BRITISH STANDARD

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Method for

Calibration of radiometers for use in fire testing

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Fire Standards Committee (FSM/-) to Technical Committee FSM/1, upon which the following bodies were represented:

Association of British Roofing Felt Manufacturers
Association of Building Component Manufacturers Ltd.
Association of Structural Fire Protection Contractors and Manufacturers
British Coal
British Fire Services' Association
British Floor Covering Manufacturers' Association
British Plastics Federation
British Railways Board
British Rigid Urethane Foam Manufacturers' Association
British Wood Preserving Association
Cement and Concrete Association
Chemical Industries Association
Chief and Assistant Chief Fire Officers' Association
Concrete Society
Constructional Steel Research and Development Organisation
Department of Education and Science
Department of the Environment for Northern Ireland
Department of the Environment (Housing and Construction Industries)
Department of the Environment (Property Services Agency)
Department of Transport (Marine Directorate)
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users Association
Eurisol (UK) Association of Manufacturers of Mineral Insulation Fibres
Fibre Building Board Organization (FIDOR)
Fibre Cement Manufacturers' Association Limited
Fire Insurers Research and Testing Organisation (FIRTO)
Fire Offices' Committee
Fire Protection Association
Flat Glass Manufacturers' Association
Flat Roofing Contractors' Advisory Board
Gypsum Products Development Association
Home Office
Institution of Fire Engineers
Mastic Asphalt Council and Employers' Federation
National Council of Building Materials Producers
National Grp Construction Federation
Rapra Technology Ltd.
Royal Institute of British Architects
Timber Research and Development Association
United Kingdom Antimony Oxide Manufacturers' Association
United Kingdom Atomic Energy Authority
Warrington Fire Research Centre
Wood Wool Slab Manufacturers Association
Yarsley Technical Centre Ltd.

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Department of the Environment [Building Research Establishment (Fire Research Station)]
Greater London Council

This British Standard, having been prepared under the direction of the Fire Standards Committee, was published under the authority of the Board of BSI and comes into effect on 27 February 1987

The following BSI references relate to the work on this standard:
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Contents

Foreword

This British Standard has been prepared under the direction of the Fire Standards Committee and describes a method for the calibration of radiometers used in fire testing. It should be of value to those working in industry and research who are concerned with the measurement of heat transfer by thermal radiation.

A number of fire tests described in British Standards and International Standards published by the International Organization for Standardization (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 radiometers to measure irradiance.

This standard describes a method for the calibration of radiometers for use as working standards by comparison with a radiometer of known sensitivity referred to as a secondary standard. The latter will have been calibrated by reference to a defined primary standard of irradiance. Since the standard is intended to apply to radiometers for use in fire tests, the radiator employed is limited to a surface temperature in the range of 800 °C to 1 000 °C.

NOTE A suitable primary standard of irradiance is maintained by the Fire Research Station, Boreham Wood, Herts WD6 2BL.

The calibration of radiometers for use as primary and secondary standards requires considerable expertise and equipment outside that normally available in a fire testing laboratory and is not covered by this standard. For information on the calibration of primary standards and for a detailed account of the principles of the measurement of thermal radiation reference should also be made to J. Sci. Inst., **40,** pp 216 – 220, May 1963, Simms, D.L. & Hinkley, P.L. *An absolute radiometer for the range 0.1 – 2.5 cal* cm^{-2} sec^{-1} *(0.4 – 10 W* cm^{-2}*).*

Information on accuracy of calibration, care of radiometers and guidance notes for carrying out the calibration are given in Appendix A, Appendix B and Appendix C. Appendix D gives details of a specific piece of equipment which has been found satisfactory. Appendix E outlines a suitable procedure for the maintenance of a secondary standard of irradiance at a test laboratory.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard describes a method for the calibration of radiometers for use in fire testing.

This method may be used to calibrate instruments that are used to measure a rate of heat transfer (heat-flux density) due to a combination of radiation and convection (but see Appendix C which gives guidance notes concerning calibration).

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

Appendix A gives information on the accuracy of the calibration and reference should be made to the standard describing the test for which the radiometer is intended. Appendix B gives guidance on care of radiometers.

NOTE The title of the publication referred to in this standard is given on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1
radiometer

a transducer that converts radiant flux into an electrical signal

2.2
radiant flux

power (energy per unit time) emitted, transferred or received in the form of radiation

2.3
irradiance (at a point on a surface)

the quotient of the radiant flux incident on an infinitesimal element of surface containing the point, by the area of that element

2.4
absorptance

ratio of the absorbed radiant flux to the incident flux

2.5
receiver

that part of a radiometer which receives and measures thermal radiation

2.6
working-standard radiometer

a radiometer to be calibrated by reference to a secondary standard for subsequent use to monitor irradiance during the course of fire tests

2.7
secondary-standard radiometer

a radiometer with a calibration traceable to a primary standard, used only for calibration of working-standard radiometers

2.8
sensitivity (of a radiometer)

the ratio of the output voltage to the irradiance in the plane of the receiver

NOTE With some radiometers, sensitivity may vary with irradiance.

3 Principle

The calibration of radiometers for use as working standards is carried out by comparing radiometer response at various levels of irradiance with the response of a secondary-standard radiometer at the same levels of irradiance. The measurements are made at different levels of irradiance by varying the distance between the radiant source and the radiometer.

4 Apparatus

NOTE Appendix D gives details of a specific piece of equipment which has been found satisfactory.

4.1 *Radiator,* with effective radiating area plane, vertical, having no dimension less than 280 mm or more than 470 mm, operating at a constant temperature, uniform over the area, of between 800 °C and 1 000 °C.

4.2 *Mounting apparatus,* designed to bring the receiver of each radiometer (working standard and secondary standard) quickly in turn into a preset, locked position opposite the centre of the radiator and capable of being moved towards or away from the radiator in order to vary the irradiance. The movement shall be over a range which will provide an appropriate range of irradiance, and shall avoid placing the radiometer in any plume of combustion gases from the radiator. The means for locking the radiometer in position shall be rigid and such that the plane of the receiver of the radiometer is parallel to the plane of the radiator and the centre of the receiver lies on the normal from the centre of the radiator.

The radiometer mounting apparatus shall be designed so that radiometers are not mounted directly over a substantial mass of metal or other material that will get hot when the radiant panel is running.

NOTE 1 Any undue interference with the natural airflow towards and up to the radiant panel should be avoided.

The mounting apparatus shall incorporate means to support two (or more) radiometers which may differ in size and mounting arrangements and shall be designed so that the radiometers can be positioned with their receivers in the same vertical plane parallel to the face of the panel. No part of the mounting apparatus shall project in front of the radiometers being tested.

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

NOTE 2 Where the secondary-standard and working-standard radiometers are not identical in shape, then a special positioning device may be needed.

4.3 *Instrumentation*

4.3.1 *Secondary-standard radiometers,* three or more secondary-standard radiometers are required for periodic intercomparisons to maintain a reliable standard of irradiance. A suitable scheme for these intercomparisons is outlined in Appendix E.

4.3.2 *Recording instrumentation,* capable of assimilating the incoming data and producing a record, both permanent and immediately available to the operator, of the reading of each radiometer at intervals of not greater than 5 s, having range settings appropriate to the outputs of the radiometers.

4.4 *Additional equipment*

4.4.1 *Locating spacer,* of any convenient thickness for positioning radiometers in relation to any special positioning device.

4.4.2 *Protective clothing,* such as heat-resisting gloves, and eye protection if necessary.

4.4.3 *Low-pressure air supply and/or water supply,* for radiometers requiring these cooling media (see **C.5**).

5 Test environment

5.1 The test apparatus shall be contained in a room with a ceiling height at least 1.5 m above the top of the radiator. Any wall, floor, ceiling or other surface within 2 m of the radiator shall not have a shiny finish, particularly a shiny metallic finish. Any side walls shall be at least 1.5 m from the radiometer under test.

5.2 Adequate provision shall be made for the removal of any combustion gases from the area of the apparatus.

5.3 The test apparatus shall be contained in an essentially draught-free environment, particular care being taken to avoid draughts across the instruments under test. If necessary, screens shall be provided but these shall be at least 1.5 m from the radiometer under test.

6 Setting up procedure

6.1 General

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

6.2 Mounting and alignment of radiometers

6.2.1 With the radiator off, mount the secondary-standard radiometer and the working-standard radiometer or radiometers which are to be calibrated in the mounting apparatus. Take care to ensure that all leads and tubes to radiometers are protected against radiation (wrapping with thin shiny aluminium foil has been found suitable; see **C.6**), and that they do not become entangled in any mechanism when it is moved. If a water-cooled or forced air-cooled radiometer is to be tested, then connect the appropriate supply and ensure that the flow rate is in accordance with the manufacturer's recommendations.

6.2.2 Adjust the radiometers in turn horizontally, vertically and in angular orientation so that when brought into the test position their receivers lie in the same plane parallel to the plane of the radiant panel, with the centres of the receivers on the normal from the centre of the panel.

Ensure that the receivers of the radiometers are clean and not obstructed in a sight line to the radiator when in the test position. Place small screens in front of the radiometers to shield them from the radiator.

NOTE As far as possible, the radiometers should be screened from radiation except during actual readings.

6.2.3 Connect the secondary-standard and working-standard radiometers independently to the recording instrumentation using appropriate leads.

Turn on the radiator and adjust its control to give an operating temperature in the range 800 °C to 1 000 °C. Allow the radiator to reach a steady state before commencing measurements.

NOTE Laboratories supplying instruments for calibration should be aware that with a new working-standard radiometer or one which has not been previously used, it is advisable to age the receiver 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 receiver to radiation for 20 h to 25 h in a series of exposures of several hours duration, at an irradiance approximating to the maximum at which it is likely to be used. With some types of radiometer it may be advisable to monitor sensitivity and continue ageing until it has stabilized.

7 Calibration

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

7.2 Remove any screens shielding radiometers from the radiator.

7.3 Set the secondary-standard radiometer at its central position on the mounting apparatus and lock it in this position.

7.4 Move the radiometer towards the radiator to a suitable position and lock it in this position.

7.5 Continue the exposure in this position until the value recorded from the radiometer is essentially constant over a period of 1 min. Note the radiometer output (S_1).

7.6 Move the working-standard radiometer to the position occupied by the secondary-standard radiometer.

7.7 Continue the exposure in this position until the value recorded from this radiometer is essentially constant over a period of 1 min. Note the radiometer output (W).

7.8 Return the secondary-standard radiometer to its central position and repeat **7.5**, obtaining an output (S_2).

7.9 Repeat the measurements, alternating the working-standard and secondary-standard radiometers until two successive measurements from the latter differ by less than 1 % (see **C.6**).

7.10 Repeat **7.2** to **7.9** with the mounting apparatus at decreasing distances from the radiator until at least five different levels of irradiance have been used (see Appendix A). Ensure that the actual distances used result in irradiance levels that cover the required calibration range of the working-standard radiometer and are evenly spread over that range. From the final position, repeat **7.2** to **7.9** with the mounting apparatus at increasing distances from the radiator until at least five different levels of irradiance have been used making a total of at least 10.

8 Calculation of results

8.1 General

Derive the irradiance corresponding to an output of W from the working-standard radiometer from the arithmetic means of those two consecutive values of S bracketing this reading (see **7.9**) and the calibration data available for the secondary-standard radiometer.

Present the results either graphically (see **8.2**) or mathematically (see **8.3**).

8.2 Graphical presentation

8.2.1 Tabulate the irradiance and the output of the working-standard radiometer at each distance from the radiant panel used.

8.2.2 Construct a graph of irradiance as ordinate against output voltage from the working-standard radiometer as abscissa.

8.2.3 The graph now represents the calibration of the working-standard radiometer with reference to the secondary-standard radiometer used.

8.3 Mathematical presentation

8.3.1 Express the calibration in the form of a regression equation of irradiance on millivolt output, using the usual statistical techniques. For many instruments a linear regression equation will be suitable but some instruments require second-order regression techniques to express adequately the relationship between output and irradiance.

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

If such readings are noticed at the time of the laboratory work repeat them and discard them if they 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 then an objective statistical test may be required to decide whether to retain or to exclude it.

9 Report

The report shall include the following.

a) Reference to this British Standard.

b) Reference to the source of calibration of the secondary-standard radiometer and the date of its last calibration.

c) Identification of the calibrated working-standard radiometer (e.g. manufacturer, model, serial number).

d) Irradiance range employed.

e) Date of calibration.

f) Results as detailed in clause **8**.

g) Name of calibrating laboratory.

h) Name of sponsor.

Appendix A Accuracy of calibration

The accuracy of calibration of the working-standard radiometer depends on the accuracy of calibration of the secondary-standard radiometer and also on the accuracy with which the intercomparison can be made. The latter depends both on the accuracy of positioning of the working-standard radiometer in relation to the secondary-standard radiometer and on the statistical errors due to averaging, combining or comparing sets of data which, because of random processes such as physical perturbations and reading errors, exhibit some variation. The 95 % confidence limits for the calibration of the secondary-standard radiometer by, for example, the Fire Research Station, have been estimated as about ± 3 %. These take into account the uncertainties in the physical properties of the absolute instrument employed, and the (rather small) statistical errors introduced in calibrating by this means high-range, precision thermopiles which in turn are used to calibrate working-standard radiometers.

The main error due to imprecise positioning will arise from errors in positioning with respect to the distance from the panel. Because of the relatively large angle subtended by the source at the receiver for much of the irradiance range applying, the error in irradiance is much less than would be expected from the inverse square law (with a small source). It has been calculated that between 100 mm and 450 mm from the radiant panel, the error in irradiance caused by an error of 1 mm in positioning with respect to distance from the panel of one radiometer to the other is 0.4 % to 0.6 %, average about 0.5 %. For instruments of identical size and construction it should not be difficult to position radiometers to this accuracy, and ± 0.5 % may be regarded as 95 % confidence limits.

When radiometers of different types and dimensions are being compared, greater positioning errors may be possible and if the receivers are of substantially different sizes then another kind of error is possible. If a radiometer with a large receiver (for example 10 cm^2 to 20 cm^2) is being calibrated by means of a radiometer of small receiver area (for example 1 cm^2) then, for the highest accuracy, account needs to be taken of the fact that the average irradiance over the whole of the large receiver area is in general not quite the same as the irradiance at its centre, and with which the reading of the radiometer with the smaller receiver is associated.

The statistical error of the comparisons naturally depends on the number of experimental observations. For one type of radiometer the 95 % confidence limits for the sensitivity obtained by using only one observation (i.e. one reading of the working-standard radiometer bracketed by readings of the secondary-standard radiometer) 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 %.

The combination of the confidence limits due to these different sources of variation is by root-mean-squares and hence the confidence limits for the calibration of a radiometer could be $\sqrt{(3^2 + 0.5^2 + 1.2^2)} = \pm 3$ % for good conditions. The terms within the brackets in this expression represent the uncertainties in the sensitivity of the secondary-standard radiometer, in the positioning and in the statistical combinations of observations, respectively.

Appendix B Care of radiometers

The accuracy of the calibration may be affected by the condition of the radiometers. Because of their delicate construction, some types of instrument can be easily damaged. When a radiometer is not in use a cover, constructed in such a way that it does not touch the receiver, should be placed over the receiver to protect it from damage and dust. If dust is seen on the receiving surface it should be removed by blowing gently. If the receiver 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.

Appendix C Guidance notes

C.1 Limiting conditions for instrument calibrations

An upper limit of irradiance is set in part by the need to avoid placing instruments with their receivers in the plume of combustion products from the panel. This is undesirable because it causes rapid fluctuations in reading and in any case means that the heat-flux being received is not solely radiation. Even for heat-flux meters (see **C.3**), where it may be thought that some convection transfer could be tolerated in calibration it has to be remembered that in the same velocity/temperature field the convection transfer will depend on the geometry and temperature of the receiver, so that it could be different for different types of instrument. Bringing the radiometer close to the radiant panel in an attempt to increase irradiance is of diminishing effectiveness as the angle subtended at the radiometer by the panel becomes very large and with some types of receiver could give a calibration unrepresentative of the angle within which radiation would normally be accepted in practice.

C.2 Temperature of radiator

The equivalent black-body temperature of the panel can be measured by means of a total-radiation pyrometer which should view a large part of the radiating area, or from a reading of irradiance (I) in front of the panel at a position and for a receiver orientation for which the configuration factor of the radiator (ϕ) is known. The average black-body absolute temperature of the panel is then:

$$\left(\frac{I}{\phi\sigma}\right)^{\frac{1}{4}}$$

where

σ is the Stefan-Boltzman constant.

C.3 Radiometers and heat-flux meters

With radiometers whose receivers are flat and coincident with the front face of the enclosing protective body, radiation can be received from a solid angle of nearly 2π and proximity to the radiator is limited only by any need to avoid the plume of combustion gases.

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

In calibrating a radiometer 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 absorptance of the receiver surface to be known.

It is convenient for so-called "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 standard. 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 absorptance of the receiver surface, whilst convection transfer does not. The calibration of a heat-flux meter by means of radiation will normally be 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 would be more accurate to derive a calibration in terms of radiant energy actually absorbed by the receiver. 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. For blackened surfaces the difference between these sensitivities should however not be more than a few per cent.

It should also be remembered that convection transfer depends on the local temperature and velocity of flow of gases 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 or forced air-cooled) instrument will generally require adjustment to obtain the corresponding heat transfer rate to a hot or warm body, and the adjustment will differ according to whether convective or radiative components predominate.

C.4 Instruments with windows

To reduce susceptibility to draughts, or to reduce convection transfer to the receiver, some instruments have windows of radiation-transmitting materials. Such materials may 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, will also vary with source temperature. Large errors can be caused with an instrument with a window if the calibration obtained for one source temperature is employed when the instrument is in fact being used to measure radiation from a source at a substantially different temperature.

C.5 Water-cooling and forced air-cooling

Instruments intended to be water-cooled or forced air-cooled should be so cooled during calibration. However, extremely cold water should not be used as it can cause moisture condensation on the instrument which could affect its sensitivity.

C.6 Calibration procedure

In setting up the instruments and connecting up the wiring, care should be taken to avoid as far as possible conditions giving rise to parasitic e.m.f's 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 panel being reflected by nearby objects, e.g. polished-aluminium surfaces, on to the instruments facing the panel. Only minimum quantities of aluminium foil should be used to protect electrical leads and this should be crinkled to randomize reflections.

The receivers of the instruments should be kept free from dust by gently blowing across their surface. Durable black coatings may, if necessary, be gently cleaned with a very salt brush.

As mentioned in **C.1**, the instruments should not be placed so close to the radiator that they are in any plume of hot combustion products.

The use of successive output values from the secondary-standard radiometer (S_1 and S_2), which are required to differ by less than 1 %, is intended to reduce the effects of variation with time of panel irradiance. Under normal testing conditions, it should not be necessary to take more than a few values for S before the required maximum 1 % difference is achieved.

It may also be helpful to obtain a distance/irradiance relationship to provide an approximate check on measurement and to ensure that no interference is encountered from any hot plume.

Appendix D Suitable apparatus

D.1 Apparatus

D.1.1 *General*

The apparatus described in this appendix is suitable for comparing radiometers at irradiances up to 55 kW/m². The apparatus (see Figure 1 to Figure 4) consists of a vertically-positioned gas-fired surface-combustion radiant panel, facing a sliding frame on which the radiometer(s) to be calibrated and a secondary-standard radiometer are mounted. The frame is capable of being moved in a horizontal plane both perpendicular to and parallel to the panel. By sliding the frame in a direction parallel to the panel, the receiver of each radiometer can be brought quickly in turn into position opposite the centre of the radiant panel.

By sliding the frame towards or away from the panel, the irradiance level can be varied.

D.1.2 *Radiant panel and ancillary systems*

D.1.2.1 *Radiant panel*, of the surface-combustion type, of nominal dimensions 0.3 m × 0.3 m with a porous refractory face capable of operating continuously at an equivalent black-body surface temperature of approximately 1 100 K (see **C.2**).

D.1.2.2 *Gas supply,* to the panel of either propane or natural gas and capable of giving a total output (radiation and convection) of 35 kW.

In adjusting the gas and air supplies the aim is to obtain a panel at the required temperature but without flames emerging from it. Typical flow rates for a natural gas/air mixture are about 0.75 L/s of natural gas and 8 L/s air.

D.1.2.3 *Air supply,* taken from outside the immediate environment of the radiant panel.

D.1.2.4 *Flow meters, pressure regulators, control valves and safety devices,* for inclusion in the gas and air supply lines to the radiant panel and necessary for the correct operation of the panel.

D.1.3 *Radiometer mounting assembly*

D.1.3.1 *General.* The mounting assembly comprises a mounting frame, lateral slide and main (longitudinal) slide together with a supporting frame (see Figure 1). The assembly provides a means of moving the radiometers in a horizontal plane in directions parallel and perpendicular to the plane of the face of the radiant panel.

D.1.3.2 *Lateral slide,* capable of being locked in position on the main slide with a quick-release clamp, so that the mounting frame can be slid along the lateral slide without displacement of the lateral slide on the main slide. Adjustable stops are provided on the lateral slide to permit the mounting frame to be brought rapidly and precisely to definite positions.

D.1.3.3 *Main slide,* to enable the mounted instruments to be moved perpendicular to the plane of the panel through a distance of approximately 50 mm to 900 mm from it so as to cover a reasonable range of irradiance. A scale and pointer are provided to indicate the location in either direction of traverse.

D.1.3.4 *Supporting frame,* rigidly mounted in relation to the radiant panel so that the radiant panel is centrally situated above the width of the supporting frame and facing along its length, and the centre of the radiant panel is at approximately the same height as the centre of the receiver of a radiometer when mounted in its clamp for testing purposes.

D.1.3.5 *Removable positioning device,* (see Figure 3) which allows accurate positioning of the radiometers and is fixed to the supporting frame. This is designed to enable a radiometer to be precisely located without the possibility of its receiver being touched.

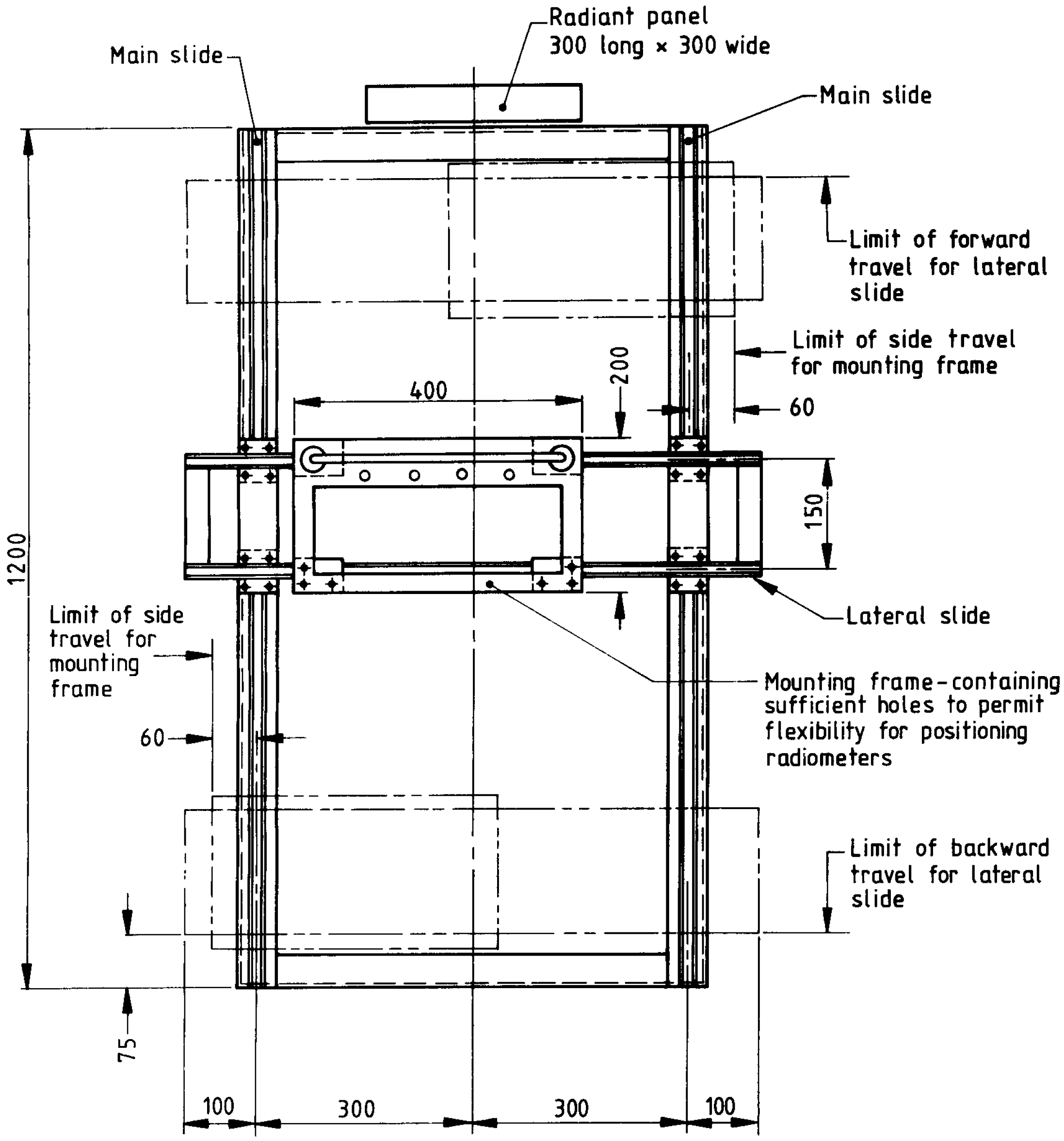
D.2 Mounting procedure

Place the positioning device in position and lock it firmly. Move the mounting frame towards the radiant panel until the secondary-standard radiometer is close to the positioning device. Adjust the angular position of the radiometer, both horizontally and if necessary vertically, until its receiver is essentially parallel to the plane of the positioning device. Adjust the radiometer until the centre of the receiver is at the same height as the centre of the positioning device. Clamp the lateral slide to the main slide. Adjust the lateral position of the radiometer until the centre of the receiver is exactly opposite the centre of the positioning device. Use a spacer or feeler gauge, if necessary, to gauge accurately the distance between the face of the radiometer and the positioning device. Take care not to touch the receiver with the spacer. Clamp a stop on the lateral slide in place so that the mounting frame can subsequently be returned precisely to this position.

Move the mounting frame laterally, without disturbing the position of the lateral slide on the main slide, until the radiometer to be calibrated is opposite the positioning device. Adjust its angular, vertical, lateral and forward/ backward position using the spacer or feeler gauge as used for the secondary radiometer, until it is precisely lined up.

Clamp a stop on the lateral slide in place so that the mounting frame can subsequently be returned precisely to this position.

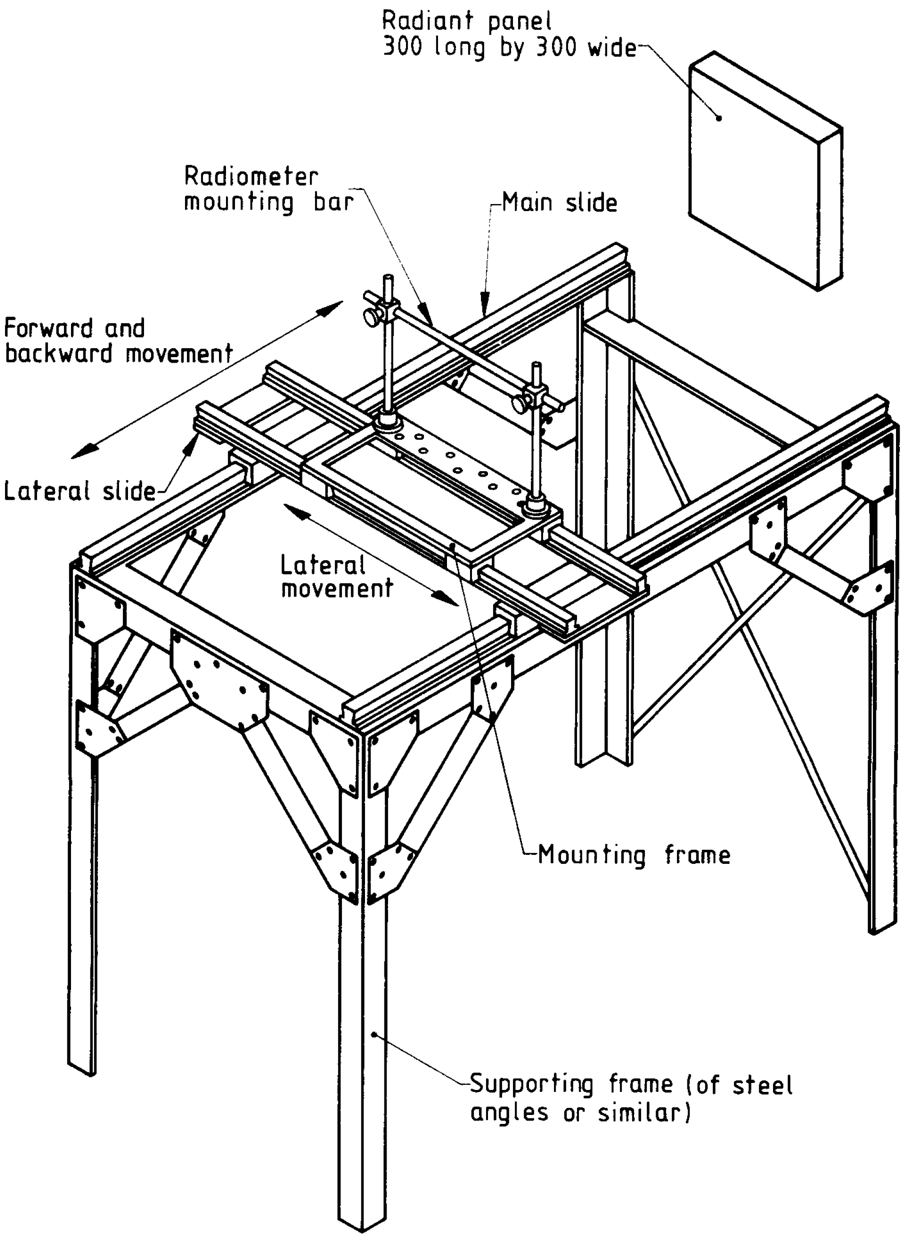
NOTE As far as possible, the radiometers should be screened from radiation except during actual readings.



All dimensions are in millimetres.

NOTE End stops should be provided on the main slide and the lateral slide. Those on the lateral slide should be adjustable.

Figure 1 — Plan of track arrangement for calibration of radiometers showing extent of parallel and perpendicular travel



All dimensions are in millimetres.

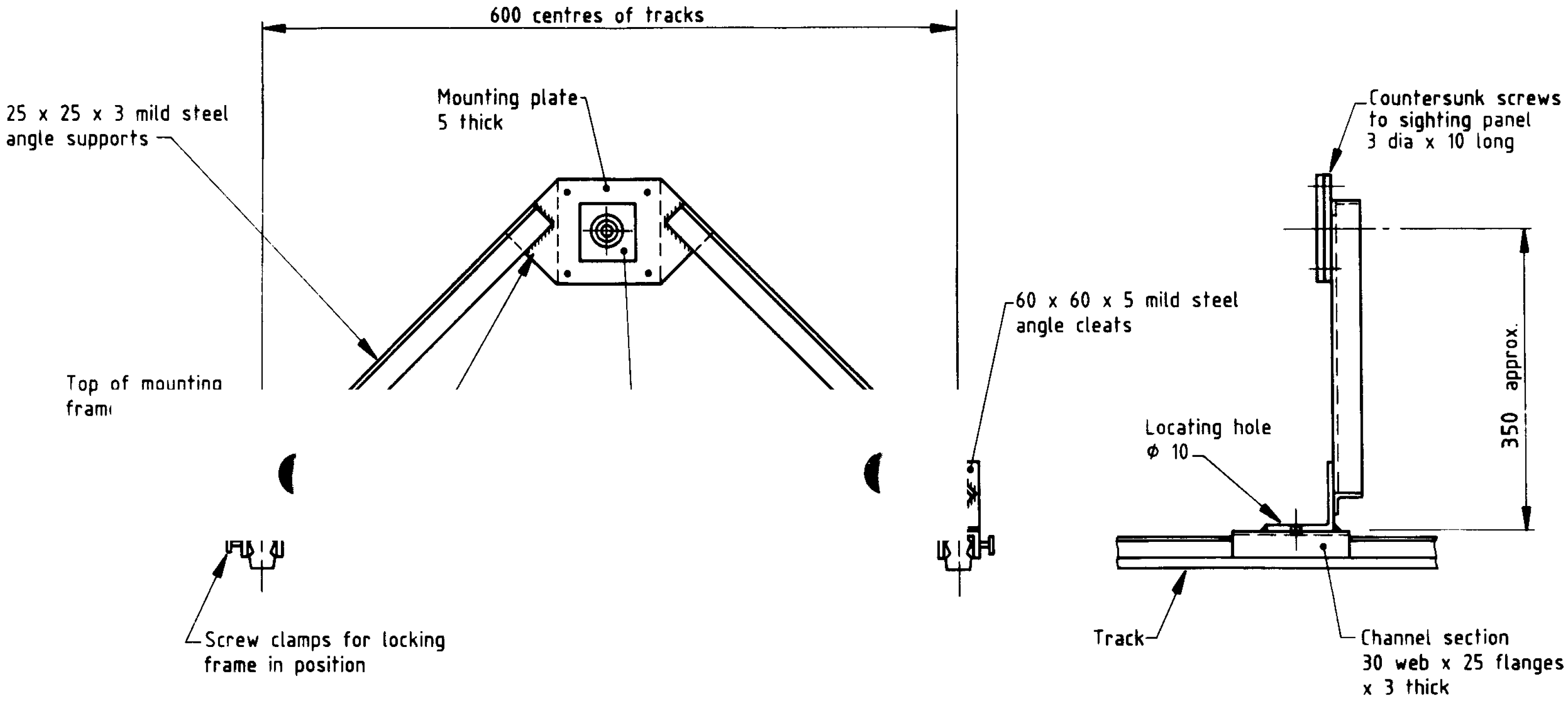
NOTE 1 The bearings and trackway on both the main and the lateral slide should be constructed of hardwearing, corrosion-resistant and heat-resistant material. (The types shown are patented encapsulated bearings, with a steel ball cage, running on cold drawn trackways.)

NOTE 2 Fine control of movement on both slides should be achieved by using a screw-type adjustment mechanism, if required.

NOTE 3 The runners on the main slide should be clamped in position with screw clamps when the lateral slide is being used.

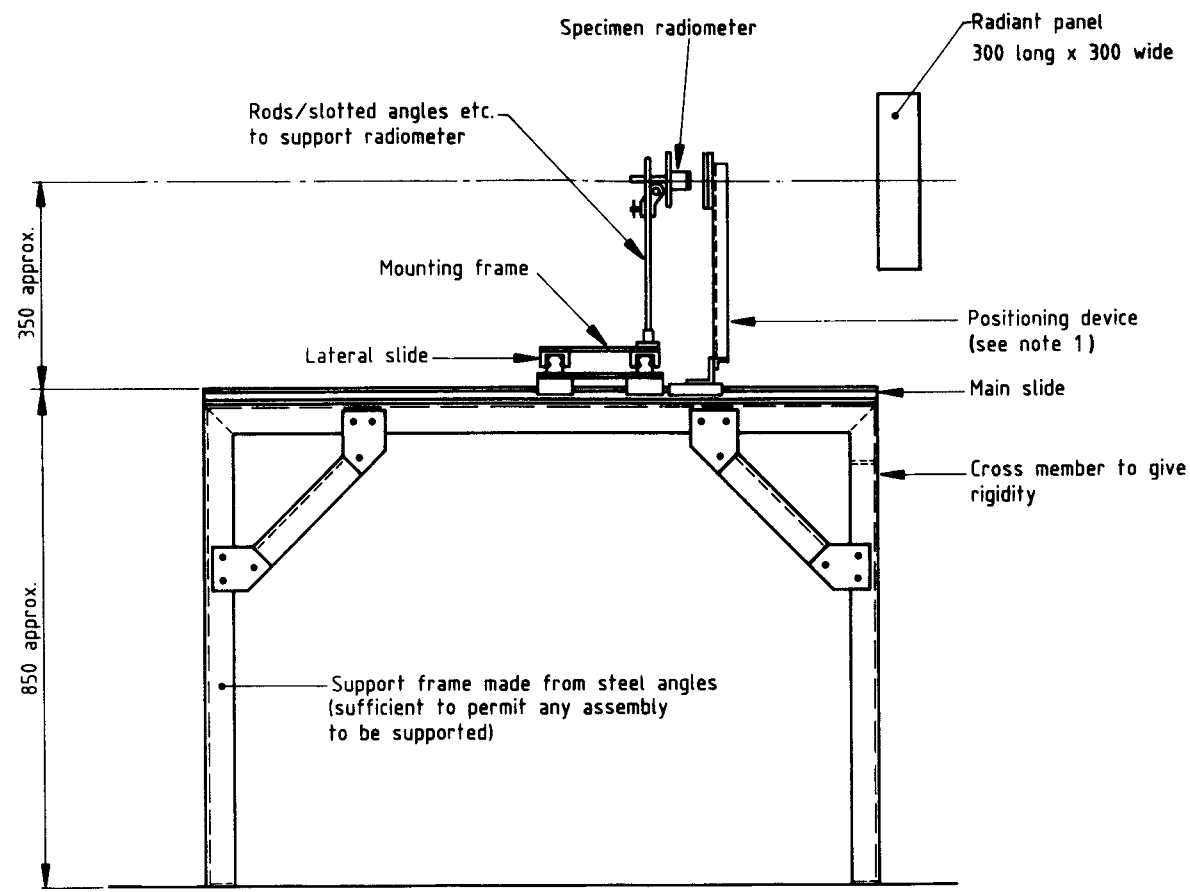
NOTE 4 The mounting frame should be coated with a heat-resistant matt black finish.

Figure 2 — Isometric view showing arrangement of radiometer mounting assembly



All dimensions are in millimetres.

Figure 3 — Detail of positioning device for radiometers



All dimensions are in millimetres.

NOTE 1 The positioning device is so constructed as to fit on the main slide trackways and be fixed in position using the screw clamps in the feet of the device.

NOTE 2 An adequate stock of rods, angles, clamps, etc. should be available to facilitate mounting a wide range of radiometers. All mounting components should be coated with a heat-resistant matt black finish.

Figure 4 — Side elevation of apparatus showing method of positioning radiometers

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

E.1 This appendix 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 radiometers which are reserved entirely for calibration and intercomparison 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 matter, the maintenance of calibration of secondary-standard instruments is generally more straightforward.

E.2 The first step is to designate *three* radiometers (A, B, C) as secondary-standard instruments to be reserved henceforth solely for calibration work, these will usually be commercially available foil heat-flux meters. These may either be new instruments purchased specially, or instruments which have seen some use in the test laboratory but have not been abused. In some cases records of calibration may indicate certain instruments as having a stable sensitivity over a period of years and such instruments would be 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.

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

E.4 A should be compared with B and also with C using the apparatus and methods described in this standard but using in each case about 20 data pairs, for enhanced statistical accuracy. To simplify 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 intercomparisons can be averaged and expressed in single values, i.e.:

$$R_{AB(0)} = \frac{\text{Mean output of A}}{\text{Mean output of B}}$$

$$= \frac{\text{Sensitivity of A}}{\text{Sensitivity of B}}$$

Similarly for A and C

For instruments whose output is not accurately proportional to irradiance, the comparisons could be made using some other parameter, e.g. output for a given irradiance, for example 25 kW/m^2, obtained by some averaging, regression or curve-fitting process.

E.5 All three instruments should then be calibrated at a standardizing laboratory maintaining a primary standard of irradiance, the laboratory should be informed of the purpose of the calibration. The instruments should preferably be transported by hand but if sent by post should be very well packed with resilient foam to cushion them against shocks in transit. The sensitivities obtained are denoted as S_A, S_B, S_C.

E.6 Intercomparisons of A with B and with C should be carried out as soon as the instruments are received back at the test laboratory ($R_{AB(1)}$, $R_{AC(1)}$).

E.7 The data obtained in **E.5** and **E.6** above help to ensure that the calibrations for A, B and C applying when they have returned to the test laboratory are as reliable as possible and provide a base from which the continuing constancy of calibration of all three can be judged.

Agreement between $R_{AB(0)}$ and $R_{AB(1)}$ (and also between $R_{AC(0)}$ and $R_{AC(1)}$), i.e. before and after calibration in the standardizing laboratory, gives evidence that no significant changes in sensitivity have taken place at this time. Agreement between S_A/S_B and R_{AB} (and similarly between S_A/S_C and R_{AC}) helps to confirm the validity of the test laboratory's method.

E.8 For foil heat-flux meters, differences in ratios greater than 1.3 % should be regarded as statistically significant at about the 5 % level and hence requiring investigation, or at least closer monitoring. This value arises from combining errors due to positioning (coefficient of variation of 0.25 % assumed) with the error due to averaging of observations (coefficient of variation of 0.4 % assumed for 20 data pairs).

The standard error for the difference between two ratios of outputs or sensitivities is then:

$$2.5 \sqrt{(0.4^2 + 0.25^2)}$$

$$= 0.67 \%$$

Then differences of more than about 2 × 0.67 = 1.3 % will be statistically significant at the 5 % level.

This is a provisional value and should be revised as further data become available.

E.9 With this criterion to judge the significance of differences, the various ratios stated in **E.5** and **E.6** should be examined and compared with S_A/S_B, S_A/S_C. Agreement of all ratios is naturally satisfactory but if a significant difference is found, then the source of the difference will often be apparent, or at least shown as very likely, because the three instruments give two independent interrelationships.

For example with the following values:

$R_{AC(0)} = 0.912$ $R_{AB(0)} = 0.953$

$S_A/S_C = 0.920$ $S_A/S_B = 0.950$

$R_{AC(1)} = 0.915$ $R_{AB(1)} = 0.975$

$R_{AB(1)}$ is significantly different from the other ratios involving A and B, and since the ratios involving A and C are all in agreement, the likelihood is that there has been a change in the sensitivity of B after its calibration by the standardizing laboratory.

Serious differences in ratios would generally require further investigation. Statistically significant but small differences would generally only require careful monitoring. The accumulation of further ratios over a period of perhaps 6 months to a year might permit a decision to be made.

E.10 The test laboratory should now be in a position to make accurate calibrations of other radiometers. If no discrepancies have been found relating to A, then this instrument should be used as principal secondary standard and the calibration obtained by the standardizing laboratory (S) applied, if a significant discrepancy relating only to A has been found A then B and C should be chosen as principal secondary standard and intercompared to obtain $S_{BC(1)}$. Significant discrepancies involving possibly more than one instrument would require resolution before a reliable calibration of other radiometers could be made.

E.11 With A as principal secondary standard, B and C should be strictly reserved for future comparisons, and should preferably be locked away to prevent accidental misuse. At intervals, determined in part by the passage of time and in part by the volume of calibration work, A should be compared with B and C (using about 20 data pairs). As a rough guide it is suggested that the inter-comparison is required after 25 calibrations, or 6 months with fewer calibrations. However, if calibrations are very infrequent, the intercomparison of A with B and C could be left until a calibration was required.

E.12 At this intercomparison, ratios $R_{AB(2)}$ and $R_{AC(2)}$ are obtained which enable a new value for the sensitivity of A to be derived, on the assumption that B and C have remained stable and only A has varied.

Estimates of the current sensitivity of A are given by:

$$S_A \times \frac{R_{AB(2)}}{R_{AB(1)}}$$

$$S_A \times \frac{R_{AC(2)}}{R_{AC(1)}}$$

and if these two estimates are not significantly different (i.e. do not differ by more than 1.3 %), then the mean of the two values is the appropriate value to use for calibrations until the next intercomparison is made. If the estimates differ significantly from each other, further investigation is required to see where the discrepancy lies, and what should be taken for the sensitivity of A.

It should however be noted that a small but acceptable drift in real sensitivity of A can cause both estimates of sensitivity to be significantly greater or less than the previous value. This may be acceptable, although the drift should not exceed, for example, 1.5 % otherwise the calibrations made will have been unnecessarily inaccurate.

E.13 The process of the use of A as principal working standard with periodic intercomparison of A with B and C may continue along the lines detailed in **E.11** and **E.12**. Only if significant or unacceptably large discrepancies are found need the procedure be varied and more frequent monitoring, assignment of different instruments as standards, recalibration at the standardizing laboratory, etc. be made.

E.14 As an overall check on the validity of the procedure it is recommended that one of the instruments A, B or C be recalibrated at the standardizing laboratory every year, with intercomparisons before and after this at the test laboratory.

E.15 Continuity and a methodical approach are essential in long-term work of this kind. It is highly desirable that the work should be assigned to one reliable person and it is essential that he or she should keep full, accurate and detailed records.

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Publication referred to

J. Sci. inst., **40**, pp 216 – 220, May 1963, Simms, D.L. & Hinkley, P.L. *An absolute radiometer for the range 0.1 – 2.5 cal* cm^{-2} sec^{-1} *(0.4 – 10 W* cm^{-2}*)*[1].

[1] Referred to in the foreword only.

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