^{-2} 0–50 kW m^{-2}	±3 % ±3 % ±3 %	0,5 % 0,5 % 0,5 %

Purposes:

P1 adjusting heating strength from furnace/heater to the location of specimen prior to fire test

P2 measuring incident heat flux at some points in the specimen surface during fire test

P3 measuring incident heat flux at some points distant from the specimen during fire test

10.2 Ignitability test: ISO 5657

The specimen is exposed to thermal radiation on their upper surface at selected levels of constant irradiance within the range 10 kW m^{-2} to 70 kW m^{-2} and the ignition time is measured. A heat flux meter is attached to a non-combustible board which is placed in the specimen position. The temperature of the cone heater is adjusted in order to obtain the required incident heat flux to the specimen position. Gardon or Schmidt-Boelter type heat flux meters can both be used for the purpose. A heat flux meter with working range of up to 70 kW m^{-2} should be used. Its absorber should be not more than10 mm in diameter.

10.3 Spread of flame test: ISO 5658 series

The distribution of incident heat flux in the plane of the specimen is specified in the standards.

In order to achieve repeatability with earlier testing, prior to the test itself the complete system is adjusted. This is done by measurement of the heat flux at the fixed locations using a heat flux meter inserted into holes in a non-combustible board (for example, silica acid calcium board with a density of about 800 kg m^{-3}). The board is temporarily put in place of the specimen and the gas supply to the heat source is adjusted in order to get the prescribed distribution of heat flux. The area of the non-combustible board within 300 mm from the edge receiving lower heat flux is lowered by 10 mm in order to prevent convective heat flux around the area. This is necessary because in that area the convective flux is relatively high in comparison with the radiant heat flux. When no measurement is done in a hole, it should be closed by plugs made of the specimen material and with a minimum discontinuity of the surface area. Incident heat flux at a location closest to the heat source is about 50kW m^{-2}, enough to ignition to clothes and a burn, so care should be taken when conducting the experiment.

10.4 Heat release, smoke production and mass loss: ISO 5660 series and ISO 17554

In this test, the heat flux meter is used to verify the heat flux level at the location of the specimen. A Schmidt-Boelter type heat flux meter with a working range of 0 kW m^{-2} to 100 kW m^{-2} should be used for adjusting the heat flux level. The diameter of the black paint on the absorber is about 12,5 mm. It is important to ensure that the cooling water is flowing and that the vulnerable black coating on the absorber is handled with care. In order to maintain a stable reference, calibration of the heat flux meter should be done on a daily basis. The absorber should be positioned at the location of the central part of the specimen. If necessary, the specimen holder should be removed in order to be able to place the sensor at that particular location.

10.5 Full-scale room test for surface products: ISO 9705 and ISO 13784 series

In this test, a heat flux meter is mounted at the geometric centre of the floor of the test room. The target surface protrudes from the floor surface by 5 mm to 30 mm. Use of any window is prohibited. An optional heat flux meter may be mounted at the geometric centre of the opening of the test room.

10.6 Façade tests: ISO 13785 series

In ISO 13785-1, one heat flux meter is installed on the upper edge of the main façade, in order to measure heat flux during the fire test. The heat flux meter is housed in a square non-combustible insulation board 200 mm × 200 mm, for supporting its surface in the same plane as the façade specimen. While in ISO 13785-2, total of four heat flux meters are installed at higher positions within the façade specimen, flush with the outer face of the specimen as far as possible, in order to measure heat flux on the façade caused by thermal current spouting from the chamber opening.

10.7 Spread of flame test for floor coverings: ISO 9239 series

In ISO 9239 the specimen is exposed to a specified distribution of heat flux along the longitudinal surface. The maximum heat flux to the specimen is 11 kW m^{-2} in ISO 9239-1 and 25 kW m^{-2} in ISO 9239-2. Adjustment of the radiant panel heat source is carried out with a dummy specimen with holes, in which a heat flux meter is inserted.

10.8 Intermediate-scale heat release calorimeter (ICAL): ISO 14696

The irradiance level to the specimen is adjusted using a heat flux calibration panel of 1 000 mm × 1 000 mm made of 12 mm to 13 mm thick calcium silicate board of nominal density 600 kg m^{-3} to 850 kg m^{-3}. Five rows and columns of holes (25 holes in total) are drilled with their centres 224 mm apart and 52 mm from the edges on all sides of the panel. Heat flux meter is inserted in the holes and extends 15 mm toward the radiant panel from the exposed surface of the calibration panel to minimize the convective heat transfer contribution during the measurement. Heat flux is measured in several distances between the calibration panel and the radiant panel, i.e. 300 mm, 400 mm, 600 mm, 800 mm, 1 000 mm, 2 000 mm, 3 000 mm, 4 000 mm, 5 000 mm and 6 000 mm.

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