
British Standard Methods for Determining thermal insulating properties

Part 3. Tests for thermal transmittance and conductance

Section 3.1 Guarded hot-box method

Méthodes de détermination des propriétés d'isolation thermique
Partie 3. Essais de la transmittance et de la conductance thermiques
Section 3.1 Méthode de la boîte chaude gardée

Verfahren zur Bestimmung der wärmedämmenden Eigenschaften
Teil 3. Prüfung des Wärmedurchgangs und der Wärmeleitfähigkeit
Abschnitt 3.1 Verfahren mit Wärmeschrank

Foreword

This Section of BS 874 was prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee.

Previous editions of BS 874 summarized the methods available for determining thermal insulating properties, and indicated which methods were applicable to various materials intended for use in a variety of temperature ranges, but the methods themselves were not defined in detail.

The growing importance of energy conservation and the need to have reliable information about the insulating properties of materials requires detailed specifications of the test methods. Accordingly, a complete revision of the standard is being undertaken, with each test method being fully specified. The full revision of BS 874 will take several years to complete, and it has therefore been decided to issue each test method as a separate Section of BS 874 as and when it is completed, thus gradually replacing the 1973 edition.

The method presented in this Section replaces those given in 4.3 of BS 874 : 1973, which have been deleted by amendment. Equipment of the type now described has been in existence for some time but, until recently, was uncommon in the UK. Nevertheless, the current state of development of the method enables it to be incorporated into the present revision of BS 874.

It should be appreciated that experience in the use of the method is limited. This is especially true for constructions which have local variations of thermal conductance within the test area and spanning the boundary between the metering and guard areas, such as composite masonry elements. Further research on such elements is continuing in order to quantify the effects of these variations of thermal conductance on the accuracy of measurement. Revision of this Section may become necessary as more experience is gained in the use of the method.

The accuracy levels and the reproducibility which may be expected from the method are not well established. Precision experiments, of the type described in BS 5497 : Part 1 : 1979, are necessary before reliable estimates for these can be given.

It is recommended that this Section of BS 874 be read in conjunction with BS 874 : Part 1.

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

Contents

	Page
Foreword	Inside front cover
Committees responsible	Back cover
Method	
0 Introduction	2
1 Scope	2
2 Definitions	2
3 Principle	2
4 Apparatus	3
5 Test elements	7
6 Test procedure	8
7 Expression of results	8
8 Test report	8
Appendices	
A The use of a hot-box apparatus to determine the heat transfer coefficient of a test element smaller than the metering area	10
B Heat transfer at surfaces	13
C Control of the guard space environment	15
Figures	
1 Sketch of a guarded hot-box apparatus	16
2 Example of placement of thermocouples for assessment of surface temperature	17
3 Thermopile connections	18
4 Temperature measuring positions on each side of the metering area of the test element	19

Method

0 Introduction

The method described in this Section is intended for tests on large building elements such as parts or sections of walls, roofs, floors, etc., where the thermal properties may not be uniform due to the method of fabrication and the materials used.

A slightly modified procedure, given in appendix A, enables tests to be made on smaller elements such as window systems.

The design and construction of an apparatus suitable for application of the method is a complex subject and needs to be based on sound scientific principles. This Section gives guidelines for apparatus design and the minimum criteria that need to be followed in this respect.

It is important that users of this method are fully conversant with the principles of heat flow and with precise measurement techniques. All instruments used in this method are required to be traceable to the National Physical Laboratory (NPL) or to a laboratory acceptable to the NPL.

1 Scope

This Section of BS 874 describes a method for determining the steady-state thermal transmittance and thermal conductance of construction elements using the guarded hot-box apparatus.

The method is suitable for construction elements with thermal transmittances and conductances in the range $0.1 \text{ W}/(\text{m}^2 \cdot \text{K})$ to $15 \text{ W}/(\text{m}^2 \cdot \text{K})$ for testing within a temperature range of -50°C to 50°C .

Apparatus designed in accordance with this standard is capable of measurement to an accuracy of $\pm 5\%$ on test elements of uniform thermal conductance (i.e. elements with no thermal bridges between surfaces) in the conductance range $0.5 \text{ W}/(\text{m}^2 \cdot \text{K})$ to $5 \text{ W}/(\text{m}^2 \cdot \text{K})$. Present information suggests that the repeatability of the measurements is within 2% . No data are available at present on the reproducibility of the method.

NOTE 1. The determination of thermal transmittances or conductances below $0.5 \text{ W}/(\text{m}^2 \cdot \text{K})$ requires measurements of high precision, and therefore may be less accurate. Thermal transmittances or conductances in the range above $5 \text{ W}/(\text{m}^2 \cdot \text{K})$ may also be less accurate as there may be higher surface temperature variations and difficulties with measurement of representative surface temperatures. In addition, greater inaccuracies are to be expected for test elements of non-uniform conductance (i.e. elements with thermal bridges between surfaces).

Some building elements may pose difficult problems of measurement and careful consideration is required before a test method is chosen. For example, elements with projections or with thick metal faces could cause difficulties in the conventional guarded hot-box configuration, as could test elements smaller than the test area. In such circumstances consideration should be given to testing in accordance with appendix A of this Section or to the use of the calibrated hot-box (see BS 874 : Section 3.2*).

Thermal conductance measurements are not appropriate on test elements of particularly non-uniform construction (see clause 7).

The apparatus is not designed for measurements where there is transport of air through the test element during the test.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purpose of this Section of BS 874, the definitions given in BS 874 : Part 1 apply.

3 Principle

The basis of the method is the measurement, at equilibrium, of the heat flux through the test element and the corresponding temperature difference(s) across it. The apparatus is shown schematically in figure 1 and consists of three principal items; a metering box, a guard box and a cold box. The test element is placed between the cold box and the guarded metering box. The test area is as defined in 4.2. Heat supplied to the metering box passes through the test element to the cold box, which is controlled at a constant low temperature. The environment in the space between the metering box and guard box is controlled so as to ensure that, as far as possible, the total heat supplied to the metering box passes through the test element in a direction normal to its faces, by minimizing both the heat flow through the sides and back of the metering box and also lateral heat transfer in the test element at the metering box periphery (see 4.3.1).

Heat may be supplied to the metering box at a constant rate, in which case the apparatus slowly reaches the desired equilibrium condition.

Alternatively, the temperature in the metering box may be kept constant by suitable control of the heat input.

When thermal equilibrium is achieved, i.e. when the temperature on either face of the test element and the heat flow through it are constant, then the final measurements are taken.

Heat exchange at the hot and cold surfaces of the test element involves both convective and radiant components. The former depends upon air temperature and air speed and the latter depends upon the temperatures and the emissivity of surfaces 'seen' by the element surface. The effects of the heat transfer by convection and radiation are conveniently combined in the concept of an 'environmental temperature' and a surface coefficient. Thermal transmittance is defined between two environmental temperatures and therefore suitable temperature measurements are required to enable these to be determined (see appendix B). This is particularly important with test elements of low thermal resistance for which the surface resistances form a significant fraction of the total resistance.

* In preparation.

Strictly, the thermal conductance of a building element is a meaningful term only if its faces are isothermal. However, if the test element is sufficiently uniform it is acceptable to take area-weighted surface temperatures for the calculation of thermal conductance even though small temperature variations are present. If the thermal properties of the test element are sufficiently non-uniform to produce significant surface temperature variations, then the attribution of a thermal conductance to the element is to be avoided (see clause 7).

Errors will arise if the heat flux through the test element is non-uniform in the region of the perimeter of the metering box, since there will be a component of heat flow parallel to the surface of the test element either towards or away from the metering box. To minimize this, the distance between the metering box and the guard box has to be sufficiently wide and the surface temperatures of the test element in the metering box have to be closely matched with the corresponding surface temperatures in the guard space. These requirements also impose constraints upon the width of the metering box perimeter seal and upon the dimensions of the cold box relative to the guard box.

Normally the test element will cover the open faces of the metering and guard boxes but in some cases, in particular for the testing of window units, the test element may be smaller than the area defined by the perimeter of the metering box. For this the test element is surrounded by a panel of known thermal properties, enabling the heat flow through the test element to be deduced from the total heat input. The necessary adaptations to the method for measurements on small test elements are described in appendix A.

4 Apparatus

4.1 General

The test apparatus shall comprise the various components shown schematically in figure 1, together with the necessary instrumentation to control and measure the rate of heat flow through the test element and the temperatures on either face of it.

When designing the apparatus, the required heating and cooling capacities shall be determined having regard to:

- (a) the range of thermal transmittances for which the apparatus is designed;
- (b) the construction of the various boxes;
- (c) the range of laboratory temperatures likely to be encountered during tests.

All instruments used in this method shall be traceable to the National Physical Laboratory or to a laboratory acceptable to the NPL.

NOTE. The apparatus may be designed either for manual operation or for automatic control. However, it is strongly recommended that automatic control of the guard and cold space temperatures is installed, so that the power inputs to these spaces will be automatically adjusted for fluctuations in the temperature of the laboratory environment.

4.2 Metering box

The metering box is normally of square or rectangular cross section. The one open side shall be provided with a perimeter seal so that, when the metering box is pressed against the test element by a suitable loading system, air flow between the metering box and the guard box is prevented. The linear dimensions of the test area shall be at least 1 m and not less than three times the maximum thickness of any test element.

The following, taken together, are considered to be sufficient to ensure that any uncertainty in the definition of test area will not exceed $\pm 1\%$, but alternative methods of achieving this degree of uncertainty are acceptable.

- (a) To avoid significant contact and shielding effects on the test element caused by the perimeter seal and the edges of the walls of the metering box, neither the contact width of the seal nor the thickness of the wall edges adjacent to the seal shall exceed 2 % of the smaller linear dimension of the test area.
- (b) Where necessary, the walls of the metering box shall be tapered from their full thickness down to the width of the seal, or nearly so, to achieve the thickness specified in (a). Any such tapering shall be applied over a distance from the seal of at least one full thickness of the metering box walls.
- (c) The test area normally shall be defined by the centre-line of the perimeter seal. However, if the thickness of the test element is less than the contact width of the seal, the test area shall be taken as the average of those areas defined by the centre-line and the inside edge of the perimeter seal.

Representative hot face temperature measurement for the test element shall be taken at least 100 mm from the projected edge of the inside of the walls of the metering box, e.g. see figure 2.

NOTE 1. When designing apparatus, consideration should be given to typical module sizes of test elements (see 5.1). The depth of the metering box is governed by the practical constraints of its construction and the equipment it is to house, but it should be kept as small as possible without sacrificing uniform air distribution in order to minimize the surface area, and thereby limit heat transfer to and from the guard space.

The walls of the metering box shall be sufficiently well insulated to ensure that any heat flux through the sides and back of the box is small compared with that through the test element.

NOTE 2. A minimum thermal resistance of the walls of $1.0 \text{ m}^2 \cdot \text{K/W}$ is recommended.

NOTE 3. A sandwich construction of two metal or plywood skins with insulating material between them has been found satisfactory for the walls of the metering box.

If transmittance measurements are being made, a baffle shall be fixed in the metering box, parallel to the surface of the test element, in order to provide a radiating surface of near uniform temperature.

NOTE 4. It is recommended that a baffle be fixed in the metering box for all measurements, in order to assist in producing uniform air velocities and temperature distributions.

When testing vertical construction elements, the baffle shall extend the full width of the metering box and shall have

gaps at the top and bottom to allow air circulation unless the specific test conditions require otherwise.

NOTE 5. When testing vertical construction elements the baffle can assist in providing a laminar air stream over the surface, and its distance from the test element can give a measure of control of the vertical temperature gradient in the air stream. The magnitude of this gradient will depend on the air speed, on the distance between the baffle and the surface of the test element and on the conductance of the element. It is recommended that the temperature gradient in the air stream should not exceed 1 K/m for test elements of thermal transmittance up to 1 W/(m²·K) and a maximum of 2 K/m for elements of higher transmittance. The temperature gradient can be altered by suitable combination of air speed and baffle position. It should be noted that the air speed will influence the convective coefficient and thus only limited adjustment of air velocity may be possible. If desired, circulating fans may be installed in the metering box to assist natural convection if it is required to achieve particular values of the convective coefficient that cannot be obtained using natural convection alone. In this case means should be provided to measure the air speed across the test element surface.

When testing horizontal construction elements, the baffle shall extend the full width of the metering box; the presence of gaps at either end depends upon the exact test conditions desired.

NOTE 6. When testing horizontal construction elements, the use of a horizontal baffle in the metering box can assist in achieving the desired boundary conditions. It may, for example, be used in conjunction with fans to produce an air stream across the face of the test element. Alternatively, it may be moved further away from the test element, so that natural convection currents are established. In this latter case the baffle could, if required, be extended at each end to close any gaps.

Where conditions of natural convection in the metering box are required, the distance between the baffle and the test element shall be not less than 150 mm.

Where higher air speeds are imposed across the face of the test element, for example by fans, it is permitted gradually to reduce the distance between the baffle and the test element, to assist the control of air velocity and air temperature gradient to a minimum of 40 mm at an air velocity of 3 m/s or greater.

NOTE 7. It is important to ensure that air temperature sensors are placed outside the boundary layer associated with each surface. See 4.5.3.

If the fans and their motors are installed inside the metering box then their power consumption shall be measured (taking account of any phase angle) and added to that supplied by the heater. If only the fan blades are inside the metering box, then the heat contribution of the blades shall be determined, possibly from measurements of the apparent change in conductance of a suitable test element with and without fans in use.

All surfaces in the metering box that can radiate to the surface of the test element shall be of matt black finish, and shall have an emissivity of at least 0.9.

A low temperature, extended source heater shall be installed in the metering box behind the baffle and so shielded that it does not radiate directly to the surface of the test element nor produce local hot-spots on the baffle.

NOTE 8. Resistance wire has been found satisfactory for the construction of the heater.

The power consumption of the heater shall be measured to an accuracy of $\pm 0.25\%$. The total uncertainty in the

determination of the net power input into the metering box due to the heater, fans, power loss in the leads and heat transfer through the sides and back walls shall not exceed $\pm 1.0\%$.

4.3 Guard box and guard system

4.3.1 General. The following two important conditions shall be satisfied if the guarded hot-box apparatus is to yield accurate results.

- (a) The heat flux into the surface of the test element from the metering box shall be determined accurately.
- (b) This heat flux shall be along paths which are generally perpendicular to the plane of the test element, so that any lateral heat transfer, particularly in the region of the metering box perimeter seal, is very small.

The following clauses (4.3.2 to 4.3.6) contain requirements and recommendations to ensure that these conditions can be met.

4.3.2 Limitation of heat transfer through the sides and back of the metering box. In order to ensure that the heat flux through the test element is accurately known, heat transfer through the sides and back of the metering box shall be measured and a correction made. This correction shall be restricted to less than 10 % of the total power supplied to the metering box by suitably controlling the environment in the guard space, so that the temperature gradient across the thickness of the walls of the metering box is sufficiently small.

One method of measuring the heat flow through the sides and back of the metering box is to install a thermopile to measure the average temperature difference between the inner and outer surfaces of the metering box (see figure 3(a)). There shall be a sufficient number of thermocouples in the thermopile to ensure that the heat flow can be estimated with sufficient accuracy to meet the necessary criterion for the net power input specified in 4.2.

NOTE 1. As a guide, there should be at least one differential pair of junctions for each 0.25 m² of metering box surface area.

NOTE 2. The product of the average temperature gradient across the metering box walls, obtained from the thermopile, and the heat exchange coefficient for the metering box provides an estimate of the correction to be applied. The heat exchange coefficient for the metering box may be calculated from its dimensions and the known thermal conductivities of its constituent materials, or by direct measurement, possibly in the apparatus itself. A reasonable estimate of the effective area of the sides and back of the metering box is obtained by taking an average of their internal and external areas.

4.3.3 Guarding the metered area of the test element against the effects of the laboratory environment. In order to minimize the effects of changes in the laboratory environment on the test element in the metering area, there shall be an adequate width of guard space, as follows.

The width of the guard space required (measured between the outside of the metering box walls and the inside of the guard box walls) is dependent upon the thickness of the test element and upon the insulation, if any, around the outer edges of the test element. If the outer edges of the test specimen are insulated with material of thermal resistance of at least 1 m²·K/W, then the guard space shall be at least as wide as the thickness of the test element.

If the edges of the test element are uninsulated then the guard space width shall be at least 1.5 times the thickness of the test element. In no case, however, shall any part of the guard space be less than 150 mm wide. These requirements are based upon the assumption that during a test the laboratory temperature is always between the metering box and cold box temperatures. If this is not so then additional insulation of thermal resistance of at least $1 \text{ m}^2 \cdot \text{K/W}$ shall be required on the edges of the test element.

4.3.4 Restriction of the temperature gradient across the metering box perimeter seal on the surface of the test element. It will usually be impracticable to correct the lateral heat flow in the test element caused by surface temperature differences in the metering and guard box areas. Consequently, it shall be ensured that such surface temperature differences are kept within certain limits by careful control of the guard space environment, as follows.

NOTE 1. It should be emphasized that what is trying to be achieved here is the limitation of any consistent bias in temperature between one side of the perimeter seal and the other, and not variations in temperature arising from differences in conductance from one part of a test element to another.

The average difference in surface temperature of the test element between each side of the perimeter seal shall be determined from pairs of measurements, taken at intervals not exceeding 500 mm around the seal. Where possible, each pair of surface temperature measurements shall be made at points where similar thermal conductances occur, taking due account of the effects of local changes in these (if known) on local surface temperature variations. In order to be outside the influence of the metering box walls, the measurements shall be made approximately 50 mm from the projected intersections of the surfaces of the metering box walls (ignoring any tapered portion) with the test element (see figure 3(b)). This distance shall, if necessary, be increased from 50 mm to take account of local thermal conductance variations as described above. The average difference in temperature so determined shall not exceed 0.5 K.

NOTE 2. The limit of 0.5 K is more difficult to achieve on non-uniform test elements, and the temperatures are more difficult to measure reliably. If the test element is such that the design limits of the apparatus are approached or, particularly, if a low conductance test element is faced on the side in contact with the metering box with highly conducting material, then this limit of 0.5 K may be too wide. In these circumstances a lower limit of 0.15 K is desirable.

NOTE 3. Information regarding the running conditions of the apparatus, obtained in tests on more uniform test elements of similar thermal conductance, may be used as a guide to setting environmental conditions in the guard box when testing non-uniform elements.

4.3.5 Control of the guard system (see appendix C).

A control system shall be installed in the guard space in order to achieve the requirements described in 4.3.2 and 4.3.4.

NOTE 1. It is usually not possible to operate the apparatus so that both the temperature differences across the metering box walls and on the surface of the test element between either side of the metering box perimeter seal are zero. Usually, the environment in the guard space will be controlled to provide the optimum compromise which satisfies the limits set out in 4.3.2 and 4.3.4 (see also C.2).

NOTE 2. Some form of automatic control of the guard space environment is an advantage, possibly using the signal from one or

other of the two thermopiles previously described to regulate the power supplied to the guard space.

4.3.6 General considerations for the design of the guard box. To achieve accurate results, particularly with non-homogeneous test elements, the environment in the guard space needs to be as similar as possible to that in the metering box. Therefore all internal surfaces in direct radiation exchange with the test element surface shall be matt black, and the heating and air circulation within the guard box shall be such as to ensure that air and radiant temperatures, temperature gradients and heat transfer coefficients are matched as closely as possible to those in the metering box.

NOTE 1. Insulation of the guard box walls is advantageous. It reduces heat exchange by radiation between the outer surfaces of the metering box and the inner surfaces of the guard box, by making the two surface temperatures closer to one another. However, if the guard box is insulated it may be necessary to install means of cooling, as well as heating, within the guard space, so that satisfactory control can be achieved. If the design of the apparatus is such that the guard box temperature is always intended to be above the laboratory temperature, then cooling can be readily achieved by controlled mixing of air from the laboratory with air from the guard space.

There shall be an air-tight seal between the guard box and the surface of the test element.

NOTE 2. Compressible foam rubber in conjunction with a clamping device has been found satisfactory for use as an air-tight seal.

4.4 Cold box

The cold box provides a controlled environment at constant low temperature and is usually insulated to reduce the load on the cooling system. Temperature control shall be achieved using a heat exchanger and a cooled circulating medium such as water or air, controlled by a suitable combination of continuous cooling and intermittent heating. The height and width of the cold box shall be not less than the corresponding dimensions of the guard box.

If thermal transmittance measurements are being made then a baffle shall be installed in the cold box, the design criteria being the same as those already described for the metering box (see 4.2). In cases where it is required to assess the performance of a particular structural form, it is permissible for the design of the baffle to be chosen to reflect that form: in that case the details of the baffle design shall be included in the test report. Where higher surface coefficients are required in the cold box, as in the case of the simulation of outside conditions on test elements, this shall be achieved by higher air velocities over the face of the test element. The direction of any forced air flow should, where possible, be such as to supplement natural convection (i.e. upwards for vertical test elements). Means shall be provided for measuring the velocity of the air stream.

NOTE 3. It is recommended that the temperature gradient in the air stream over the face of the test element should not exceed 1 K/m for test elements of thermal transmittance up to $1 \text{ W/(m}^2 \cdot \text{K)}$ and 2 K/m for elements of higher transmittance.

Direct radiation exchange between any cooling element in the cold box and the surface of the test element shall be prevented by suitable shielding. If the cold box is to be operated at temperatures approaching or below 0°C then consideration shall be given to potential problems of condensation and icing.

All surfaces in the cold box which can radiate to the surface of the test element shall be of matt black finish, and shall have an emissivity of at least 0.9.

An air-tight compressible seal shall be fitted between the cold box and the test element.

4.5 Temperature measurement equipment

4.5.1 General. For the measurement of thermal conductance, the mean surface temperature over the metering area on each face of the test element is required. Measurement of thermal transmittance requires that air and mean radiant temperatures are measured in the hot and cold boxes, so that the two environmental temperatures may be calculated (see appendix B).

Thermocouples generally will be the most commonly used thermometers for this test method (see clause 6 of BS 874 : Part 1 : 1986 for more detailed discussion) but the use of other suitable thermometers is not excluded.

Thermocouples shall be made from a stock of calibrated wire or wire which has been certified by the supplier to comply with BS 4937 to a tolerance of $\pm 0.4\%$, otherwise individual thermocouple calibration shall be required. A potentiometer or digital voltmeter with a resolution of $1\text{ }\mu\text{V}$ or better shall be used to measure the output from the thermocouples. The uncertainty in the measurement of temperature difference between the hot and cold faces of the test element at a point shall not exceed $\pm 1\%$ of the temperature difference. The uncertainty in the measurement of the voltage output from a thermopile shall not exceed $\pm 4\text{ }\mu\text{V}$.

4.5.2 Surface temperatures. Thermocouples made from wire not exceeding 0.25 mm in diameter shall be used for measuring surface temperatures to minimize heat conduction along the wires. Thermocouples shall be in intimate contact with the surface for at least 25 mm from their junctions. They shall be cemented or taped securely to the surface, following isothermals where possible.

A sufficient number of thermocouples shall be used to enable the mean surface temperature to be determined, as follows. For homogeneous test elements there shall be a minimum of nine on each face, uniformly distributed over the test area. For large test areas, this number shall be increased as necessary such that there is at least one thermocouple per 0.5 m^2 of test area. If the test element is non-homogeneous, then sufficient additional thermocouples shall be placed to provide representative temperatures for each discrete region of the element, the average surface temperature being determined on the basis of the proportionate areas of each region. Within each discrete region the variability of temperature shall be explored to determine the position of the thermocouples.

For the measurement of mean radiant temperatures of surfaces 'seen' by the test element in metering and cold boxes, there shall be a minimum of nine thermocouples, appropriately distributed on each surface to take account of its relative radiant influence on the test element.

4.5.3 Air temperatures. For the measurement of air temperatures in the metering and cold boxes there shall be a minimum of nine thermocouples in the air spaces on

each of the test elements, uniformly distributed in relation to the test area. For large test areas, this number shall be increased as necessary such that there is at least one thermocouple per 0.5 m^2 of adjacent test area.

Thermocouples shall be positioned outside the boundary layer associated with each surface. Where air movement is by natural convection, thermocouples shall be placed not closer than 75 mm to a surface. Where an air velocity is imposed it is permitted gradually to reduce this distance, but it shall not be less than 20 mm at an air velocity of 3 m/s or greater. Thermocouples shall be shielded from radiation if their junction diameter is greater than 1 mm.

4.6 Temperature stability of the apparatus

When equilibrium has been reached, any fluctuations in the average air temperature on the hot and cold sides of the metering area shall not exceed 1 % of the air-to-air temperature difference between hot and cold over a period of at least 8 h.

4.7 Performance checking and validation of apparatus

After construction of an apparatus the following performance checks shall be carried out in order to establish its satisfactory operation and to provide estimates of overall accuracy. Check:

- (a) that temperatures and temperature gradients are sufficiently uniform;
- (b) the uniformity of the surface temperature of the metering box walls to ensure that the number of thermocouples in the metering box is adequate;
- (c) that the heat flow and temperature difference across the test element for a given mean test element temperature are proportional to each other;
- (d) the effect of metering/guard box temperature imbalance;
- (e) that the level of laboratory temperature does not affect the result;
- (f) the effect of air velocities in the boxes;
- (g) the conditions required to minimize the temperature gradient on the surface of the test element across the metering box seal.

4.8 Verification procedures

Verification tests shall be carried out using test elements of uniform conductance. The conductances of the verification test elements shall be determined from the known thermal conductivities of the materials and shall cover as wide a range of conductances and thicknesses as possible. The thermal conductivities shall be determined using the guarded hot-plate apparatus as described in BS 874 : Section 2.1. This thermal conductivity apparatus shall be traceable to the NPL or to a laboratory acceptable to the NPL. Any differences between calculated and measured conductances shall be carefully investigated and corrective measures taken if necessary.

The accuracy assigned to measurements made using this apparatus shall take into account the results obtained during verification tests.