British Standard

BRITISH STANDARD

BS 476-6: 1989

Fire tests on building materials and structures —

Part 6: Method of test for fire propagation for products

UDC 614.841.332:620.1:69.01:536.463:001.4

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Fire Standards Policy 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 Cement Association
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
Chemical Industries Association
Chief and Assistant Chief Fire Officers Association
Concrete Society
Department of Education and Science
Department of the Environment (Building Research Establishment)
Department of the Environment (Construction Industries Directorate)
Department of the Environment (Property Services Agency)
Department of the Environment for Northern Ireland
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 Organisation (FIDOR)
Fibre Cement Manufacturers' Association Limited
Fire Protection Association
Flat Glass Manufacturers' Association
Flat Roofing Contractors Advisory Board
Gypsum Products Development Association
Home Office
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Loss Prevention Council
Mastic Asphalt Council and Employers' Federation
National Council of Building Materials Producers
RAPRA Technology Ltd.
Royal Institute of British Architects
Steel Construction Institute
Timber Research and Development 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:

Autoclaved Aerated Concrete Products Association
London Scientific Services
National GRP Construction Federation
Phenolic Foam Manufacturers' Association
Queen Mary College Industrial Research
Thermal Insulation Manufacturers and Suppliers Association (TIMSA)

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Contents

Foreword

This Part of BS 476 has been revised under the direction of the Fire Standards Policy Committee primarily to specify a replacement calibration sheet because of problems of availability of the sheet currently specified. Experience with a wide range of materials has indicated that the non-combustible material now specified should not produce test results which are more onerous. At the same time, consideration was given to specifying a similar replacement for the walls of the combustion chamber and the specimen holder but this has not been done because the different thermal properties likely to be encountered could have caused major (and possibly unpredictable) changes in results and because the material now proposed was thought to be insufficiently robust. In addition, because the combustion chamber walls are not handled continually, expert advice indicates that the possible hazard associated with asbestos is low. It is intended in due course to replace this method entirely, but progress on this depends on work in the International Standards Organization (ISO) and the European Committee for Standardization (CEN).

Consideration was also given to the fuel gas and, in order to improve a difficult supply situation, a standard test gas has been specified. Generally, the derived indices will not vary as a result of using this gas. Engineering drawings for the apparatus are published as PD 6498.

The summary test report formerly included in BS 476-6 has been deleted.

In this method of test, a specimen of the product (material, composite or assembly) is subjected to a specific heating regime. The test takes account of the combined effect of factors such as the ignition characteristics, the amount and the rate of heat release, and the thermal properties of the product in relation to their ability to accelerate the rate of fire growth. The test result is expressed in terms of a fire propagation index that is the summation of three time-based subindices. The higher the fire propagation index, the greater is the influence of the product on accelerating the growth of a fire. The method of computation of the subindices ensures that greater significance is placed on those factors affecting the early stages of the test compared with those affecting the later stages.

Whilst this test has been designed to give information on the performance of a product in the early stages of a fire, it should not be considered or used by itself for describing or appraising the fire hazard of a material, composite or assembly under actual fire conditions or as the sole source on which a valid assessment of hazard pertaining to fire propagation can be based.

A series of second generation “reaction to fire” tests, including an ignitability test (now available as BS 476-13), a surface “spread of flame” test and a heat release test are under preparation within ISO Technical Committee ISO/TC 92, Fire tests for building materials and structures. The United Kingdom is participating in this work with a view to adopting these tests as national standards.

Attention is drawn to the Health & Safety at Work etc. Act 1974, and the need to ensure that the method of test specified in this standard is carried out under suitable environmental conditions to provide adequate protection to personnel against the risk of fire, inhalation of smoke and/or toxic products of combustion.

Caution. The mechanical sawing of asbestos cement components attracts the provision of the Asbestos Regulations 1969. Adequate methods exist to control levels of dust during such operations and these are detailed in the Control and Safety Guides[1)] issued by the Asbestosis Research Council.

[1)] Available from the Asbestos Information Centre, St. Andrews House, 22/28 High Street, Epsom KT17 8AH.

This Part of BS 476 supersedes BS 476-6:1981 which is withdrawn. However, the latter will still be made available on request since it is referred to in building regulations.

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 to iv, 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.

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1 Scope

This Part of BS 476 specifies a method of test, the result being expressed as a fire propagation index, that provides a comparative measure of the contribution to the growth of fire made by an essentially flat material, composite or assembly. It is primarily intended for the assessment of the performance of internal wall and ceiling linings.

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

2 Definitions

For the purposes of this Part of BS 476, the definitions given in BS 4422-1, BS 4422-2 and BS 4422-5 and BS 476-10 apply, together with the following.

2.1
assembly

a fabrication of materials and/or composites that can contain air gaps

2.2
composite

a combination of materials which are generally recognized in building construction as discrete entities, e.g. coated or laminated materials

2.3
exposed surface(s)

the surface(s) of the product subjected to the heating conditions of the test

2.4
essentially flat surface

a surface from which can be obtained specimens that have an irregularity from a flat plane which is less than ± 3 mm

3 Suitability of a product for testing

3.1 Surface characteristics

3.1.1 A product having one of the following is suitable for evaluation by this method:

a) an essentially flat exposed surface;

b) a surface irregularity that is evenly distributed over the exposed surface (see **A.1**) provided that:

1) at least 50 % of the surface of a representative square area of 225 mm × 225 mm lies within a depth of 6 mm from a plane taken across the highest points on the exposed surface;

2) any cracks, fissures or holes do not exceed 6.5 mm in width nor 10 mm in depth, and the total area of such cracks fissures or holes at the surface does not exceed 30 % of a representative square area of 225 mm × 225 mm of the exposed surface.

3.1.2 When an exposed surface does not comply with the requirements of either **3.1.1** a) or **3.1.1** b) it is permissible for the product to be tested in a modified form with a flat exposed surface; this shall be stated in the test report.

3.2 Asymmetrical products

A product submitted for this test could have faces that differ or could contain laminations of different materials arranged in a different order in relation to the two faces. If either of these faces can be exposed in use within a room, cavity or void, then both faces shall be tested.

3.3 Products with particular burning characteristics

This method of test could be inadequate for assessing products that react in particular ways under exposure to the specified heating conditions (see **9.2**). In this case provision is either made to apply a suffix to the result [see **10.4.2** and clause **11** g)], or prohibit an assessment being made because the product is unsuitable for testing by this method (see **10.4.3**).

NOTE Products showing these characteristics should be assessed by other test methods.

4 Test specimens

4.1 Number of specimens

The test sample shall comprise a minimum of three and a maximum of five specimens for each face to be tested.

4.2 Size of specimens

NOTE Specific advice on the testing of assemblies is given in **A.2** and appendix B.

4.2.1 The specimens shall be square, with sides 225 ± 1.5 mm long.

4.2.2 Products of normal thickness 50 mm or less shall be used to full thickness.

4.2.3 For products of normal thickness greater than 50 mm, the specimens shall be obtained by cutting away the unexposed face of the product to reduce the thickness to 50^{+0}_{-3} mm.

4.3 Edge effects

Where the specimen is backed by an air gap (see appendix B), ensure that the perimeter of the specimen will not permit flame to penetrate into the cavity. Similarly, where a flame-retardant coating is applied to a surface, the edge detail shall be such as to prevent ignition of the underlying layers.

4.4 Conditioning of specimens

All specimens shall be conditioned to constant mass (see **A.3**) at a temperature of 23 ± 2 °C and a relative humidity of 50 ± 5 %, and maintained in this condition until required for testing.

NOTE Constant mass is considered to be attained when two successive weighing operations, carried out at an interval of 24 h, do not differ by more than 0.1 % of the mass of the specimen, or 0.1 g, whichever is the greater.

5 Test apparatus

5.1 General

5.1.1 All dimensions given in the following description of the test apparatus are nominal unless tolerances are specified.

5.1.2 The test apparatus (see Figure 1 to Figure 3) shall consist of a combustion chamber with a specimen holder fixed to one face. The combustion chamber shall contain a horizontal gas burner tube and two electrical heating elements and shall be surmounted by a removable steel chimney and cowl.

5.2 Combustion chamber

The walls of the chamber shall be made from 12.5 mm thick asbestos cement board[2)] having a dry density within the range 1 300 kg/m^3 to 1 450 kg/m^3. The internal dimensions of the chamber shall be 190 mm × 190 mm × 90 mm.

An air inlet slot measuring 96 mm × 25 mm and a mica observation window measuring 50 mm × 50 mm shall be provided together with a hole for the discharge of combustion gases and a suitable fixing for the chimney and cowl. A steel baffle plate 200 mm × 40 mm shall be fixed horizontally to the top of the combustion chamber above the window. Four steel rods shall be fitted to the combustion chamber to enable the specimen holder to be located and fixed firmly in position during each test.

5.3 Specimen holder

The specimen holder shall be made from asbestos cement board having the same dry density as that of the walls of the combustion chamber (see **5.2**). The holder shall be recessed to take a specimen of area 225 mm × 225 mm and a recess depth of 12.5 mm, 25 mm or 50 mm, depending upon the thickness of the specimen to be tested.

5.4 Gasket

A non-combustible compressible gasket, 1 mm thick, shall be provided for interposing between the specimen holder and the combustion chamber to assist in obtaining an adequate seal (see **A.2**).

5.5 Chimney and cowl

The chimney shall be 190 mm long and 38 mm internal diameter and made of 1.0 mm thick steel. It shall be provided with a removable steel cowl also made of 1.0 mm thick steel 152 mm high and 76 mm internal diameter having two diametrically opposite bushed circular holes to take the thermocouples and their locating devices as specified in Figure 3. The chimney and cowl shall have a surface of low reflectivity and shall have an overall mass in the range of 530 g to 550 g (see **A.4.3**).

5.6 Gas burner

The gas burner shall comprise a horizontal stainless steel tube of wall thickness 1.5 mm and 9 mm bore closed at each end and fitted with a central gas supply pipe. The burner tube shall have a row of 14 holes of 1.5 mm diameter at 12.5 mm centres arranged so that the gas jets impinge horizontally on the specimen 25 mm above the floor of the combustion chamber. When the calibration sheet (see **8.1**) is in position, the holes in the tube shall be 3^{+1}_{-0} mm from the face of the calibration sheet.

5.7 Electric heating elements

The two heating elements shall be pencil type electric elements[3)], each of 1 000 W rating and of 16 mm maximum diameter, and the heating coil shall be 190 mm in length with a pitch of approximately 1 turn per millimetre. The elements shall be supported horizontally with their centres at a distance of 45 mm from the face of the specimen and arranged at 64 mm vertical centres symmetrically in the combustion chamber.

Each heating element shall be enclosed in a transparent silica tube 17 ± 1 mm internal diameter, having a wall thickness of 1.1 ± 0.25 mm and a length of 210 ± 2 mm.

The heating elements shall be connected in parallel with copper busbars and the end terminals shall be protected with suitable guards that, if made of metal, shall be effectively earthed. The framework of the apparatus, including the chimney and the cowl, shall be earthed.

[2)] Obtainable from the Fire Research Station, Melrose Avenue, Borehamwood, Herts WD6 2BL.

[3)] A commercial electric fire element with a 229 mm fixing centre is generally suitable.

5.8 Thermocouples

The thermocouples shall be 0.2 mm diameter nickel chrome/nickel aluminium conductors contained in a 1 mm diameter mineral insulated 18-8 stainless steel sheath with a grounded hot junction. They shall be provided with aluminous porcelain insulators (not recrystallized alumina) of 3.5 mm external diameter, 1.3 mm bore and 50 mm length. Provision shall be made to ensure that the extreme tips of the sheaths containing the hot junctions of the thermocouples are correctly located 3 mm beyond the ends of the insulators and midway between the inside of the cowl and the outside of the chimney (see **A.4.4** and Figure 3).

6 Ancillary equipment

6.1 Manometer

The manometer shall be capable of reading up to at least 1.0 kPa[4)] and of being read to within an accuracy of 0.05 kPa.

6.2 Gas flowmeter

The flowmeter shall be a direct-reading instrument graduated in L/min with a maximum flow not greater than 5 L/min and capable of being read to an accuracy of 0.05 L/min. It shall be calibrated for use with a gas whose relative density to air at 15 °C and 0.75 kPa is 0.365, and shall have an accuracy of ± 2 % of maximum flow.

6.3 Gas pressure regulating and control valves

The valves vary according to the type of flowmeter used but shall be capable of maintaining the pressure and flow of gas to the flowmeter at the levels specified in **7.2**.

6.4 Millivolt temperature indicator

An indicator shall be provided which is capable of monitoring the millivolt output of the thermocouples. This shall be either a potentiometric or digital device which is precalibrated to be capable of indicating temperatures to the nearest 1 °C and shall have a response time no worse than 10 ms/ °C (1 s/100 °C). It may be provided with means for cold junction compensation but if this is not provided, it shall be capable of negative readings (i.e. capable of indicating that the hot junctions of the thermocouples are at a lower temperature than their cold junctions).

A suitable potentiometric chart recorder is a multirange recorder capable of operating in the ranges – 25 °C to + 225 °C (– 1 mV to + 9 mV) and – 100 °C to + 900 °C (– 5 mV to + 45 mV) with an accuracy of 0.5 % of full scale deflection.

A single-range chart recorder shall not be used unless it has an accuracy and resolution comparable to that of the multirange recorder described above.

6.5 Wattmeter

The wattmeter shall be capable of measuring up to 2 kW with an accuracy of ± 2 %, and shall be of a type that integrates voltage and amperage and does not assume constant voltage input.

6.6 Variable transformer

The variable transformer shall be capable of handling a maximum of 2 kV A and of regulating the voltage output from zero to a maximum value equal to that of the input voltage. The voltage output shall vary linearly over the range.

6.7 Electric oven

The oven shall be capable of maintaining a temperature of 103 ± 2 °C, and shall be of sufficient size to accommodate the calibration sheet (see **8.1**).

6.8 Gas igniter

A commercially available battery-powered gas igniter operating on a continuous spark or heated coil is suitable.

6.9 Desiccator

The desiccator (or desiccating cabinet), required to house the calibration sheet, shall contain self-indicating silica gel.

6.10 Timing device

The timing device shall be capable of recording elapsed time to the nearest second and shall be accurate to within 1 s in 1 h.

6.11 Balance

The balance shall be capable of weighing to an accuracy of 0.1 g.

7 Setting up procedure

7.1 Siting of apparatus

The apparatus shall be located in an essentially draught-free room of volume not less than 15 m^3 and shall be protected from direct sunlight. If the extraction of combustion products from the room is necessary during the test, this shall be effected in such a way as to avoid causing draughts over the apparatus. The apparatus shall be set level with the chimney and cowl vertical.

[4)] 1.0 kPa = 101.97 mmH_2O.

7.2 Gas supply

Standard test gas G112 as specified in BS 4947 shall be supplied to the apparatus at a pressure not exceeding 1.0 kPa. The flow shall be capable of being adjusted, by means of the gas control valves, to give a heat output of 527.5 ± 10 W. A method of calculating the required flow rate is described in **A.5**.

7.3 Interconnection of ancillary equipment and test apparatus

7.3.1 *General* A. line diagram of the connections between the ancillary equipment and the test apparatus is shown in Figure 4.

7.3.2 *Electricity supply.* The electric elements of the apparatus shall be connected in series with the wattmeter and the variable transformer.

7.3.3 *Temperature measurement.* The thermocouples shall be connected to and in series with the temperature indicator by means of compensating leads (see **A.4.4**). The cold junctions shall be maintained at a constant temperature throughout the test. The hot junctions of the thermocouples in the cowl shall be checked for correct location before each calibration and test (see **5.8**).

8 Calibration

8.1 Calibration sheet

A square calibration sheet with sides 225 ± 1.5 mm long shall be cut from asbestos-free, heat treated, calcium silicate board with an oven dry density (see appendix C) of 850 kg/m^3 ± 10 % and $12.7^{+0}_{-0.8}$ mm thick[5)].

The shrinkage in the plane of the board shall be less than 0.3 % after heat soaking for 4 h at 1 000 °C.

The calibration sheet shall be kept in the desiccator after oven drying or after completion of a previous calibration test.

8.2 Frequency of calibration

Calibration of the apparatus shall be carried out to ensure consistency of operation and to give a reference against which the performance of a product is measured (see **A.4**). The repeatability of the calibration value, *C*, shall be established (see **8.4.2**); calibration shall be carried out before the start of a test of each group of up to five specimens, unless the apparatus is in continuous daily use, in which case not more than ten specimens shall be tested between calibrations.

8.3 Calibration procedure

8.3.1 Ensure that the test apparatus is at ambient temperature at the start of the test (see **A.6**).

8.3.2 Check that the hot junctions of the thermocouples in the cowl are correctly located.

8.3.3 Keep the calibration sheet in the desiccator and do not remove until immediately before it is required for mounting in the specimen holder. At the start of the test, insert the sheet into the specimen holder. Where necessary (see **A.2**), back the sheet with non-combustible material that has been conditioned prior to use by the method described for test specimens in **4.4**, and ensure that when the holder is clamped on to the combustion chamber, the face of the sheet is in contact with the walls of the combustion chamber.

8.3.4 Adjust the gas flow to give a heat output of 527.5 ± 10 W (see **A.5**) and then turn off.

8.3.5 Switch on the thermocouple output indicator and record the initial output E_i, in mV, measured by the thermocouples inside the cowl.

8.3.6 After allowing any residual gas within the combustion chamber to disperse, simultaneously turn on the gas supply and ignite the jets using the gas igniter; time the test from the time of ignition. After 2 min 45 s, turn on the electrical supply to give an indicated input of 1 800 W; at 5 min after the time of ignition, reduce this indicated input to 1 500 W.

8.3.7 Record the output from the thermocouples, E_r, in mV, at:

a) 0.5 min intervals, up to and including 3 min from the time at which the gas was ignited; then

b) 1 min intervals, up to 10 min from the time at which the gas was ignited; then

c) 2 min intervals, up to 20 min from the time at which the gas was ignited.

If a multirange chart recorder is used, select the lower range scale of the chart recorder from the start of the test and adjust it to the higher range when 95 % full scale deflection is indicated.

8.3.8 Calculate the actual output rise E_c, in mV, for the calibration sheet from the following expression:

$$E_c = \frac{E_r - E_i}{2}$$

[5)] Interlaboratory trials have identified a single commercially available product which fulfills these requirements and performs satisfactorily during continual testing. For information on the availability of this product apply to Enquiries Section, BSI, Linford Wood, Milton Keynes MK14 6LE, enclosing a stamped addressed envelope for reply.

where

E_c is the output rise indicated from the thermocouples of the flue gases for the calibration sheet, in mV;

E_r is the output indicated from the thermocouples at the intervals specified in **8.3.7**, in mV;

E_i is the initial output indicated from the thermocouples in **8.3.5**, in mV.

NOTE For instruments that do not have cold junction compensation, the initial output measured by the thermocouples in **8.3.5**, E_i may be negative, in which case the expression for E_c becomes the following:

$$E_c = \frac{E_r - (-E_i)}{2} = \frac{E_r + E_i}{2}$$

8.3.9 For the calibration sheet, calculate the calibration value, C, from the expression:

$$C = \sum_{t\,=\,0.5}^{t\,=\,3} \frac{\theta_c}{10t} + \sum_{t\,=\,4}^{t\,=\,10} \frac{\theta_c}{10t} + \sum_{t\,=\,12}^{t\,=\,20} \frac{\theta_c}{10t}$$

where

θ_c is the actual temperature rise to the nearest °C converted from E_c;

t is the time, in min, at the intervals specified in **8.3.7**.

8.4 Calibration requirements

8.4.1 At 3 min, 5 min, 10 min and 20 min from the time at which the gas is ignited, the actual temperature rise θ_c above the initial temperature converted from E_i shall be within the tolerance limits specified in Table 1.

NOTE A typical calibration curve is shown in Figure 5.

Table 1 — Allowable limits for calibration

Time from ignition of gas, t	Limits for rise above initial temperature
min	°C
3	27 to 39
5	85 to 110
10	175 to 205
20	230 to 260

8.4.2 The calibration value, C, shall not differ by more than 1.0 between consecutive calibrations (see **A.4**). When the apparatus is not in continuous use, at least two calibration tests shall be carried out to establish this consistency.

9 Test procedure

9.1 Procedure

9.1.1 Once a satisfactory repeatable calibration is achieved, allow the apparatus and specimen holder to cool to ambient temperature, remove a specimen from the conditioning chamber and mount it in the specimen holder. Where necessary (see **A.2**), back it with non-combustible packing, previously conditioned in accordance with **4.4**, to ensure that when the holder is clamped on to the combustion chamber, the face of the test specimen is in contact with the walls of the combustion chamber.

9.1.2 Carry out the test procedure as specified in **8.3.1**, **8.3.2** and **8.3.4** to **8.3.7** inclusive.

9.1.3 Decomposition of the specimen during test may result in the formation of soot deposits on the thermocouple hot junctions, which may interfere with the accurate measurement of gas temperatures. To minimize this effect, clean the thermocouples at least 30 s before every temperature reading after the first 3 min of test (see **8.3.7**), by removing them from the chimney and cleaning them with fine wire wool or a fine wire brush, then replacing them.

9.1.4 Record the mV output from the thermocouples of the flue gases throughout the duration of the test. Note the actual mV output at the intervals specified in **8.3.7** and the mV rises above the initial mV reading.

9.1.5 Calculate E_s, the output from the thermocouples for the test specimen, in mV, by the same method specified for E_c in **8.3.8** and convert it to temperature rise for the flue gases, θ_s.

9.1.6 The determination of the fire propagation index requires results from three specimens, but if any specimen exhibits the behaviour described in **9.2**, test up to a maximum of five specimens in an attempt to obtain three valid test results (see **10.4.3**).

9.2 Observations during test

Throughout the test, carefully observe the material's behaviour within the apparatus (see **A.7**) and take special note of any of the following phenomena:

a) intumescence or deformation or spalling of the specimen that tends to block the burner ports so that the required gas input cannot be maintained;

b) melting or slumping of the specimen that results in material escaping from the air inlet or being confined to the recess of the specimen holder, where it is not exposed to the heating conditions;

c) air flow through the apparatus being restricted owing to obstruction of the inlet port by fallen material or by soot accumulation in the chimney.

Occurrence of any of the above phenomena shall deem the test on that specimen to be invalid.

10 Calculation of results

10.1 Test results

The fire propagation index and the individual subindices for each specimen shall be calculated to the first decimal place from valid test results obtained on three specimens (see **9.1.6**).

10.2 Index of performance of specimens

The index of performance, S, for each of the specimens tested shall be calculated from the subindices, s_1, s_2 and s_3, according to the respective temperature ranges as follows:

$$S = s_1 + s_2 + s_3$$

where

s_1, s_2 and s_3 are given by the expressions

$$s_1 = \sum_{t\,=\,0.5}^{t\,=\,3} \frac{\theta_s - \theta_c}{10t}$$

$$s_2 = \sum_{t\,=\,4}^{t\,=\,10} \frac{\theta_s - \theta_c}{10t}$$

$$s_3 = \sum_{t\,=\,12}^{t\,=\,20} \frac{\theta_s - \theta_c}{10t}$$

where

θ_s is as defined in **9.1.5**;

θ_c is as defined in **8.3.9**;

t is as defined in **8.3.9**.

Only positive values of $(\theta_s - \theta_c)$ shall be used in the calculation.

10.3 Fire propagation index

The index of overall performance, I (fire propagation index), of the product shall be calculated from the individual results of each test as follows:

$$I = i_1 + i_2 + i_3$$

where i_1, i_2 and i_3 are given by the expressions

$$i_1 = {}^1/_3\,[(s_1)_A + (s_1)_B + (s_1)_C]$$

$$i_2 = {}^1/_3\,[(s_2)_A + (s_2)_B + (s_2)_C]$$

$$i_3 = {}^1/_3\,[(s_3)_A + (s_3)_B + (s_3)_C]$$

where

A, B and C represent individual specimens giving valid test results;

s_1, s_2 and s_3 are as defined in **10.2**.

NOTE The indices of performance are calculated to the first decimal point. Although they are therefore stated with this precision there is no suggestion that this degree of accuracy is achieved by the test.

10.4 Expression of results

10.4.1 The fire propagation index shall be stated without a suffix where the first three specimens tested give valid results.

10.4.2 The fire propagation index shall be stated with a suffix "R" where four or five specimens have to be tested to obtain three valid results.

10.4.3 Where less than three valid results are obtained from five specimens, no fire propagation index shall be stated and the product shall be designated "unsuitable for assessment by this method".

11 Test report

The test report shall quote the individual results obtained for each specimen tested. Any observations made during the test and comments on any difficulties experienced during testing as described in **9.2** shall also be given, together with the following:

a) name and address of testing laboratory;

b) name and address of sponsor;

c) name and address of manufacturer/supplier, if known;

d) date of test;

e) full description of the product tested sufficient to describe its construction and to allow its identification. Different materials will need to be described in different ways but the description shall always contain sufficient information to allow the product to be accurately identified and differentiated from other similar products.

All the components of the specimen shall be described and the description shall include as much information as possible, including the following where applicable:

1) trade name(s);

2) generic identification of material(s);

3) thickness(es);

4) density(ies) or mass(es) per unit area;

5) details that may be significant to the fire performance of the material, e.g. type and level of any flame retardant treatment;

f) details of the form in which the specimens were tested (material, composite or assembly), together with specimen thickness and, where appropriate, orientation, backing material and the face or faces subjected to the test and whether the material was tested in a modified form;

g) the fire propagation index, I, for the product, with the suffix "R" if appropriate, and the subindices i_1 and i_2;

h) the statement that the suffix "R" to the fire propagation index indicates that the results should be treated with caution;

i) the statement: "The test results relate only to the behaviour of the test specimens of the product under the particular conditions of test; they are not intended to be the sole criterion for assessing the potential fire hazard of the product in use".

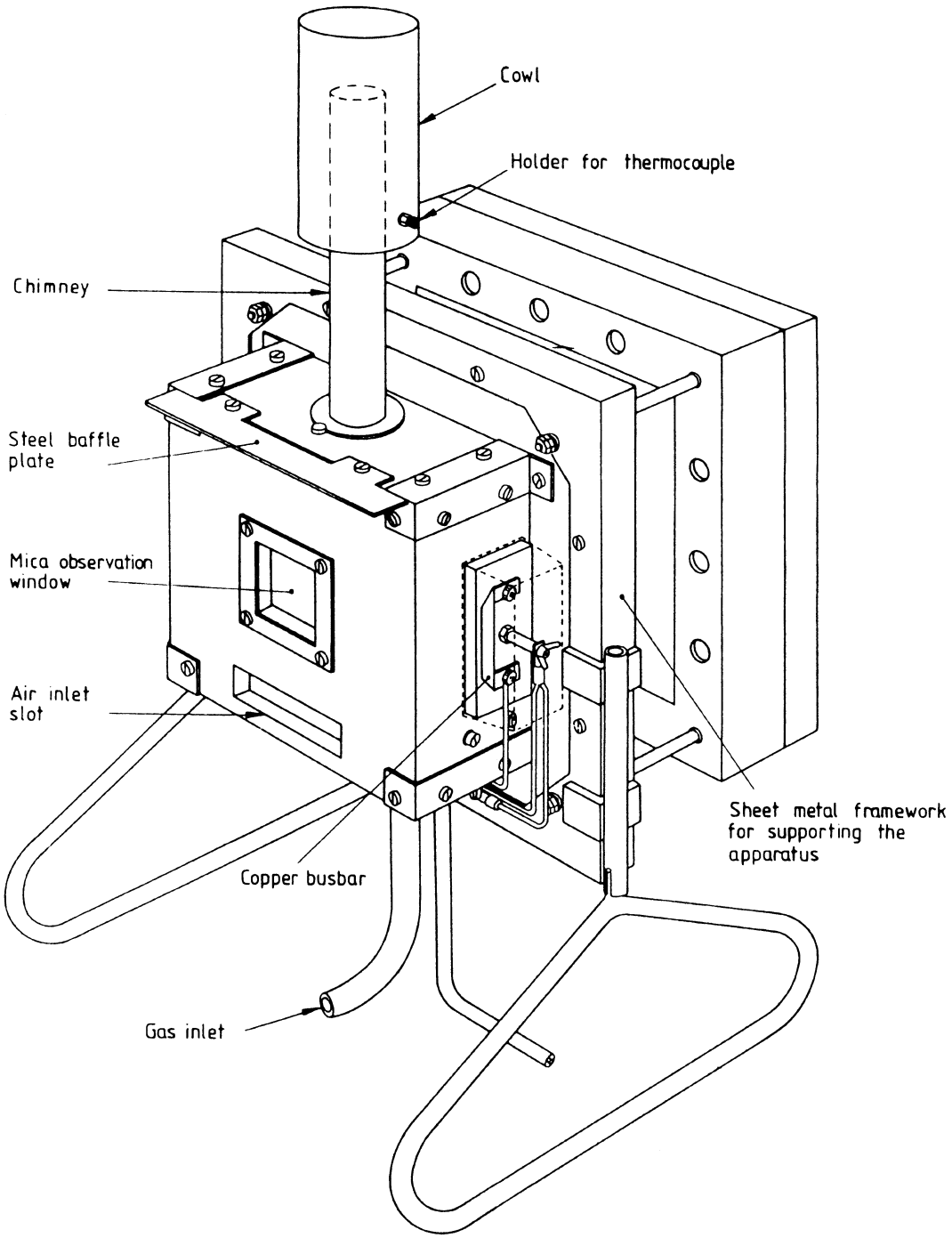

Figure 1 — Diagrammatic representation of the apparatus: front

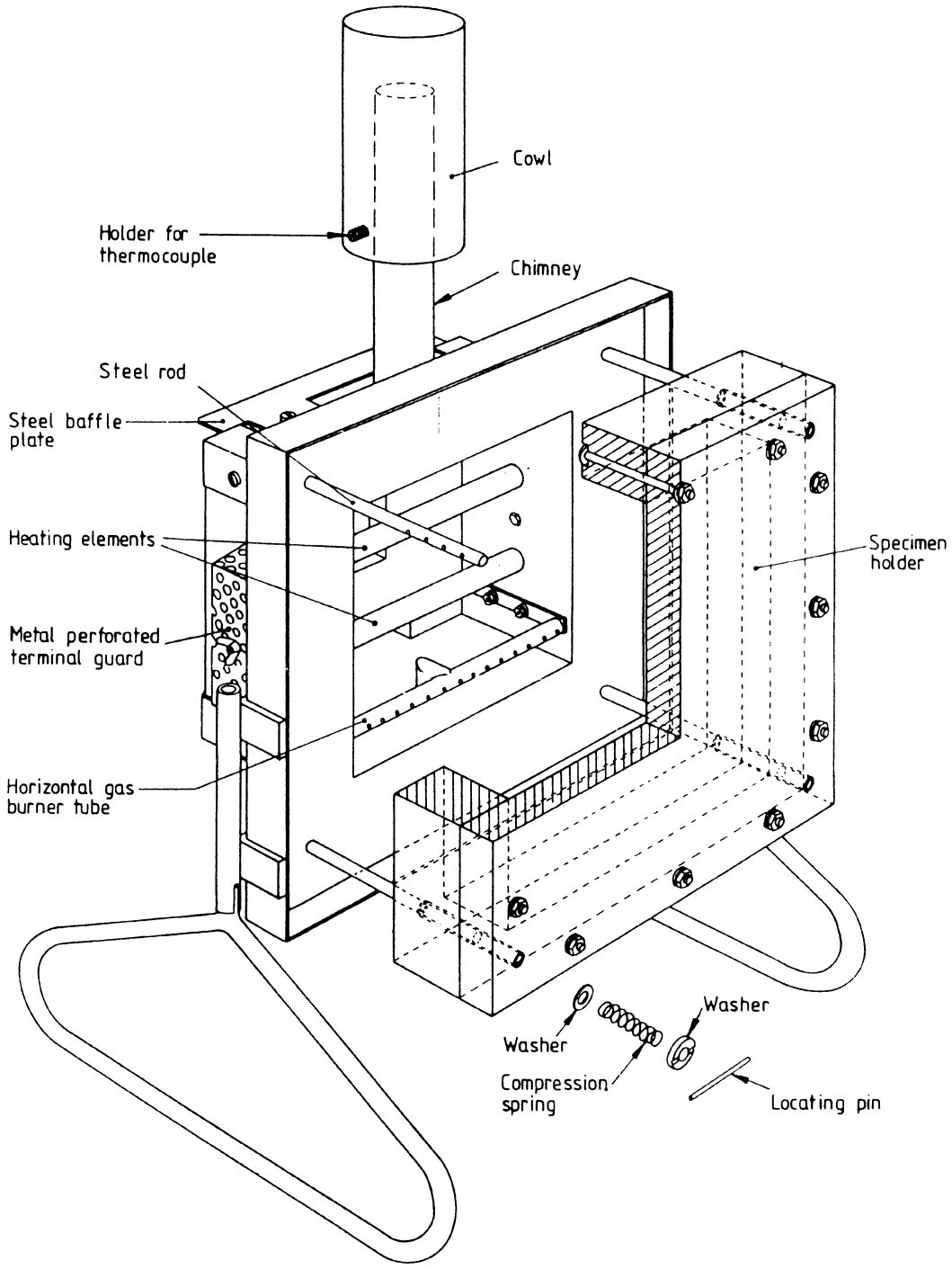

Figure 2 — Diagrammatic representation of the apparatus: rear

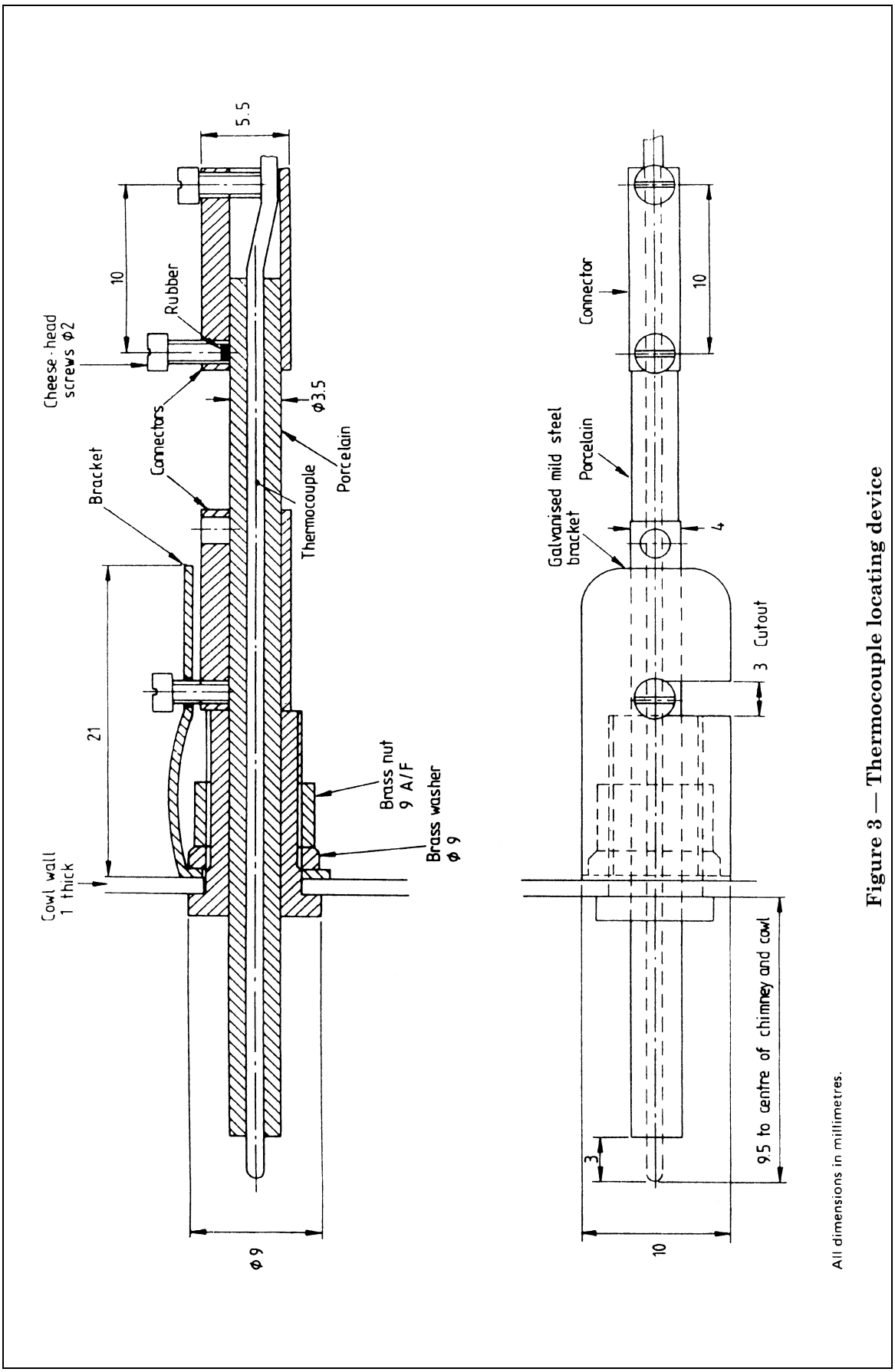

Figure 3 — Thermocouple locating device

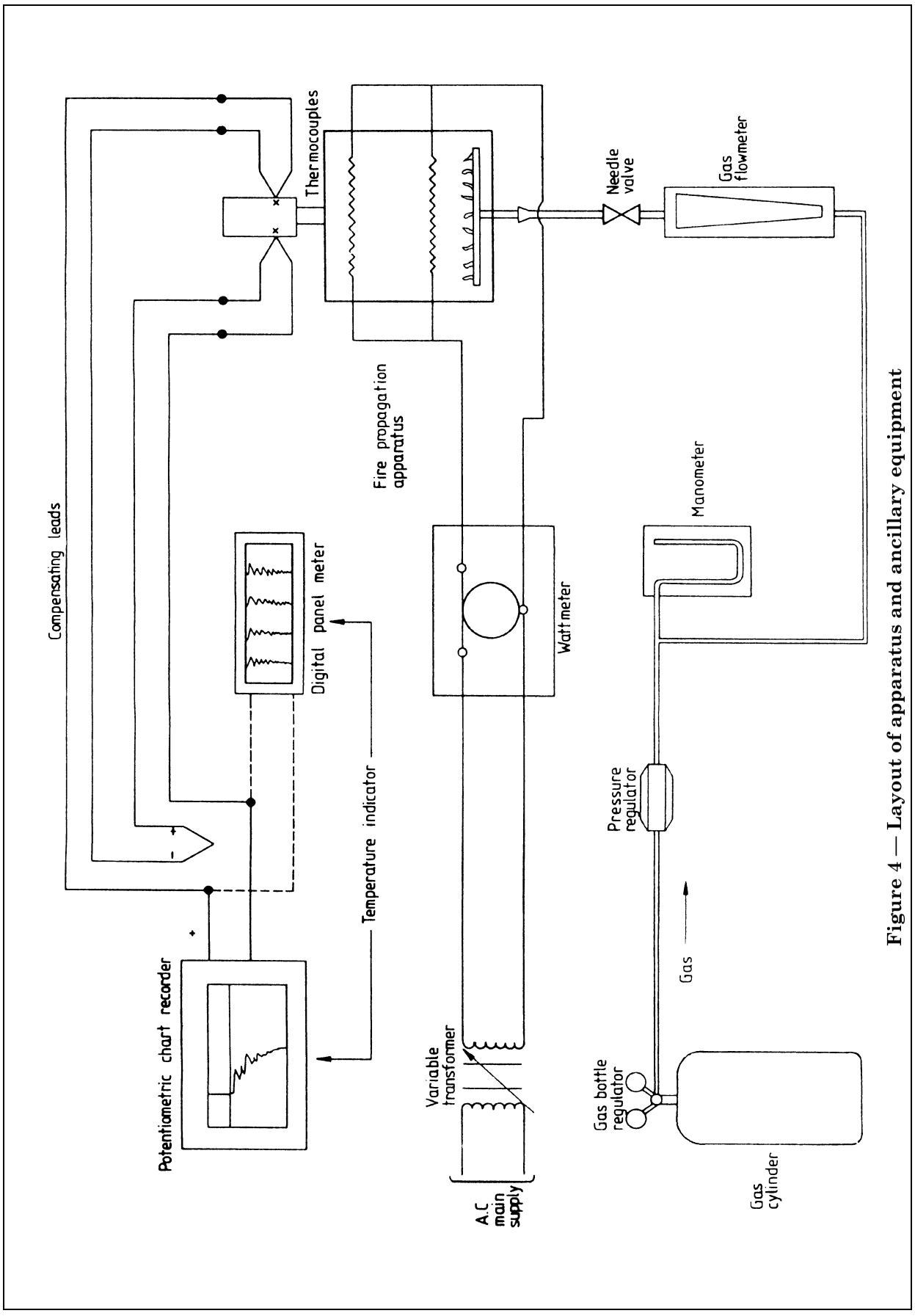

Figure 4 — Layout of apparatus and ancillary equipment

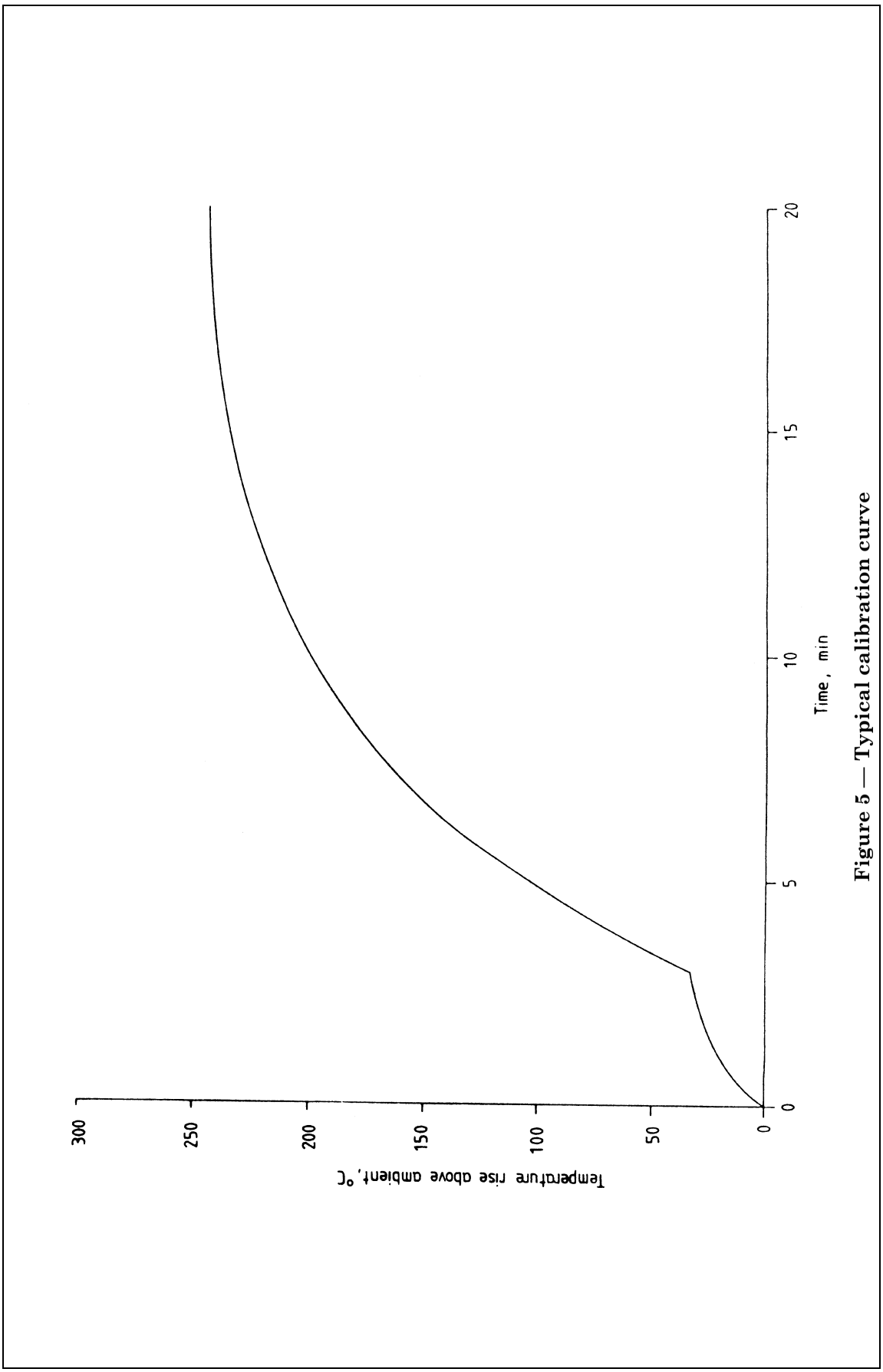

Figure 5 — Typical calibration curve

Appendix A Guidance for operators

A.1 Surface irregularities

Where assessment of the area of surface irregularity (see **3.1.1**) is required, this can be carried out by machining the surface to a depth of 6 mm below the highest point and estimating the machined surface area.

A.2 Specimen construction

Where non-combustible packing is required (see **9.1.1**), the sheet immediately behind the specimen should be of non-combustible board similar to that specified in **8.1**. Behind this, or where the 12.7 mm board cannot be accommodated owing to lack of space, a non-combustible board or millboard may be used as required to fill the holder. This may be necessary when the gasket prevents the face of the specimen being in close contact with the walls of the combustion chamber.

A.3 Conditioning of specimens

Constant mass is proof of satisfactory conditioning; cellulosic materials may require more than two weeks to achieve equilibrium with the atmosphere but some plastics materials take less time. Other factors, e.g. curing before conditioning, may need to be taken into consideration.

A.4 Calibration

A.4.1 General

When not in continuous use, at least two calibration tests are carried out to establish consistency. If the temperature rises for an apparatus are either outside the allowable limits (see Table 1) or if the calibration value (see **8.4.2**) does not give the specified repeatability, the following points should be considered.

A.4.2 Density of the calibration sheet

A low density sheet may give a high calibration value (*C*). When consistency of calibration is being checked the same calibration sheet should be used for successive tests.

A.4.3 Chimney/cowl

A heavy chimney and cowl will tend to give a low calibration value. A highly polished surface will reduce heat loss and give a high calibration value (see **5.5**).

A.4.4 Temperature measuring system

This is a frequent source of erroneous results and great care should be exercised to ensure that the hot junctions of thermocouples, etc. are precisely located. The sheathed thermocouples should be not less than 100 mm long.

A.4.5 Gas supply

The gas flow should not show an initial surge due to pressure build up behind the on/off valve. If this occurs a by-pass valve should be introduced. Ignition should always coincide with supply of gas to the burner.

A.5 Calculation of gas flow rate

The Wobbe index of the test gas will normally be provided by the gas supplier and is specified in BS 4947 as 19.49 MJ/m^3 for test gas G112. In addition, the calorific value of the specific supply to be used should be obtained in order that the relative density of the gas can be checked to ensure that it complies with the requirement of **7.2** by substituting the actual values in the following expression:

$$\text{relative density} = \left(\frac{\text{calorific value}}{\text{Wobbe index}}\right)^2$$

The gas flow rate should be calculated as in the following example.

For a gas of calorific value 11.81 MJ/m^3, and for the required heat output from the burner of 527.5 ± 10 W (see **8.3.4**), the required rate of flow is given by the following:

$$\frac{527.5 \times 60}{11.81 \times 1\,000}\ \text{L/min} = 2.68\ \text{L/min}$$

NOTE Values for Wobbe index and calorific value are often quoted in imperial units. Metric and imperial equivalences are as follows:

1 MJ/m^3 ≈ 238.86 cal/L;

1 W = 1 J/s ≈ 14.33 cal/min;

1 Btu/ft^3 ≈ 0.0373 MJ/m^3.

For the actual values quoted in the example above, 527.5 ± 10 W ≈ 7 559 ± 143 cal/min and 11.81 MJ/m^3 ≈ 2 821 cal/L, and the expression for the gas flow rate is:

$$\frac{7\,559}{2\,821}\ \text{L/min} = 2.68\ \text{L/min}$$

A.6 Cooling apparatus

The cooling of the apparatus to ambient temperature between tests is important and may take approximately 2 h. Care should be taken to ensure that the cooling is thorough and not merely superficial, particularly if artificial means of cooling are used.

A.7 Product testing

Failure to achieve valid test results from certain types of product described in **9.2** may be recognized by the following behaviour.

a) *Failure to maintain the required gas flow as indicated by the flowmeter.* An attempt should be made to maintain the required flow by opening the flow regulator without increasing the inlet pressure to the flowmeter beyond 1.0 kPa.

b) *Melting or slumping of products.* Escape of molten products through the air inlet is obviously visible during the test but slumping of a product within the combustion chamber may occur and can only be noted by continual close observation. Shrinkage of some specimens into the specimen holder may only be observed on completion of the tests.

c) *Restriction of the flow of air and/or combustion products through the apparatus.* This may be indicated by a drop in the temperature curve caused by blockage of the air inlet by a collapsed sample or of the throat of the chimney by massive carbon deposits. Severe blockage may result in flames emerging from the air inlet.

Appendix B Effect of thermal characteristics on the performance of assemblies

With thin materials or composites, particularly those with a high thermal conductivity, the presence of an air gap and the nature of any underlying construction may significantly affect the ignition performance of the exposed surface. Increasing the thermal capacity of the underlying construction increases the "heat sink" effect and may delay ignition of the exposed surface. Any backing provided to the test specimen and in intimate contact with it, such as the non-combustible packing pieces, may alter this "heat sink" effect and may be fundamental to the test result itself. The influence of the underlying layers on the performance of the assembly should be understood and care should be taken to ensure that the result obtained on any assembly is relevant to its use in practice.

The following advice is offered on the construction and preparation of test specimens.

a) Where the thermal properties of the product are such that no significant heat loss to the underlying layers can occur, e.g. a material/composite greater than approximately 6 mm thick of high thermal capacity and/or low thermal conductivity, then the product should be tested backed only by the specimen holder.

b) Where the product is normally used as a free-standing sheet and the characteristics noted in a) do not apply, then an air space should be provided at the back of the product by testing over non-combustible perimeter battens 20 mm wide and 12.5 mm thick.

c) Where the product is to be used over a low density non-combustible substrate and the characteristics noted in a) do not apply, then the product should be tested in conjunction with that substrate.

d) Where the product is to be used over a combustible substrate and the characteristics noted in a) do not apply, then the product should be tested in conjunction with that substrate.

Appendix C Determination of dry density of calibration sheet

The calibration sheet shall be dried at a temperature of 103 ± 2 °C to constant mass (see footnote to **4.4**) and allowed to cool in the desiccator. Weighing should be carried out to an accuracy of ± 0.1 g. The thickness of the sheet should be measured at the quarter and midpoints of each side to an accuracy of 0.1 mm, the measuring instrument having flat contacting surfaces. The mean of the twelve readings should be taken as the thickness of the board and the linear dimensions of each side should be measured to an accuracy of 0.5 mm.

Publications referred to

BS 476, *Fire tests on building materials and structures.*
BS 476-10, *Guide to the principles and application of fire testing.*
BS 476-13, *Method of measuring the ignitability of products subjected to thermal irradiance*[6)].
BS 4422, *Glossary of terms associated with fire.*
BS 4422-1, *The phenomenon of fire.*
BS 4422-2, *Building materials and structures.*
BS 4422-5, *Miscellaneous terms.*
BS 4947, *Specification for test gases for gas appliances.*
PD 6498, *Detail drawings for fire propagation apparatus specified in BS 476-6:1981*[6)].

[6)] Referred to in the foreword only.

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