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Fire tests — Calibration and use of heat flux meters —

Part 3:
Secondary calibration method

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

Partie 3: Méthode d'étalonnage secondaire

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Contents

Page

Foreword

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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.

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 14934-3 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

ISO 14934 consists of the following parts, under the general title *Fire tests — Calibration and use 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 many fire test methods, the radiation level is specified and, therefore, it is of great importance that the radiant heat flux is well defined and measured with sufficient accuracy. Radiant heat transfer is also the dominant mode of heat transfer in most real fires.

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 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, however, also depends 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: (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 to convective heat transfer. A comparison of measurements between the two types of meters in secondary (or transfer) calibration methods allows a characterization of the influence of convection in the method. Where possible, in calibrations and in measurements of radiative heat flux, it is advisable that the uncertainty calculations include the uncertainty associated with removing the 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 the calibration of fire-test methods as well.

This part of ISO 14934 describes a method for the calibration of total heat flux meters used in fire testing. A number of fire tests described in International Standards published by ISO require test specimens to be exposed to specified levels of irradiance. It is, therefore, necessary for fire test laboratories to be able to maintain working-standard heat flux meters to measure irradiance.

This part of ISO 14934 describes a method for the calibration of heat flux meters for use as working standards by comparison with a heat flux meter of known sensitivity, referred to as a secondary standard. The latter will have been calibrated by reference to a defined primary standard of irradiance from a close-to-black source.

The calibration of heat flux meters for use as primary and secondary standards requires considerable expertise and equipment that is not covered by this part of ISO 14934. For information on the calibration of primary standards and for a detailed account of the principles of the measurement of thermal radiation, reference is also made to ISO 14934-2.

Information on the accuracy of calibration, care of heat flux meters and guidance notes for carrying out the calibration are given in Annexes A to C. Annex D outlines a suitable procedure for the maintenance of a secondary standard of irradiance at a test laboratory.

Fire tests — Calibration and use of heat flux meters —

Part 3:
Secondary calibration method

1 Scope

This part of ISO 14934 specifies a method for the calibration of heat flux meters for use in fire testing.

This method applies only to instruments having plane sensing surfaces. It does not apply to sensing surfaces in the form of wires, spheres, etc.

Annex A gives information on the accuracy of the calibration. It is intended that reference be made to the International Standard describing the test for which the heat flux meter is intended. Annex B gives guidance on the care of heat flux meters. Annex C gives guidance notes concerning calibration.

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

3 Terms and definitions

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

4 Principle

Calibration of heat flux meters (total hemispherical radiometers and total heat flux meters) for use as working standards is carried out by comparing heat flux meter response at various levels of irradiance with the response of a secondary-standard heat flux meter of the same type at the same levels of irradiance. The measurements are made at different levels of irradiance, which is obtained by varying the distance between the radiant source and the heat flux meter or by varying the temperature of the radiant source. The secondary-standard heat flux meter shall be calibrated according to one of the primary methods described in ISO 14934-2.

Working standard heat flux meters may also be calibrated directly in any of the primary calibration furnaces described in ISO 14934-2. In this case, it is not necessary to follow the calibration procedure described in this part of ISO 14934.

5 Apparatus

5.1 Radiant source

The radiant source can be spherical, flat or conical. It shall be an electrically powered heater. The irradiance from the radiant source shall be maintained at a preset level by controlling the temperature. This can be done as with the heater described in ISO 5660-1. The temperature shall be kept constant during the calibration. The source shall be larger than the measuring surface of the heat flux meters under calibration.

The radiant source shall be placed in such a way that the irradiance from the radiant source is given vertically downward to the heat flux meter to be calibrated, which is placed below the radiant source.

5.2 Mounting arrangements

The mounting apparatus shall be designed to bring the sensing surface of each heat flux meter (working standard and secondary standard) quickly in turn into a preset position opposite the centre of the radiant source in such a way that the irradiance to the heat flux meter can be varied. This can be achieved, for example, by a system where the position of a heat flux meter is fixed and adjusting the output from the radiant source (for example the conical heater of ISO 5660-1, ISO 13927 and ISO 17554) or a temperature-controlled flat-faced radiant source with a mounting system of heat flux meter, which fixes the position of a heat flux meter.

Irradiance to the heat flux meter can be changed by changing the distance between the radiant source and the heat flux meter or by changing the power (i.e. temperature) of the radiant source.

The movement of, or a change in, radiant source power shall be over a range that provides an appropriate range of irradiance. The heat flux meter shall not be placed in any convective air flow initiated by the radiant source. The means for locking the heat flux meter in position shall be rigid and such that the centre of the sensing surface is on the normal from the centre of the radiator.

The heat flux meter mounting apparatus shall be designed so that meters are not mounted directly over a substantial mass of material that gets hot when the radiant panel is running, and so that it can be placed in position after the irradiance of radiant source reaches a preset level.

The mounting apparatus shall incorporate a means to support two (or more) heat flux meters that can differ in size, and mounting arrangements shall be designed so that the heat flux meters can be positioned with their sensing surfaces in the same vertical plane parallel to the face of the radiant source. No part of the mounting apparatus shall project in front of the heat flux meters being tested.

All exposed surfaces of the heat flux meter mounting apparatus shall be coated with a heat-resisting, matt, black finish.

NOTE Where the secondary-standard and working-standard heat flux meters are not identical in shape, a special positioning device can be needed.

5.3 Instrumentation

5.3.1 Secondary-standard heat flux meters

Three or more secondary-standard heat flux meters are required for periodic inter-comparisons to maintain a reliable standard of irradiance. A suitable scheme for these inter-comparisons is outlined in Annex D.

5.3.2 Recording instrumentation

Instrumentation shall be capable of assimilating the incoming data and producing a record, both permanent and immediately available to the operator, of the reading of each heat flux meter at intervals not longer than 5 s, having range settings appropriate to the outputs of the heat flux meters. It is recommended to use the same recording instrumentation for both secondary and working heat flux meters.

5.4 Additional equipment

5.4.1 Protective clothing

Protective clothing, such as heat-resisting gloves and eye protection, should be worn, as necessary.

5.4.2 Low-pressure water supply

Low-pressure air and/or water supply for the heat flux meters should be supplied as required. An example is given in Clause C.7.

6 Test environment

6.1 Room

The influence of the surroundings should be stable over time. The radiation from everything except for the radiant source should be limited to 1 % of the radiant source radiation during the entire procedure.

6.2 Draught

The test apparatus shall be contained in an essentially draught-free environment, where the air flow does not exceed 0,2 m/s when the apparatus is cold. Particular care shall be taken to avoid draught across the instruments under test. If necessary, screens shall be provided, but these shall be at least 1,5 m away from the heat flux meter under test.

7 Setting up procedure

7.1 General

Check that the apparatus is assembled correctly. Ensure that any mounting apparatus moves smoothly in relation to the face of the radiant source. Lubricate any sliding parts using a heat-resisting grease or graphite, if necessary.

Laboratories supplying instruments for calibration should be aware that with a new working-standard heat flux meter or one that has not been previously used, it is advisable to age the sensing surface artificially before a calibration is carried out to avoid, or reduce, initial drift in sensitivity. It is recommended that this be done by exposing the sensing surface to radiation for 20 h to 25 h in a series of exposures of several hours' duration, at an irradiance near the maximum at which it is likely to be used. With some types of heat flux meters, it is advisable to monitor sensitivity and continue ageing until it has stabilized.

7.2 Mounting and alignment of heat flux meters

7.2.1 With the radiant source off, mount the secondary-standard heat flux meter and the working-standard heat flux meter, or heat flux meters that are being calibrated, in the mounting apparatus. Ensure that all leads and tubes to heat flux meters are protected against radiation (wrapping with thin, shiny aluminium foil has been found suitable; see Clause C.8), and that they do not become entangled in any mechanism when it moves. Connect the secondary-standard and working-standard heat flux meters independently to the recording instrumentation using appropriate leads.

If a water-cooled heat flux meter is being tested, connect the appropriate supply and ensure that the flow rate is in accordance with the manufacturer's recommendations. The temperature of the cooling water shall be the ambient room temperature and shall not be below the dew point of the ambient temperature.

7.2.2 Place the mounting apparatus into position for calibration. Adjust the heat flux meters in turn horizontally, vertically and at an angle, so that when brought into the test position, their sensing surfaces lie in the same plane relative to the radiant source, with the centres of the sensing surfaces on the normal from the centre of the radiant source.

Ensure that the sensing surfaces of the heat flux meters are clean and that the line-of-sight between the sensing surfaces and the radiator is not obstructed when in the test position. Place small screens in front of the heat flux meters to shield them from the radiator.

As far as possible, the heat flux meters should be screened from radiation except during actual readings.

8 Typical calibration procedures

8.1 Switch on the recording instrumentation, allowing any necessary time for warming up.

8.2 With the heat flux meter mounting apparatus away from the calibration position, switch on the radiant source and set the temperature to a preset level.

8.3 After the temperature of the radiant source reaches a preset level, place the radiation shield.

8.4 Place the heat flux meter mounting apparatus in preset position. Set the secondary-standard heat flux meter at its central position on the mounting apparatus and lock it in this position.

8.5 Remove the radiation shield to expose the meter to the radiant source. Continue the exposure in this position until the temperature of the radiant source reaches the preset level and the value recorded from the heat flux meter is essentially constant over a period of 1 min. Note the heat flux meter output reading (F_1). Reinsert the radiation shield.

8.6 Move the working-standard heat flux meter to the position occupied by the secondary-standard heat flux meter.

8.7 Remove the radiation shield to expose the meter to the radiant source. Continue the exposure in this position until the temperature of the radiant source reaches the preset level and the value recorded from this heat flux meter is essentially constant over a period of 1 min. Note the heat flux meter output (W). Reinsert the radiation shield.

8.8 Return the secondary-standard heat flux meter to its central position and repeat 8.3, obtaining another output reading (F_2).

8.9 Repeat the measurements, alternating the working-standard and secondary-standard heat flux meters until two successive measurements from the latter differ by less than 1 % (see Clause C.8).

8.10 Repeat 8.2 to 8.9 with the radiant source set at different power levels until at least ten different levels of irradiance have been used (see Annex A). Ensure that the irradiance levels cover the required calibration range of the working-standard heat flux meter and that they are evenly spread over that range.

It is advisable to start at a low irradiance and increase the power up to the maximum required, and then decrease the power (covering the same power levels) so that outputs are obtained from increasing irradiance and decreasing irradiance.

9 Calculation of results

9.1 General

Derive the irradiance corresponding to an output of W from the working-standard heat flux meter from the arithmetic means of those two consecutive values of F bracketing this reading (see 8.8) and the calibration data available for the secondary-standard heat flux meter.

Present the results graphically (see 9.2) and mathematically (see 9.3).

9.2 Graphical presentation

Tabulate the irradiance and the output of the working-standard heat flux meter at each irradiance level used during the calibration.

Construct a graph of irradiance as ordinate against output voltage from the working-standard heat flux meter as abscissa.

The graph now represents the calibration of the working-standard heat flux meter with reference to the secondary-standard heat flux meter used.

9.3 Mathematical presentation

Express the calibration in the form of a regression equation of irradiance on output readings, expressed in millivolts. For many instruments, a linear regression equation is suitable but some instruments require second-order regression techniques to express adequately the relationship between output and irradiance. The evaluation of the uncertainty in the regression curve should be performed according to 9.4.

Before subjecting the data to statistical or other analysis, examine them for outlying observations; readings occasionally arise that appear to be substantially out of line with the main body of the readings and that can affect substantially an overall calibration obtained, for example, by regression techniques.

If such readings are noticed at the time of the laboratory work, repeat the readings and discard any that are not confirmed.

Discard outlying readings where a physical explanation exists for questioning their validity, for example, where some disturbance is known to have occurred.

NOTE Where no physical reason exists for suspecting the accuracy of an outlier, an objective statistical test can be required to decide whether to retain or exclude it.

9.4 Uncertainty in regression curve

The number of radiation levels used for calibration influences the uncertainty in the regression of the calibration. When a linear regression has been performed, then the standard deviation, $\hat{s}^2$, is calculated either by means of the computer program used for the regression or from Equation (1):

$$\hat{s}^2 = \frac{1}{\nu}\sum_{i=1}^{m}(\hat{y}_i - y_i)^2 \tag{1}$$

where

ν is the number of degrees of freedom;

m is the number of radiation levels;

$\hat{y}_i$ is the value from the model;

y_i is the measured value for the level x_i.

The number of degrees of freedom, ν, equals number of radiation levels minus the number of parameters that are set in the regression, i.e. 2 for linear regression. The uncertainty for the regression curve is then calculated as the standard deviation times a coverage factor in order to get a 95 % confidence interval. If the degree of freedom is small, i.e. less than 10, then this shall be taken from the t-distribution.

10 Test report

The test report should contain the following information:

a) reference to the source of calibration of the secondary-standard heat flux meter and the date of its last calibration;

b) source temperature to the nearest 50 °C;

c) identification of the calibrated working-standard heat flux meter (e.g. manufacturer, model, serial number);

d) irradiance range employed (use the sentence: “This heat flux meter has been calibrated in the range from x to y kW/m^2”);

e) date of calibration;

f) results as detailed in Clause 10;

g) instrument temperature;

h) date and identification number of the report;

i) name and address of calibrating laboratory;

j) name and address of the client, if known;

k) name and type of heat flux meter under calibration;

l) calibration method;

m) identification of the calibration equipment used;

n) traceability of measurements;

o) any deviation from the calibration method;

p) uncertainty of the test results;

q) date and signature;

r) reference to this part of ISO 14934.

Annex A
(informative)

Accuracy of calibration

The accuracy of calibration of the working-standard heat flux meter depends on the accuracy of calibration of the secondary-standard heat flux meter and also on the accuracy with which the inter-comparison can be made. The latter depends both on the accuracy of positioning of the working-standard heat flux meter in relation to the secondary-standard heat flux meter and on the statistical errors due to averaging, combining or comparing sets of data that, because of random processes such as physical perturbations and reading errors, exhibit some variation. Establishing confidence limits for the calibration of secondary-standard heat flux meters is the subject of several ongoing investigations (HFCAL and FORUM). In the absence of new data, an uncertainty of better than ± 6 % (95 % confidence limit) is a conservative estimate. The main error due to imprecise positioning arises from errors in positioning with respect to the distance from the radiant source. Because of the relatively large angle subtended by the source at the sensing surface for much of the irradiance range applying, the error in irradiance is much smaller than can be expected from the inverse square law (with a small source). For instruments of identical size and construction, it should not be difficult to position the heat flux meters to this accuracy, and ± 0,5 % can be regarded as 95 % confidence limits. These uncertainties apply to relative errors, but not absolute uncertainties, since there is neither a specification on the uniformity of the radiant heat flux across the face of the panel nor a requirement that the heat flux meters be Lambertian.

When heat flux meters of different types and dimensions are compared, greater positioning errors can be possible and, if the sensing surfaces are of substantially different sizes, then another kind of error is possible. If a heat flux meter with a large sensing surface (for example 10 cm^2 to 20 cm^2) is being calibrated by means of a heat flux meter of small sensing surface area (for example 1 cm^2), then, for the highest accuracy, it is necessary to take account of the fact that the average irradiance over the whole of the large sensing surface area is, in general, not quite the same as the irradiance at its centre, and with which the reading of the heat flux meter with the smaller sensing surface is associated.

The statistical error of the comparisons naturally depends on the number of experimental observations. For one type of heat flux meter, the 95 % confidence limits for the sensitivity obtained by using only one observation (i.e. one reading of the working-standard heat flux meter bracketed by readings of the secondary-standard heat flux meter) have been estimated as about ± 4 %. With 10 observations, and with a procedure for discounting obvious outlying observations, this can be reduced to about ± 1,2 %, and with 20 observations with outliers discarded, to about ± 0,8 %.

Annex B
(informative)

Care of heat flux meters

The accuracy of the calibration may be affected by the condition of the heat flux meters. Because of their delicate construction, some types of instrument can be easily damaged. When a heat flux meter is not in use, a cover, constructed in such a way that it does not touch the sensing surface, should be placed over the sensing surface to protect it from damage and dust. If dust is seen on the receiving surface, it should be removed by blowing gently. If the sensing surface is covered by a window, dust should be removed with a soft dry brush. Cleaning by rubbing or using solvents is not recommended. Mechanical shock and vibration can cause breakages in a thermopile circuit.

If the original surface coating of the sensor is damaged or contaminated even in the slightest, the sensitivity of the heat flux meter quoted by the manufacturer or the subsequent calibration might no longer be valid, since the absorptivity can have changed. If this occurs with a secondary standard, the secondary standard heat flux meter should be retired or recalibrated against a primary standard.

Annex C
(informative)

Guidance notes

C.1 Use of electrically powered radiant source

Because the convective contribution of a gas-fired radiant source is comparatively large and such a radiant source releases combustion gases and flame, an electrically powered radiant source should be used.

C.2 Limiting conditions for instrument calibrations

Even for heat flux meters (see Clause C.4), where it can be thought that some convection transfer might be tolerated in calibration, it should be noted that in the same velocity/temperature field the convection transfer depends on the geometry and temperature of the sensing surface, so that it can be different for different types of instruments. Bringing the heat flux meter close to the radiant source in an attempt to increase irradiance is of diminishing effectiveness, as the angle subtended at the heat flux meter by the panel becomes very large and, with some types of sensing surfaces, can give a calibration unrepresentative of the angle within which radiation is normally accepted in practice.

C.3 Heat flux meters

With heat flux meters whose sensing surfaces are flat and coincident with the front face of the enclosing protective body, radiation can be received from a solid angle of nearly 2π sr.

However, some heat flux meters have a more limited field of view and for these it is very important that the radiant source should always be within the field of view of the instrument, i.e. all parts of the sensing surface can receive radiation directly from all parts of the radiating source. The comparison of two heat flux meters having different angles of view can result in a large error if the radiant source were larger than the field of view of one or both of them. Even for heat flux meters of the same type, having the same limited, nominal angle of view, the area of the radiant source viewed is unlikely to be identical in each case and errors can still result.

In calibrating a heat flux meter in terms of voltage output per unit of radiant energy incident on unit area per unit time (i.e. irradiance), it is unnecessary for the absorptivity of the sensing-surface surface to be known, as long as the absorptivity does not change.

It is convenient for so-called total heat flux meters, i.e. instruments intended to measure radiative and convective heat-transfer rates, separately or combined, to be calibrated by the method described in this part of ISO 14934. However, several points should be especially borne in mind in applying a calibration in terms of irradiance to the measurement of a combined convective and radiative heat-transfer rate. The different nature of these heat-transfer processes should be remembered, especially that heat transfer by radiation depends on the absorptivity of the sensing-surface surface, whilst convection transfer does not. The calibration of a total heat flux meter by means of radiation is normally in terms of *incident* not *absorbed* radiant flux. If the heat flux meter, in practice, is exposed to a combined convective and radiative transfer and the convective transfer predominates over radiative, then it is more accurate to derive a calibration in terms of radiant energy actually absorbed by the sensing surface. If, for example, the sensitivity is S_1 in terms of incident radiant flux then the sensitivity for absorbed radiant flux will be S_1/a where a is the absorptance. Even for blackened surfaces, the difference between these sensitivities can exceed several per cent.

C.4 Radiation and convection

It should also be noted that convection transfer depends on the local temperature and gas velocity and so is sensitive to the shape and position of the measuring instrument. Furthermore, measurements of the heat-transfer rate to a cold (i.e. water-cooled) instrument generally requires adjustment to obtain the corresponding heat-transfer rate to a hot or warm body.

NOTE Such adjustments can differ according to whether convective or radiative components predominate.

There is no way to estimate the difference in uncertainties of the sources presented, which is a fundamental flaw in the logic of the standard. The FORUM round-robin [5] has demonstrated that a wide variety of sources and calibration procedures is suitable, and provide an uncertainty across laboratories of about 8 %.

C.5 Instruments with windows

To reduce susceptibility to draught, or to reduce convection transfer to the sensing surface, some instruments have windows of radiation-transmitting materials. Such materials can be relatively transparent to radiation in the near infra-red region but are invariably opaque to radiation of longer wavelengths. Since the proportion of radiant energy in different parts of the spectrum varies with the temperature of the radiant source, the proportion of radiant energy absorbed by a window, and hence the sensitivity of the instrument, also varies with source temperature. For example, a window that is transparent out to a wavelength of 5 µm and opaque to longer wavelengths will transmit 83 % of the radiation from a blackbody source at 1 200 °C, but only 68 % of the radiation at 800 °C, which would produce a large error if the calibration obtained for one source temperature were used to measure radiation from a source at the other temperature.

C.6 Water-cooling

For instruments intended to be water-cooled, 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 the measurement of very low levels of heat flux, a change in temperature of the cooling water can affect the measurement considerably.

C.7 Calibration procedure

In setting up the instruments and connecting up the wiring, care should be taken to avoid conditions giving rise to parasitic electromagnetic frequencies (emfs) generated by temperature differences and/or electrical pick-up. Leads should be of copper with clean ends, should be electrically screened and should also be shielded from radiation. All electrical junctions should be in cool places, where the ambient temperature remains reasonably constant, and screened from radiation.

Care should be taken to avoid radiation from the radiant source being reflected by nearby objects, e.g. polished metal surfaces, onto the instruments facing the radiant source. Only minimum quantities of aluminium foil should be used to protect electrical leads and this should be crinkled to randomize reflections.

Avoid touching the sensing surfaces of the instruments. They should be kept free from dust by gently blowing across their surface. Durable black coatings may, if necessary, be gently cleaned with a very soft brush.

As mentioned in Clause C.1, the instruments should not be placed so close to the radiant source that they are exposed to convection flow initiated directly by the radiant source.

The use of successive output values from the secondary-standard heat flux meter (F_1 and F_2) that are required to differ by less than 1 %, is intended to reduce the effects of variation with time of radiant-source irradiance. Under normal testing conditions, it should not be necessary to take more than a few values for F before the required maximum 1 % difference is achieved.

Annex D
(informative)

Procedure recommended for maintenance of a secondary standard of irradiance at a test laboratory

D.1 This annex outlines the procedure by which a test laboratory can maintain a reliable secondary standard of irradiance. It is founded on the relative stability of sensitivity of heat flux meters which are reserved entirely for calibration and inter-comparison purposes and are never subjected to the rougher conditions of measurement in fire tests and experiments. Although the absolute determination of irradiance is a complex and time-consuming procedure, the maintenance of calibration of secondary-standard instruments is generally more straightforward.

D.2 The first step is to designate three heat flux meters (A, B, C) as secondary-standard instruments to be reserved henceforth solely for calibration work. These are usually commercially available Schmidt-Boelter measurement-type (thermopile) or Gardon measurement type (foil) heat flux meters. These can either be new instruments purchased specially, or instruments that have been used in the test laboratory but have not been abused. In some cases, records of calibration can indicate certain instruments as having a stable sensitivity over a period of years and such instruments are especially suitable. The purchase of new instruments does not automatically ensure good stability of sensitivity, although on the whole new instruments are likely to be satisfactory.

D.3 One of the three, for example A, should be designated as the principal secondary standard.

D.4 A should be compared with B and also with C using the apparatus and methods described in this part of ISO 14934 but using, in each case, at least 20 data pairs, for enhanced statistical accuracy. To simplify the discussion, it is assumed that the instruments all have a millivolt output directly proportional to irradiance.

In this case, the calibration of an instrument can be expressed as a single value for sensitivity (millivolt output per kilowatt per square metre) and the results of the inter-comparisons can be averaged and expressed as a single-value inter-comparison ratio of the form, $R_{\mathrm{AB}(0)}$ as given in Equations (D.1) and (D.2) for the pair A and B:

$$R_{\mathrm{AB}(0)} = \frac{F_{\mathrm{A}}}{F_{\mathrm{B}}} \tag{D.1}$$

$$R_{\mathrm{AB}(0)} = \frac{S_{\mathrm{A}}}{S_{\mathrm{B}}} \tag{D.2}$$

where

F_{A} is the mean output of A;

F_{B} is the mean output of B;

S_{A} is the sensitivity of A;

S_{B} is the sensitivity of B.

The same applies to the pair A and C.

For instruments whose output is not linearly proportional to irradiance, the comparisons can be made using some other parameter, e.g. output for an irradiance of 25 kW/m^2, or obtained by an accepted curve-fitting process.

