Methods of testing

Refractory materials —

Part 5: Refractory and thermal properties —

Section 5.5 Determination of thermal conductivity (panel/calorimeter method) (method 1902-505)

Confirmed
December 2009

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Committees responsible for this British Standard

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

British Ceramic Research Ltd.
British Steel Industry
Engineering Equipment and Materials Users' Association
Refractories Association of Great Britain
Refractory Contractors' Association
Society of Glass Technology

This British Standard, having been prepared under the direction of the Refractory Products Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 30 August 1991

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Contents

Foreword

This Section of BS 1902-5 has been prepared under the direction of the Refractory Products Standards Policy Committee. The method described in this Section is one of three methods for the determination of thermal conductivity included in BS 1902-5, as follows.

— *Section 5.5: Determination of thermal conductivity (panel/calorimeter method) (method 1902-505);*

— *Section 5.6: Determination of thermal conductivity (hot wire method) (method 1902-506);*

— *Section 5.8: Determination of thermal conductivity (split column method) (method 1902-508)*[1].

This Section of BS 1902 is a revision of the method previously included in BS 1902-1A:1966 (obsolescent), which is withdrawn.

NOTE This Section is to be read in conjunction with BS 1902-5.0 "*Introduction*" and BS 1902-3.1 "*Guidance on sampling*". Section 5.0 sets out the general arrangement of BS 1902 and lists the Sections of Part 5.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 10, 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] In preparation.

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1 Scope

This Section of BS 1902-5 describes the panel method for determining the thermal conductivity of dense shaped and shaped insulating refractory products by a continuous flow calorimeter method. The panel/calorimeter method may be used for preformed unshaped products and for ceramic fibre products.

NOTE 1 For details of the adaptations needed for ceramic fibre products, see BS 1902-6.

The panel/calorimeter method is intended for materials having a thermal conductivity in the range 0.5 W/(m·K) to 20 W/(m·K) and hot face temperatures in the range 300 °C to 1 400 °C. For thermal conductivities below 0.5 W/(m·K) see BS 1902-5.6.

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

2 Designation

The method of determining thermal conductivity by the panel/calorimeter method described in this Section is referred to by the designation:

Method 1902-505

3 Definition

For the purposes of this Section of BS 1902, the following definition applies.

thermal conductivity (coefficient of thermal conductivity), λ, (in W/(m·K))

the rate of linear heat flow, under steady state temperature conditions, through unit area of a test piece, per unit temperature gradient in a direction perpendicular to the area

4 Principle

The quantity of heat flow unidirectionally through a test panel, heated on one face under controlled temperature conditions, is measured using a continuous flow water calorimeter.

5 Apparatus

5.1 *General*

The apparatus consists of a furnace in which a system of heaters is used to induce a uniform, unidirectional heat flow through a test panel under stable temperature gradient conditions. A continuous flow water calorimeter with guard ring is used to measure the rate of flow of heat through the test panel.

5.2 *Furnace,* comprising a chamber, which accommodates a test panel 230 mm × 230 mm × 76 (or 64) mm deep, and a heater well nominally 214 mm × 214 mm × 58 mm deep formed from shaped insulating refractory (see Figure 1). The walls and floor of the heater well are formed of 25 mm thick insulating refractory, of class 150, complying with BS 7225-1.1. The walls of the heater well are lined with 8 mm thick, 50 mm deep alumino-silicate refractory plates (60 % to 65 % Al_2O_3) which stand on a 230 mm square, 8 mm thick base of the same material. The wall plates which act as a support for the test panel are pierced with 16 mm holes at 25 mm centres to accommodate the end of the main and side heater elements.

Behind the walls a narrow chamber, which accommodates the outer heater and lower peripheral heater, is formed on the inside from 8 mm thick alumino-silicate refractory (60 % to 65 % Al_2O_3) and on the outside from 25 mm thick insulating refractory of class 150, complying with BS 7225-1.1. The remainder of the brickwork surrounding the heater well and test panel chamber is made of insulating refractory of class 130, complying with BS 7225-1.1, with a final 76 mm thickness of lower temperature insulation, e.g. diatomite brick, to give overall furnace dimensions of 690 mm × 690 mm × 380 mm height. The furnace is encased in sheet metal, and supported in a steel frame, e.g. angle iron.

NOTE Alternate holes may be extended into vertical grooves to facilitate the removal of the heaters, as shown in Figure 2.

The upper and middle peripheral heaters and a supplementary heater, consisting of coiled electrical resistance wire (see **5.3**), are laid in grooves cut in the insulating refractory. The upper and middle peripheral heaters are positioned 12 mm and 38 mm below the top level of brickwork and 33 mm behind the wall of the test panel chamber on all four sides. The supplementary heater is 50 mm below the base of the heater well and laid in a continuous groove having the form of a parallel-sided spiral covering an area of approximately 310 mm × 310 mm.

5.3 *Heaters,* in which the elements of the main, side, outer and lower peripheral heaters are formed from platinum – 20 % rhodium wire, 0.5 mm in diameter, wound on recrystallized alumina tube with 12 mm outside diameter, 8 mm inside diameter (see Figure 1 and Figure 2). The six elements forming the main heater unit are wound with different spacing, being more closely wound at the edge of the unit than at the centre. The two end elements (1 and 6 in Figure 2) are wound with a 5 mm spacing, the next two inside elements (2 and 5 in Figure 2) are wound with a 5 mm spacing at the ends with a 7.5 mm spacing over the middle 114 mm and the two centre elements (3 and 4 in Figure 2) are wound with a 7.5 mm spacing over their full length. The elements of the side and outer heaters are wound with a spacing of 3.8 mm to 4.0 mm and those of the lower peripheral heaters with a spacing of 3.3 mm to 3.5 mm. The individual elements of the main, side, outer and lower peripheral heaters are connected in series and are thinly coated with high purity alumina cement to reduce volatilization of the platinum at high temperature.

The upper and middle peripheral heaters and the supplementary heater are each formed by coiling electrical resistance wire 1.6 mm in diameter on a steel former 4.5 mm in diameter. The two peripheral heaters are drawn out to 12 or 13 turns for 25 mm.

The gauge of wire, coil spacing and resistance data for all heaters is summarized in Table 1.

5.4 *Power supply and temperature control,* allowing each heater to be separately controllable. Various methods for achieving adequate control of heater output are available including variable resistance, variable transformers and integrated circuit power controllers. A suitable control system utilizes solid state, phase-controlled, a.c. mains power regulators switched between adjustable low and high power settings by a single temperature controller operating through one of the hot face thermocouples (see clause **6**). The basic circuit for an appropriate control system is shown in Figure 3.

5.5 *Calorimeter and guard ring,* made of brass and having dimensions as shown in Figure 4. The base, sides and partition walls of both components are made either by casting or by machining from solid brass. The outside surfaces of the sides and base and the tops of sides and partition walls are machine finished. The bases of both components are tested to confirm their flatness over their full area. The top covers, which carry the water inlet and outlet tubes are made from flat brass plate and are soldered to the base parts so that the sides and partition walls make water-tight joints with the cover. The dimensions of the calorimeter are 76 mm × 76 mm × 25 mm deep and of the guard ring are 230 mm × 230 mm × 25 mm deep. The two components are assembled so that a gap of 0.8 mm exists between their adjacent sidewalls.

To ensure that the base surfaces of the calorimeter and guard ring are co-planar and that the calorimeter remains centred in the guard ring, the two are placed on a levelling plate with thin card spacers maintaining the gap between them. Brass links are soldered between the two inlet tubes and similarly between the two outlet tubes so as to lock the calorimeter and guard ring together.

In order to calculate the thermal conductivity it is necessary to know the area through which the calorimeter receives heat from the test panel; this is that area represented by the calorimeter plus half the gap between the calorimeter and guard ring. The area is calculated either:

a) from direct measurements with vernier callipers to 0.05 mm; or

b) during construction of the calorimeter and guard ring assembly, by measuring the dimensions of the calorimeter and those of the aperture into which it fits and taking the average of the two areas thus obtained.

NOTE It is essential that provision is made for the calorimeter/guard ring assembly, all metal piping and the furnace frame and case to be electrically earthed in conformity with current Institute of Electrical Engineers (IEE) Regulations.

5.6 *Water supply,* to the calorimeter and guard ring from a brass manifold, 22 mm in diameter, via plastics feed tubes which are as short as possible. Similar plastics tubing is fitted to the outlets and incorporates valves for carrying the flow of water through the calorimeter and the guard ring. The outlet ends of the plastics tubes are terminated by jets made from glass tube. Water is fed to the inlet manifold from a constant head tank capable of supplying 100 L/h.

NOTE The temperature of the water should be maintained constant and 0.5 K to 2 K below the ambient temperature.

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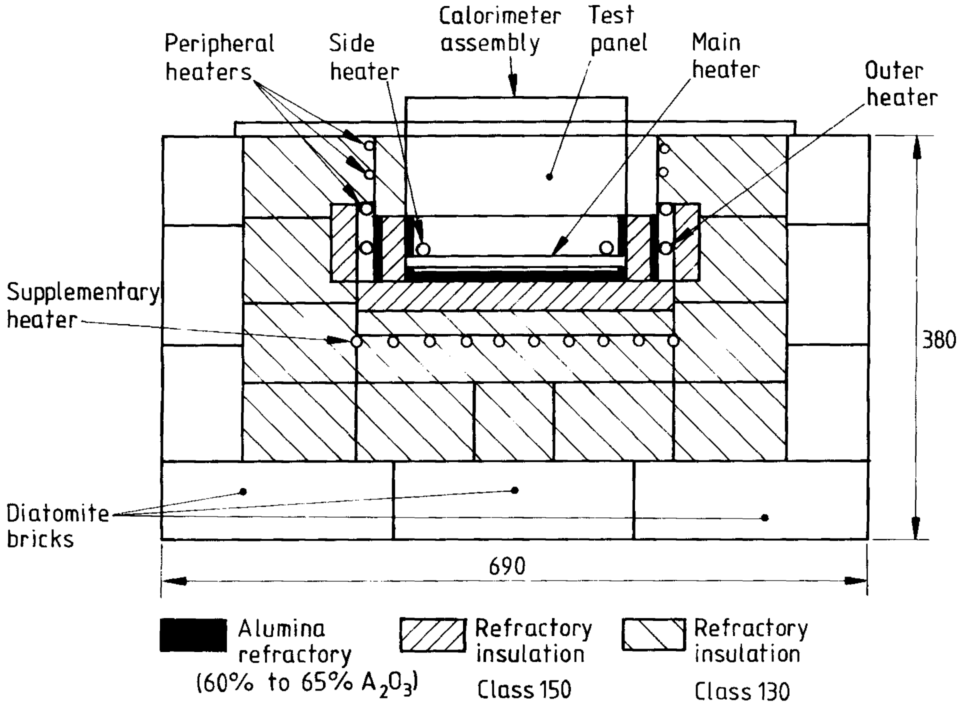


All dimensions are in millimetres.

Figure 1 — Vertical section through thermal conductivity apparatus

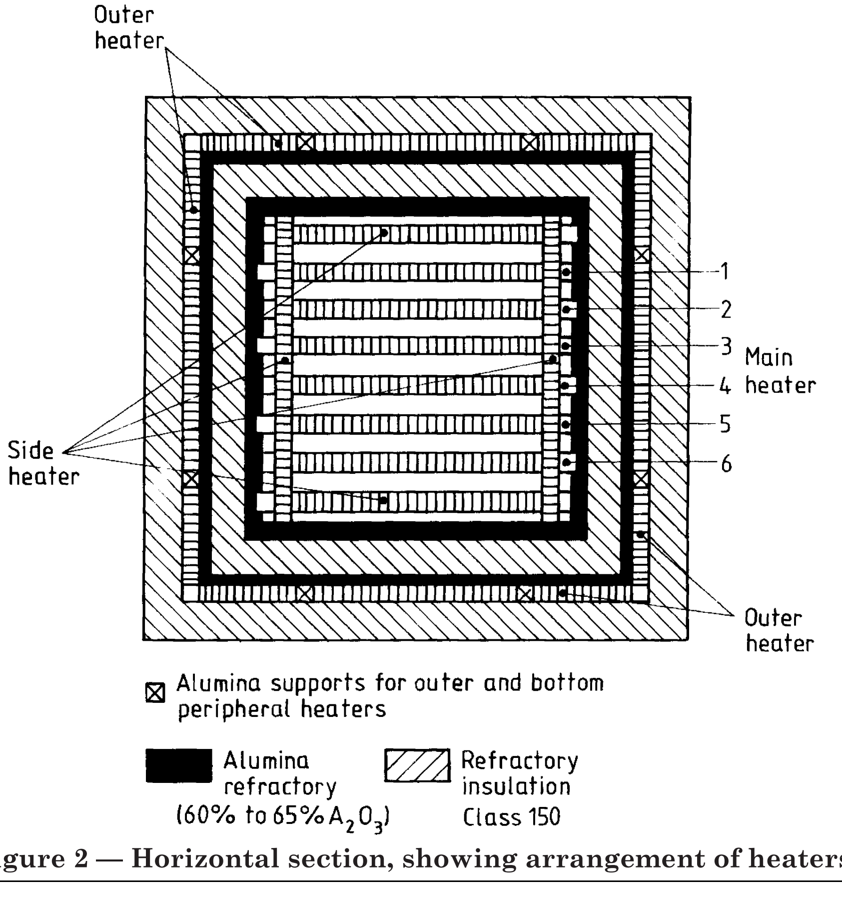
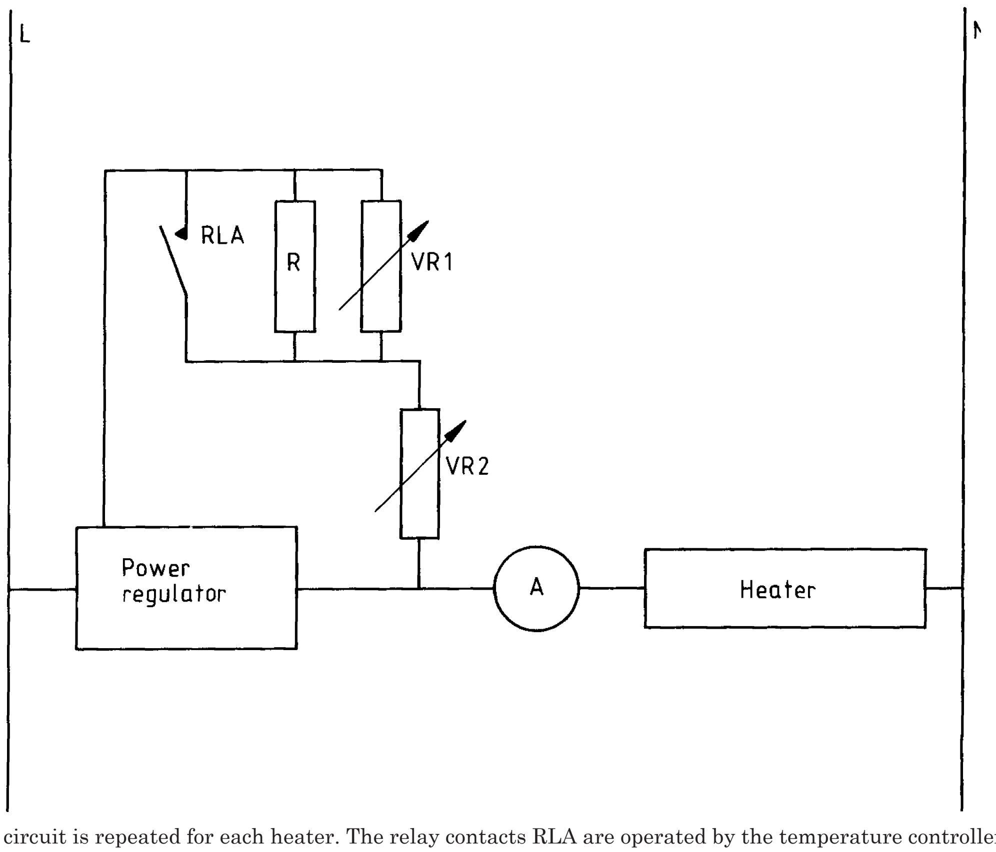


Figure 2 — Horizontal section, showing arrangement of heaters

Table 1 — Resistance wire for heaters

Material	Heater	Wire diameter	Resistance at room temperature	Length of wire	Space between turns in heater
		mm	Ω	m	mm
Platinum-20 % rhodium wire	Main	0.5	9.3	9.1	two end elements: 5 two inside elements: 5 7.5 over middle 114 two centre elements: 7.5
	Side	0.5	9.7	9.4	3.8 to 4.0
	Outer	0.5	12.1	11.5	3.8 to 4.0
	Lower peripheral	0.5	13.2	12.8	3.3 to 3.5
High temperature electrical resistance wire	Middle peripheral	1.6	9.2	12.8	12 to 13 turns per 25 mm of coil
	Top peripheral	1.6	9.2	12.8	
	Supplementary heater	1.6	23.1	33	even spacing (see note)
NOTE The spacing of the supplementary heater is not critical.					



NOTE The circuit is repeated for each heater. The relay contacts RLA are operated by the temperature controller. The variable resistors VR1 and VR2 allow adjustment of low and high current values. Values of R, VR1 and VR2 for an individual heater circuit will depend on the type of heater element and specification of the power regulator.

Figure 3 — Basic circuit for heater control system

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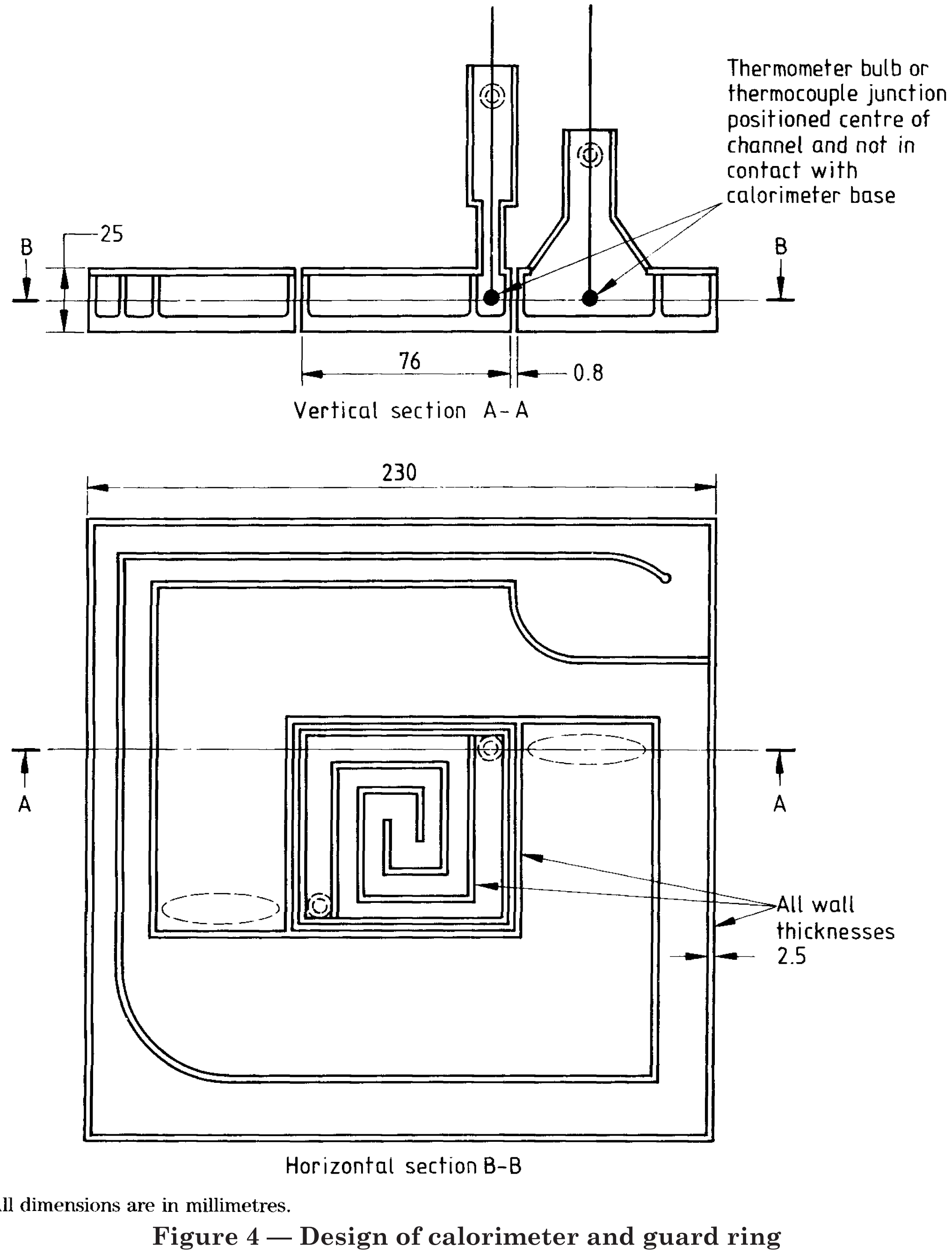

All dimensions are in millimetres.

Figure 4 — Design of calorimeter and guard ring

5.7 *Four mercury in glass thermometers,* for measuring the inlet and outlet temperatures of the calorimeter and guard ring. The thermometers have a certificate of calibration, are capable of measuring temperature over the range 0 °C to 25 °C, graduated in 0.1 K and capable of being read to 0.01 K using an attached magnifier.

NOTE Multiple thermocouples or platinum resistance thermometers may be used provided they are calibrated against a thermometer of certified accuracy and allow temperature difference between the calorimeter inlet and outlet water to be read to 0.02 K.

5.8 *Ten thermocouples,* of type R (platinum/platinum – 13 % rhodium) in accordance with BS 4937-2, for measuring temperatures of the test panel (see clause **6**) and which are connected to a temperature measuring instrument (**5.9**) using compensating connectors and cable.

5.9 *Temperature measuring instrument,* which is either:

a) a calibration certified potentiometer for measuring temperatures via thermocouples (**5.8**) to a maximum error equivalent of ± 0.5 K; or

b) a calibration certified digital temperature indicator with a range at least 0 °C to 1 400 °C capable of being read to 0.1 K with a calibration error, including traceability of standards, of ± 0.04 %.

5.10 *A multiple input selector switch,* for connecting thermocouples (**5.8**) to the temperature measuring instrument (**5.9**).

5.11 *Volumetric flasks,* 100 mL and 250 mL.

5.12 *Stop watch,* graduated in 0.2 s and accurate to 0.2 s in 2 min.

5.13 *Vernier callipers,* complying with BS 887.

6 Test panel

6.1 Construction

6.1.1 The dimensions of a test panel are nominally 230 mm × 228 mm × 76 (or 64) mm and consist of two or more prepared pieces, depending on whether the material is in the form of standard squares [230 mm × 114 mm × 76 (or 64) mm] or larger blocks or shapes.

NOTE 1 For sizes of refractory bricks, see BS 3056-1.

NOTE 2 Where the test panel comprises pieces taken from different items, these should be as similar as possible in bulk density and texture.

The construction of a test panel prepared from standard squares is shown in Figure 5(a), Figure 5(b) and Figure 5(c), depending on whether the thermal conductivity is to be measured in the direction parallel to the 76 (64) mm dimension (see **6.1.2**) or 114 mm dimension (see **6.1.3**) of the standard squares. The construction of a test panel from blocks or shapes is given in **6.1.4**.

6.1.2 The construction for measuring thermal conductivity in the 76 (64) mm direction is shown in Figure 5(a) and consists of the following:

a) a whole square which forms the centre piece of the panel;

b) three other pieces cut from two squares and having dimensions

230 mm × 76 (64) mm × 56 mm,

230 mm × 76 (64) mm × 33 mm and

230 mm × 76 (64) mm × 25 mm.

Ensure that the 76 (64) mm dimension of these pieces is the original 76 (64) mm thickness of the squares.

6.1.3 The construction for measuring thermal conductivity in the 114 mm direction is shown in Figure 5(b) and Figure 5(c) and consists of either a) or b) as follows.

a) For 76 mm thick squares:

1) two pieces, one of which forms the centre piece of the panel, obtained from squares by cutting the 114 mm width to 76 mm and thus having dimensions 230 mm × 76 mm × 76 mm;

2) two other pieces obtained from squares by cutting the 114 mm width to 76 mm, and then the 76 mm thickness to give pieces of size 230 mm × 76 mm × 51 mm and 230 mm × 76 mm × 25 mm.

b) For 64 mm thick squares:

1) a piece, which forms the centre of the panel, obtained by cutting the 114 mm width of a square to 76 mm and thus having dimensions 230 mm × 76 mm × 64 mm;

2) four other pieces obtained from squares by cutting the 114 mm dimension to 76 mm and then the 64 mm dimension to give pieces of size 230 mm × 76 mm × 57 mm, 230 mm × 76 mm × 36 mm and 230 mm × 76 mm × 25 mm.

NOTE Using these sizes, all pieces may be obtained from a minimum of four standard squares.

When constructing the panel for measurement of thermal conductivity parallel to the original 114 mm dimension of the squares, all prepared pieces are placed so that the upper (cold) face of the panel is formed of cut surfaces.

6.1.4 If the test sample is in the form of blocks or shapes, a test panel is formed either of pieces of the dimensions given in **6.1.2**, or of two pieces of dimensions 230 mm × 76 mm × 205 mm and 230 mm × 76 mm × 25 mm.

6.2 Preparation

To form a test panel, use pieces that are free of protrusions and made flat and sufficiently smooth to abut closely when formed into a panel.
One 230 mm × 230 mm face of the assembled panel is made flat by grinding, after which the pieces are re-assembled, flat face down on a levelling plate, and the upper face then made flat and parallel with the lower face.

Grooves are cut in the panel to accommodate the hot and cold face thermocouples, using a small portable diamond wheel, in the positions shown in Figure 6(a), Figure 6(b) and Figure 6(c). The depth of these grooves is such that the thermocouple junctions lie half in and half out of the grooves and are cemented in position with air setting alumina cement.

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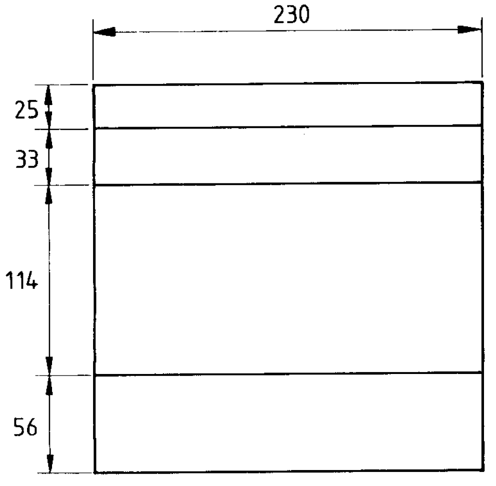
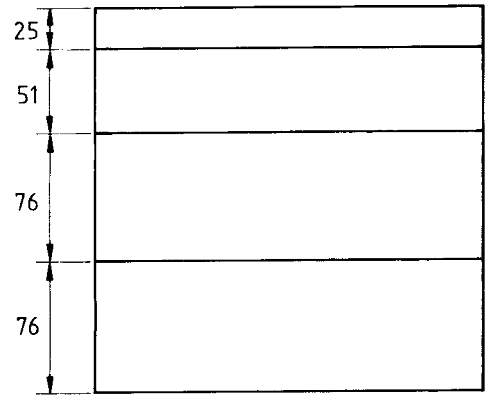
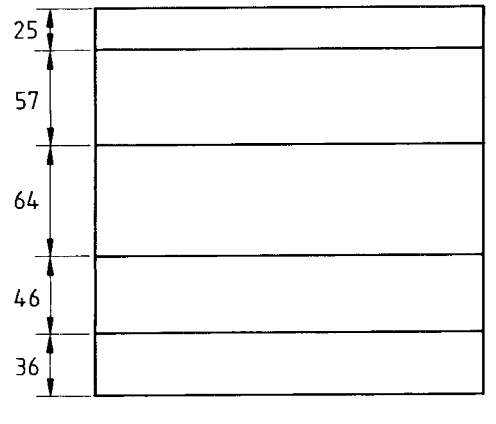


(a) Arrangement of test panel for measurement of thermal conductivity in direction of 76 (64) mm dimension of squares



(b) Arrangement for measurement in direction of 114 mm dimension of 76 mm thick squares



(c) Arrangement for measurement in direction of 114 mm dimension of 64 mm thick squares

Figure 5 — Arrangements for measurements in different dimensions

NOTE If it is thought that the test material has a relatively low electrical resistance at high temperatures, the grooves should be made sufficiently wide to accommodate fine, single-wire alumina thermocouple insulators and deep enough to take half the full diameter of the insulators. The insulators should be threaded on the thermocouples and cemented in the grooves with air setting alumina cement. The same treatment should be adopted for the side thermocouples. The distance between the hot and cold face thermocouples is taken as the depth of the panel less the diameter of the insulator.

The 230 mm × 76 mm × 25 mm piece which forms one side of the panel is employed as a detector of lateral heat flow using four thermocouples. Two grooves to accommodate the thermocouples are cut in each 230 mm × 76 (64) mm face, the grooves being parallel to and 13 mm distant from the top and bottom faces (230 mm × 25 mm), with the depth of the grooves just sufficient to accommodate the whole of the thermocouple wire and junctions. The junctions are sited midway along each groove [see Figure 6(a), Figure 6(b) and Figure 6(c)]. The thermocouples at each horizontal level are the same distance from the hot face of the panel (to within 1.0 mm) and fixed in position with alumina cement made flush with the surface of the piece.

7 Procedure

7.1 Dry the test panel at 110 ± 5 °C for a minimum period of 16 h and allow to cool. Measure the distance between the surfaces containing the hot face and cold face thermocouples and assemble the panel in the furnace. Butt the pieces comprising the panel closely together without the use of cement but with the vertical joint ends in the exposed surface filled with alumina cement and smoothed over.

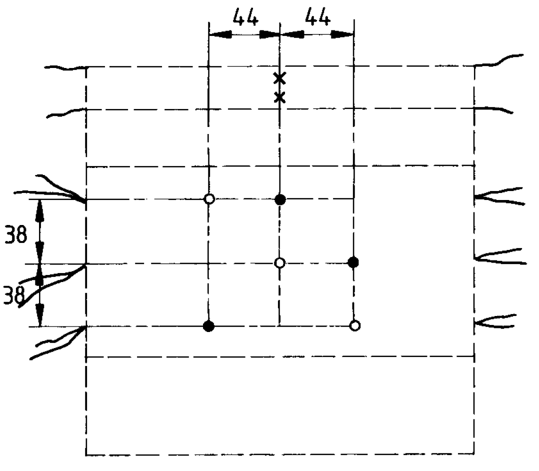
Connect all thermocouples to the temperature control and measurement instrumentation.

NOTE Connection should be made through an intermediate junction board, attached to the frame of the furnace, using compensating connectors.

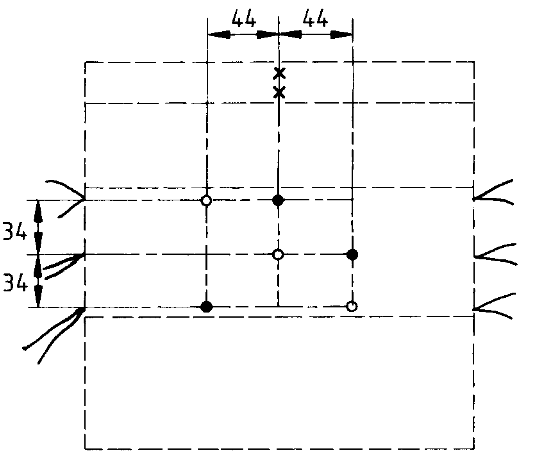
Pass a current of 3 A to 4 A through the main heater to ensure the test panel is thoroughly dry. Stop heating when the cold face temperature reaches 110 °C.

7.2 Depending on whether the test material is insulating or relatively conducting carry out one of the following procedures.

a) For insulating materials with thermal conductivity less than 1.0 W/(m·K), lay strips of ceramic fibre paper, 10 mm wide and nominally 1.0 mm thick around the edges of the test panel and place on this the calorimeter and guard ring assembly so that it is square and in line with the test panel.



(a) Position of thermocouples for panel arrangement in Figure 5(a)
Thermocouples tails exit from two opposite sides



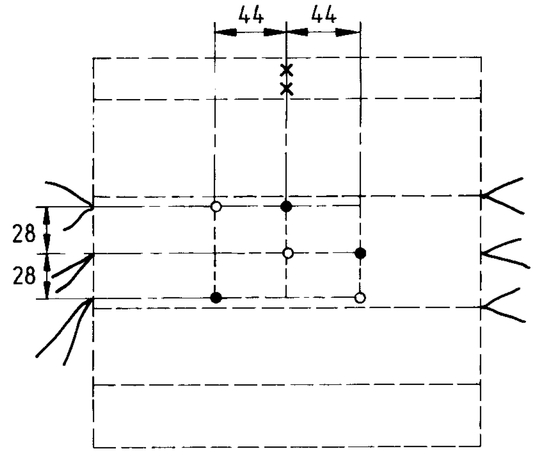
(b) Position of thermocouples for panel arrangement in Figure 5(b)

Thermocouple

● Hot face

○ Cold face

× Lateral



(c) Position of thermocouples for panel arrangement in Figure 5(c)
All dimensions are in millimetres.

Figure 6 — Corresponding positions of thermocouples for arrangements in Figure 5

NOTE The reason for using strips of ceramic fibre paper is to avoid discrete point contacts between the test panel and the calorimeter and guard ring. Ideally the ceramic fibre paper should compress to approximately 0.5 mm under the weight of the calorimeter assembly thus forming a thin air gap and uniform thermal contact.

b) For relatively conducting materials with thermal conductivity greater than 1.0 W/(m·K), spread fused alumina powder, which has been passed through a 0.25 mm aperture sieve, evenly over the exposed surface of the panel to a depth of approximately 1.5 mm and place on this a 230 mm square × 10 mm thick ceramic fibre board which has flat and parallel faces and is volume stable up to 1 100 °C. Ensure that the board is in full contact with the power over the whole area of the exposed panel surface. Carry out the procedure in a) using strips of ceramic fibre paper.

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7.3 Place a layer of insulating material of 10 mm to 15 mm thickness (ceramic fibre board or diatomite board) over the top surface of the exposed furnace refractory surrounding the calorimeter/guard ring assembly. Connect the water supply and outer tubing to the calorimeter and guard ring, place mineral wool in the space between the furnace and the plastics tubing and cover the calorimeter and guard ring with a layer of mineral wool approximately 75 mm thick.

7.4 Set the currents in the heater circuits and the water flow through the calorimeter and guard ring to appropriate values to achieve the desired hot face temperature and allow the apparatus to run for at least 12 h.

NOTE The maximum hot face temperature attainable will depend on the conductivity of the test material. The supplementary heater can be used to boost the heating of the test panel subject to a maximum temperature of 1 400 °C.

7.5 Read the temperatures of all thermocouples and the inlet and outlet water temperature to the calorimeter and guard ring and observe the temperatures until the following conditions are met:

a) the mean temperature of the hot face and the mean temperature of the cold face do not alter by more than 2 K in 30 min;

b) the horizontal temperature difference across the end piece of the test panel, at either level, is less than 10 K;

c) the temperature of the incoming water does not alter by more than 0.5 K in 1 h and the temperature rise in the calorimeter and guard ring lie in the range 2 °C to 4 °C and do not differ by more than 0.1 K.

If an adjustment has to be made to the rate of water flow, allow a period of 30 min between adjustments before temperature measurements are used in conductivity calculations.

If adjustments have to be made to the currents in the peripheral heaters and/or the main and side heaters, allow a further 4 h to elapse before further temperature readings are taken, which are repeated after a further 1 h. If after this period the above conditions are not met, make further adjustments and allow the apparatus to run for a further 12 h.

NOTE Information on appropriate heater current values for a variety of materials will be gained with experience enabling the time to achieve the required conditions for chosen hot face temperatures to be reduced.

7.6 When the conditions in **7.5** have been attained, carry out measurements to be used for the calculation of thermal conductivity in the sequence and manner given in a) to d) as follows.

a) Measure the inlet and outlet temperatures of the water flowing through the calorimeter, estimating thermometer readings to 0.01 K.

Collect a quantity of water at the calorimeter outlet in a flask of known mass and suitable capacity, over a period of not less than 2 min, timed with the stop watch (**5.12**). While the water is being collected, take further readings of the inlet and outlet temperatures at approximately 30 s intervals.

b) Measure the temperatures indicated by the three hot face and three cold face thermocouples, reading the potentiometer (**5.9**) to 0.01 mV or the digital temperature display (**5.9**) to 0.5 K.

c) Immediately following the measurement of temperatures in b), repeat the sequence of measurements described in a).

d) Weigh the flasks containing the water collected in a) and c) and determine the masses of the water collected.

7.7 The sequence described in **7.6** constitutes a single determination of thermal conductivity. Carry out at least three such determinations at intervals of 1 h, for each hot face test temperature.

7.8 If the thermal conductivity of a test panel is to be determined at more than one test temperature, carry out the procedures described in **7.5** to **7.7** for each temperature and in order of ascending temperature.

8 Calculation of thermal conductivity

8.1 Obtain a value for the rate of heat flow through the calorimeter as follows.

Take the average of the temperatures of the inlet and outlet water flowing through the calorimeter and obtain the average temperature difference θ. Take the average of the masses of water collected in the flask m, and of the times of collection T. Calculate the heat flow Q from the expression:

$$Q = \frac{m \times \theta \times c}{T}$$

where

Q is the heat flow rate (in W);

m is the average of the masses of water collected (in kg);

θ is the average difference between the inlet and outlet temperatures of calorimeter;

T is the average time of collection (in s);

c is the specific heat capacity of water at the mean temperature of the inlet and outlet water of the calorimeter [in J/(kg·K)].

NOTE The values of c in Table 2 may be used to obtain, by interpolation, a value for the calculation.

Table 2 — Specific heat capacity of water

Temperature	c
°C	J/(kg·K)
15	4185.5
20	4181.6
25	4179.3

8.2 Calculate a value for thermal conductivity using the following equation:

$$\lambda = \frac{Q \times L}{A(t_2 - t_1)}$$

where

λ is the thermal conductivity [in W/(m·K)];

Q is the heat flow rate (obtained through the test panel in accordance with **8.1**) (in W);

L is the distance measured between the hot face and cold face thermocouples (in m);

t_1 is the average temperature recorded for the cold face thermocouples (in °C);

t_2 is the average temperature recorded for the hot face thermocouples (in °C);

A is the area presented by the calorimeter plus half the gap between the calorimeter and guard ring (in m^2).

9 Test report

The test report shall include the following information:

a) the name of the testing establishment;

b) the date of the test;

c) a reference to the method of test, i.e. determined in accordance with method 1902-505;

d) a description and identification of the material tested (e.g. manufacturer, product, type, batch number);

e) where known, a reference to how the direction of heat flow corresponds to the shape of the original test item, e.g. ....standard square, heat flow in the direction of the 76 mm dimension;

f) the average values obtained for each test temperature for:

1) hot face, cold face and mean temperatures of the test panel (in °C);

2) the rate of heat flow (in W);

3) the thermal conductivity [in W/(m·K)].

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Publication(s) referred to

BS 887, *Specification for precision vernier callipers.*
BS 1902, *Methods of testing refractory materials.*
BS 1902-3.1, *Guidance on sampling.*
BS 1902-5.0, *Introduction.*
BS 1902-5.6, *Determination of thermal conductivity (hot-wire method) (method 1902-506).*
BS 1902-5.8, *Determination of thermal conductivity (split column method) (method 1902-508)*[2].
BS 1902-6, *Ceramic fibre products.*
BS 3056, *Sizes of refractory bricks.*
BS 3056-1, *Specification for multi-purpose bricks.*
BS 4937, *International thermocouple reference tables.*
BS 4937-2, *Platinum – 13 % rhodium/platinum thermocouples. Type R.*
BS 7225, *Classification of refractories.*
BS 7225-1.1, *Insulating products.*
IEE Regulations for Electrical Installations, 15th Edition, 1981.

[2] Referred to in the foreword only. In preparation.

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