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Fire tests on building materials and structures

Part 6. Method of test for fire propagation for products

Essais au feu des matériaux de construction et des structures
Partie 6. Méthode d'essai de la propagation du feu sur les produits

Feuerproben mit Baumaterialien und Bauten
Teil 6. Prüfverfahren für die Feuerwiderstandsdauer von Produkten

British Standards Institution

BS 476 : Part 6 : 1981

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Foreword

This Part of this British Standard has been revised under the direction of the Fire Standards Committee in order to improve the repeatability and reproducibility of the test results by clarifying operating procedures and more closely specifying the apparatus.

The main changes to this Part of this standard include the provision of a cleaning mechanism to minimize soot deposition on the hot junctions of the thermocouples, close specification of the form and types of products that can be tested with confidence, and the inclusion of guidance notes for operators in appendix A. Engineering drawings for the apparatus are published as PD 6498.

In this method of test, a specimen of the product (material, composite or assembly) is subjected to a specified 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, a surface 'spread of flame' test and a heat release test are under preparation within 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 and 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 issued by the Asbestosis Research Council*.

This Part of this standard supersedes BS 476 : Part 6 : 1968, which is therefore withdrawn, but will still be made available on special request, since BS 476 : Part 6 : 1968 is referred to in the National Building Regulations.



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Fire tests on building materials and structures

Part 6. Method of test for fire propagation for products

1. Scope

This Part of this British Standard 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.

2. References

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

3. Definitions

For the purposes of this British Standard, the definitions given in BS 4422 apply, together with the following.

3.1 product. The material, composite or assembly about which information is required.

3.2 material. A basic single substance or uniformly dispersed mixture.

3.3 composite. A combination of materials that are generally recognized in building construction as discrete entities.

3.4 assembly. A fabrication of materials and/or composites, that can contain air gaps.

3.5 exposed surface. That surface of the product subjected to the heating conditions of the test.

4. Suitability of a product for testing

4.1 Surface characteristics

4.1.1 A product having one of the following is suitable for testing:

- (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 x 225 mm lies within a depth of 6 mm from a plane taken across the highest points on the exposed surface;
 - (2) for surfaces containing cracks, fissures or holes not exceeding 6.5 mm in width, the total area of such cracks, fissures or holes at the surface does not exceed 30 % of a representative square area of 225 mm x 225 mm of the exposed surface.

4.1.2 When an exposed surface does not comply with the requirements of either 4.1.1(a) or 4.1.1(b) the product may be tested in a modified form with a flat exposed surface and this shall be stated in the test report.

4.2 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 may be required to be tested.

4.3 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 10.2). In this case provision is either made to apply a suffix to the result (see 11.4.2 and clause 12(g)), or prohibit an assessment being made because the product is unsuitable for testing by this method (see 11.4.3).

NOTE. Products showing these characteristics do not necessarily behave poorly in fire situations and should be assessed by other test methods.

5. Specimen construction and preparation

NOTE. Specific advice on the testing of assemblies is given in A.2.2 and appendix B.

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

5.2 Size of specimens

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

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

5.2.3 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 $50 \pm 0, -3$ mm.

5.3 Conditioning of specimens. Before testing, the specimens shall be conditioned to constant mass (see A.3) at a temperature of 23 ± 2 °C and a relative humidity of 50 ± 10 %.

6. Test apparatus

6.1 General

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

6.1.2 The test apparatus (see figures 1 to 4) shall consist of a combustion chamber with a specimen located in 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.

6.2 Combustion chamber. The walls of the chamber shall be made from 12.5 mm thick asbestos cement board* having a dry density within the approximate range 1300 kg/m³ to 1450 kg/m³. The internal dimensions of the chamber shall be 190 mm x 190 mm x 90 mm. An air inlet slot measuring 96 mm x 25 mm and a mica observation window measuring 50 mm x 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 x 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.

6.3 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 6.2). The holder shall be recessed to take a specimen of area 225 mm x 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.

6.4 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.2.1).

6.5 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 be finished externally with a heat-resisting matt black paint or similar non-reflecting surface and shall have an overall mass in the range 530 g to 550 g (see A.4.3).

6.6 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 9.1) is in position, the holes in the tube shall be 3 + 1, -0 mm from the face of the calibration sheet.

6.7 Electric heating elements. The two heating elements shall be pencil type electric elements†, each of 1000 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 properly earthed. The framework of the apparatus, including the chimney and the cowl, shall be earthed.

6.8 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 nominal external diameter, 1.3 mm nominal 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).

Clause 6.9 Thermocouple cleaning mechanism

Delete the existing clause entirely and substitute the following:

6.9 Thermocouple cleaning mechanism. A cleaning device incorporating brushes that consist of approximately 300 strands of crimped steel wire of diameter 0.091 mm (43 s.w.g.) shall be located in such a position that the horizontally oriented strands of the brushes sweep vertically over the thermocouples in the cowl. A suitable mechanism that can be attached to the baffle plate of the test apparatus is shown in figure 4.

7.1 Manometer. The manometer shall be capable of reading up to at least 1.0 kPa† and of being read to within an accuracy of 0.05 kPa.

7.2 Gas flowmeter. The flowmeter shall be a direct-reading instrument graduated in litre/min with a maximum flow not greater than 2.5 litre/min and capable of being read to an accuracy of 0.05 litre/min. It shall be calibrated for use with a gas whose relative density‡ to air at 15 °C and 0.75 kPa is 0.36, and shall have an accuracy of ± 2 % of maximum flow.

7.3 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 8.2.

7.4 Temperature indicator. The temperature indicator shall be either a potentiometric or digital device 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, then 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.

*Obtainable from the Fire Research Station, Melrose Avenue, Borehamwood, Herts WD6 2BL.

†A commercial electric fire element with a 229 mm fixing centre is generally suitable.

‡1.0 kPa ≈ 101.97 mmH₂O.

§Formerly known as 'specific gravity' (sp gr.).

7.5 Wattmeter. The wattmeter shall be capable of measuring up to 2 kW with a sensitivity not more than $\pm 2\%$ at 2 kW, and shall be of a type that integrates voltage and amperage and does not assume constant voltage input.

7.6 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.

7.7 Electric oven. The oven shall be capable of maintaining a temperature of $103 \pm 2^\circ\text{C}$, and shall be of sufficient size to accommodate the calibration sheet (see 9.1).

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

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

7.10 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.

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

8. Setting up procedure

8.1 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.

8.2 Gas supply. Reconstituted gas* having a nominal Wobbe index of 27 MJ/m^3 and a relative density to air of 0.35 to 0.37 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 $527.5 \pm 10\text{ W}$. A method of calculating the required flow rate is described in A.5.

8.3 Interconnection of ancillary equipment and test apparatus

8.3.1 General. A line diagram of the connections between the ancillary equipment and the test apparatus is shown in figure 5.

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

8.3.3 Temperature measurement. The thermocouples shall be connected to and in series with the temperature indicator by means of compensating leads (see A.4.5). 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 6.8).

9. Calibration

9.1 Calibration sheet. A square calibration sheet with sides $225 \pm 1.5\text{ mm}$ long shall be cut from asbestos

cement board $12.5 \pm 1.0\text{ mm}$ thick (see 6.2) having a dry density of 1230 kg/m^3 to 1380 kg/m^3 after oven-drying at a temperature of $103 \pm 2^\circ\text{C}$ (see appendix C). The calibration sheet shall be kept in the desiccator after oven-drying or after completion of a previous calibration test.

9.2 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 9.4.2) and calibration shall be carried out before the start of a test of a 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.

9.3 Calibration procedure

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

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

9.3.3 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 and, where necessary (see A.2.1), back it with non-combustible material that has been conditioned prior to use by the method described for test specimens in 5.3, 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.

9.3.4 Adjust the gas flow to give a heat output of $527.5 \pm 10\text{ W}$ (see A.5) and then turn off.

9.3.5 Switch on the temperature indicator and record the initial temperature, θ_i (in $^\circ\text{C}$), measured by the thermocouples inside the cowl.

NOTE. Where the recorder has cold junction compensation, θ_i is not necessarily the initial temperature of the chimney space.

9.3.6 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 1800 W; at 5 min after the time of ignition, reduce this indicated input to 1500 W.

9.3.7 Record the output from the thermocouples, θ_r , to the nearest 1°C , at:

- (a) 0.5 min intervals, up to and including 3 min from the time at which the gas was ignited;
- (b) 1 min intervals, from 4 min up to and including 10 min from the time at which the gas was ignited;
- (c) 2 min intervals, from 10 min up to and including 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.

9.3.8 Calculate the actual temperature rise, θ_c , for the calibration sheet from the expression

$$\theta_c = \frac{\theta_r - \theta_i}{2}$$

* Premixed simulated town gas is commercially available having the following composition: methane 27.4 %, nitrogen 17.4 %, hydrogen 55.2 %.

where

θ_c is the temperature rise of the flue gases for the calibration sheet, in °C;

θ_r is the temperature recorded at the intervals specified in 9.3.7, in °C;

θ_i is the initial temperature measured by the thermocouples in 9.3.5, in °C.

NOTE. For instruments that do not have cold junction compensation, the initial temperature measured by the thermocouples in 9.3.5, θ_i , may be negative, in which case the expression for θ_c becomes

$$\theta_c = \frac{\theta_r - (-\theta_i)}{2} = \frac{\theta_r + \theta_i}{2}$$

9.3.9 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 as defined in 9.3.8;

t is the time, in min, at the intervals specified in 9.3.7.

9.4 Calibration requirements

9.4.1 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 shall be within the tolerance limits specified in table 1.

NOTE. A typical calibration curve is shown in figure 6.

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	90 to 110
10	185 to 215
20	230 to 260

9.4.2 The calibration value, C , shall not differ by more than 1.0 between successive 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.

10. Test procedure

10.1 Procedure

10.1.1 Once a satisfactory repeatable calibration is achieved, a specimen shall be removed from the conditioning chamber and mounted in the specimen holder. Where necessary (see A.2.1), it shall be backed with non-combustible packing, previously conditioned in accordance with 5.3, 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.

10.1.2 The test procedure shall be that specified in 9.3.1, 9.3.2, and 9.3.4 to 9.3.7 inclusive.

10.1.3 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, the thermocouples shall be cleaned, using the brushes, approximately 20 s before every temperature

reading after the first 3 min of test (see 9.3.7). The cleaning operation shall take not more than 3 s.

10.1.4 The temperature of the flue gases shall be recorded throughout the duration of the test. The actual temperatures at the intervals specified in 9.3.7 and the temperature rises above the initial temperature shall be noted.

10.1.5 θ_s , the temperature rise of the flue gases for the test specimen, in °C, shall be calculated by the same method specified for θ_c in 9.3.8.

10.1.6 The determination of the fire propagation index requires results from three specimens, but if any specimen exhibits the behaviour described in 10.2, then up to a maximum of five specimens shall be tested in an attempt to obtain three valid test results (see 11.4.3).

10.2 Observations during test. Throughout the test, careful observation shall be made of the material's behaviour within the apparatus (see A.7) and special note shall be taken of any of the following phenomena:

- (a) intumescence or deformation 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.

11. Calculation of results

11.1 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 10.1.4).

11.2 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 10.1.5;

θ_c is as defined in 9.3.8;

t is as defined in 9.3.9.

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