

Fire tests on building materials and structures —

Part 20: Method for determination of the fire resistance of elements of construction (general principles)

ICS 13.220.50

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Engineering Equipment and Materials User's Association	United Kingdom Atomic Energy Authority
	Wood Wool Slab Manufacturers' Association
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Association of Builders Hardware Manufacturers	Guild of Architectural Ironmongers
British Steel Industry	Hevac Association
Department of the Environment (Building Research Establishment, Fire Research Station)	Intumescent Fire Seals Association
Door and Shutter Association	National Association of Lift Makers
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	Thermal Insulation Manufacturers' and Suppliers' Association (TIMSA)

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Foreword

This part of BS 476 is published by BSI Standards Limited, under licence from The British Standards Institution.

This standard has been superseded by the current BS EN 1363-1 and BS EN 1363-2 and will be withdrawn on 2 September 2029.

This Part of BS 476 has been prepared under the direction of the Fire Standards Committee and describes the general procedures and equipment required to determine the fire resistance of elements of construction. This Part should be read together with BS 476-21, BS 476-22 and BS 476-23 as appropriate which describe the detailed procedure for the testing of individual elements of construction. The four Parts taken together constitute a complete revision of BS 476-8, which is withdrawn. However, the latter will still be made available on request, since it is referred to in building regulations and other legislative documents.

Parts 20 to 23 have been prepared in such a way that Part 20 will need to be used with the subsequent Parts described.

For the purposes of these Parts, elements of construction have been categorized into three main groups:

- a) loadbearing elements that have a fire resistance;
- b) non-loadbearing elements that have a fire resistance;
- c) elements that make a contribution to the fire resistance of a structure.

The specific requirements for the testing of these groups are described in Parts 21 to 23 respectively. Guidance and background information that will assist the designer and the testing authority to select and evaluate specimens that are more representative of situations in practice are given in appendices to the four Parts.

The revision of BS 476-8 has been prepared in order to improve repeatability and reproducibility of the results obtained by more closely defining the operating procedures and the equipment used. The main changes relate to improvements in the techniques for measuring temperature, pressure and load distribution.

Following the publication of PD 6496 which analysed the differences between the requirements of BS 476-8, ISO 834, ISO 3008 and ISO 3009, and Annex 1 of the preliminary draft on an EEC Commission Directive DG 111 (document 1202, September 1977) (now replaced by EUR 8750), this revision has, where possible, adopted similar requirements to those given in the international standards, though in some cases, improvements have been made. These improvements have tended to tighten up the procedures already specified in the other standards and will therefore remain in compliance with them.

One significant change in the method is the introduction of a fixed temperature/time heating regime which assumes a notional ambient temperature rather than the use of a temperature/rise curve that is related to the actual ambient temperature at the time of the test. The reasons for this change are described in Appendix A. In some cases, it has been requested that tests be carried out according to the so-called “hydrocarbon curve”. Although the heating regime specified in clause 3 is the exposure condition required by the standard, in order to avoid the possible confusion which might arise due to non-availability of a standard for such temperature/time curves, Appendix D includes for information a heating regime which has been proposed in ISO/DIS 834 (as a preferred option) to represent special risk requirements such as may be encountered in offshore structures, etc.

A further change has been the adoption of the minimum specimen sizes specified in ISO 834. Combined with this is a greater acceptability of smaller furnaces for testing specimens of elements that are, at full size, capable of being tested in smaller furnaces. Because of the diversity of furnace designs it has not been possible to define the equipment more tightly, although A.5 does give guidance on the points to be considered in any future furnace designs. This Part has, however, eliminated the use of oil based fuels as a method of heating a fire resistance testing furnace.

The differential pressure between the furnace chamber and the laboratory has been changed slightly with respect to the magnitude, the time of application and the measuring technique. This has been done in an attempt to rationalize the pressure difference requirements for all elements under test.

Following the decision of the International Organization for Standardization, Technical Committee ISO/TC 92, Fire tests on building materials, components and structures, to dispense with the use of the criterion of stability (ultimate integrity) in the fire resistance testing procedures for fire doors and glazed elements (ISO 3008 and ISO 3009 respectively) it has been decided to adopt a similar principle in this revision. It is no longer required, therefore, to evaluate non-loadbearing elements (see BS 476-22) with respect to compliance with a stability requirement. In order to clarify the use of stability in respect to loadbearing elements a new term, loadbearing capacity, has been introduced in this revision (see clause 2 and Appendix A). The criterion for integrity has also been slightly modified and a new term, impermeability, has been introduced in order to clarify one aspect of integrity failure.

Information on the evaluation of residual loadbearing capacity is given in Appendix B.

Attention is drawn to the Health and Safety at Work etc. Act 1974, and the need to ensure that the method of test described in this standard is carried out under suitable environmental conditions to provide adequate protection to personnel against the risk of fire, and/or 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 Asbestos Research Council¹⁾.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 42, 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⁾ Available from the Asbestos Information Centre, Sackville House, 40 Piccadilly, London W1V 9PA.

0 Introduction

The objective of determining fire resistance, as described in this Part and the associated Parts of BS 476, is to assess the behaviour of a specimen of an element of building construction when subjected to defined heating and pressure conditions. The method provides a means of quantifying the ability of an element to withstand exposure to high temperatures, by setting criteria by which the loadbearing capacity, the fire containment (integrity) and the thermal transmittance (insulation) functions can be adjudged.

However, the standardized temperature/time conditions used in this evaluation are representative of only one possible fire exposure condition at the fully developed fire stage and the method does not quantify the behaviour of an element, for a precise period of time, in a real fire situation (see A.1) and Appendix D. The principle of the method is as follows.

A representative sample of the element is exposed to a specified regime of heating and the performance of the test sample is monitored on the basis of criteria described in the standard. Fire resistance of the test element is expressed as the time for which the appropriate criteria have been satisfied. The times so obtained are a measure of the adequacy of the construction in a fire but have no direct relationship with the duration of a real fire.

The test data can be used directly to show compliance with fire resistance requirements in regulations, byelaws or other safety specifications. The tests can also be used to study the behaviour of constructions at high temperatures and obtain guidance on the effect of design features on fire resistance. It is intended to extend the application of test data by agreed procedures for interpolation and extrapolation. Due to restrictions of size and the absence of surrounding construction the laboratory test cannot reproduce the actual behaviour pattern of an element in a fire. However, test data can provide a basis for making engineering evaluations. A future Part of the standard will address itself to these aspects.

1 Scope

This Part of BS 476 describes a procedure for a laboratory test for the determination of fire resistance of elements of construction.

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 apply, together with the following.

2.1

associated construction

a form of construction that may be required for the testing of some elements of construction and to which the test specimen is connected, e.g. the wall into which a glazed element would be fitted

2.2

collapse

the mechanical failure of the complete specimen that allows it to fall from the position into which it has been fixed

2.3

fire resistance

the time for which an element of building construction is able to withstand exposure to a standard temperature/time and pressure regime without a loss of its fire separating function or loadbearing function or both

2.4

fixity

the conditions at the edges, ends or supports of a test specimen through which the applied test load is either being applied or reacted (either directly or by induced moments)

2.5

restraint

the conditions at the edges, ends or supports of a test specimen through which the movement of the specimen is constrained (Examples of restraint are shown in Figure 1.)

2.6

furnace closure

a suitable form of construction designed to fill the space between the permanent opening of the furnace and the test construction so that the specified furnace conditions are maintained for the duration of the test without interconnection between the test construction and the furnace closure and which has no significant effect on the behaviour of the test specimen

2.7

impermeability

the ability of a specimen of a separating element to restrict the egress of hot gases from the unexposed face of the specimen causing ignition of the cotton pad

2.8**insulation**

the ability of a specimen of a separating element to restrict the temperature rise of the unexposed face to below specified levels

2.9**integrity**

the ability of a specimen of a separating element to contain a fire to specified criteria for collapse, freedom from holes, cracks and fissures and sustained flaming on the unexposed face

2.10**loadbearing capacity**

the ability of a specimen of a loadbearing element to support its test load, where appropriate, without exceeding specified criteria with respect to either the extent of, or rate of, deformation or both

2.11**specimen**

an element of building construction provided for the purpose of determining either its fire resistance or its contribution to the fire resistance of another building element

2.12**sustained flaming**

flaming that is visible with the naked eye and that remains visible for an uninterrupted period of not less than 10 s

2.13**test construction**

a complete assembly of a specimen and its associated construction if incorporated

2.14**separating element**

an element that is required to satisfy the criteria of integrity and insulation, in addition to loadbearing capacity if applicable, for the purposes of maintaining separation between two adjacent areas of a building in the event of a fire

3 Test conditions**3.1 Heating conditions****3.1.1 The standard temperature/time curve**

3.1.1.1 The temperature/time conditions (see Figure 2, A.2.1 and A.2.2) shall be as given by the equation

$$T = 345 \log_{10} (8t + 1) + 20$$

where

T is the mean furnace temperature (in °C);

t is the time (in min) up to a maximum of 360 min.

3.1.1.2 The mean furnace temperature (T) as given by the furnace thermocouples specified in C.1.2 shall be controlled such that it will comply with 3.1.1.1 within the tolerances specified in 3.1.2.

3.1.2 Tolerances

3.1.2.1 For the purpose of computing the percentage deviation (p), the areas under the respective temperature/time curves shall be computed (see A.2.3) at a minimum of the following time intervals:

0 min to	10 min at	1 min intervals
10 min to	30 min at	2 min intervals
30 min to	120 min at	5 min intervals
120 min to	360 min at	10 min intervals

Any deviation calculated in accordance with 3.1.2.2 shall be within the following limits:

- less than 15 % to the end of the first 10 min of the heating period or to the end of the test if this is less than 10 min;
- less than 10 % from 10 min to the end of the first 30 min of the heating period or to the end of the heating period if this is greater than 10 min but less than 30 min;
- less than 5 % from 30 min to the end of the heating period.

3.1.2.2 The percentage deviation (p) in area of the mean furnace temperature/time curve from the standard temperature/time curve is given by:

$$p = \frac{A - B}{B} \times 100$$

where

- is the area under the mean furnace temperature/time curve;
- is the area under the specified temperature/time curve.

3.1.3 Uniformity of temperature distribution. At any time after the first 10 min of the heating period, the temperature rise indicated by any of the thermocouples used to determine the mean furnace temperature shall not differ from the corresponding temperature rise given by the standard temperature/time curve by more than 100 °C.

With test constructions where either the specimen or any associated construction incorporates combustible materials that produce flaming within the furnace which can be identified to be causing localized heating or cooling of one or more of the furnace thermocouple hot junctions, the deviation of temperature rise recorded by that or those thermocouples so affected from the standard temperature curve shall not exceed 200 °C.

3.2 Pressure conditions

3.2.1 General. After the first 5 min of the heating period and for the remainder of its duration, a positive pressure relative to the laboratory shall be established within the furnace. This pressure shall be controlled to satisfy the requirements specified in **3.2.2** and **3.2.3** for the respective elements (see **A.2.4**).

3.2.2 Separating elements. The test construction shall be subjected to a pressure condition similar to that which would apply if a linear pressure gradient of 8.5 Pa per 1 000 mm height is assumed to exist together with a neutral pressure axis at a height of approximately 1 000 mm above the notional floor level. The pressure at any position on a vertical test construction and on the underside of a horizontal test construction shall be determined with respect to the elements positional height relative to notional floor level. The pressure condition shall be controlled to within ± 2 Pa. Notwithstanding the above, the pressure at the top of a vertical test construction and at the underside of a horizontal test construction shall at no time exceed a maximum value of 20 Pa.

3.2.3 Non-separating elements. Non-separating elements shall be subjected to similar pressure conditions as appropriate to separating elements with the same orientation, i.e. beams as per floors, columns as per walls.

NOTE The neutral pressure axis for vertical non-separating elements may be at a height of up to 2 000 mm (see clause 3 of BS 476-21:1987).

3.3 Ambient conditions within the laboratory

3.3.1 The ambient air temperature, as measured by the ambient temperature thermometer specified in **C.1.1**, in the general vicinity of the test construction shall be within 5 °C to 35 °C immediately prior to the heating period (see **A.2.5**, **C.7.3.2** and **C.7.3.3**).

3.3.2 For tests on separating elements where measurements of the unexposed face temperature rise are made in order to determine compliance with **10.4**, the following additional requirements shall apply:

- a) 30 min prior to the commencement of the test, the mean unexposed face temperature as indicated by the thermocouples specified in **6.4.2.1** shall be within 5 °C of the ambient temperature, but shall be not less than an actual temperature of 5 °C;
- b) during the course of the heating period the ambient temperature shall not increase above its initial value by more than 5 °C up to the time of insulation failure;

c) measurements shall be made in essentially draught free conditions.

3.3.3 For tests on separating elements where the unexposed face temperature is only being determined for other reasons, e.g. for determining the time at which to discontinue the use of the cotton pad (see **10.3.2**), the conditions a) and c) specified in **3.3.2** shall be complied with but the temperature rise in b) is permitted to increase by 15 °C.

3.4 Loss of accuracy

Where the mean furnace temperature, pressure conditions and ambient conditions in the laboratory create more severe conditions than those specified in **3.1**, **3.2** and/or **3.3**, the actual test result achieved may still be accepted as valid (see items g), k) and m) of clause **12** and **A.2.7**).

4 Test specimen

4.1 General

The test specimen and any associated construction forming a test construction shall be identical to, or representative of, the element of building construction that is to be evaluated. The specimen and any associated construction shall not be in such a state at the start of the test that the specimen would fail the permeability criteria as defined by the use of the gap gauges [see **10.3.2 b**]).

NOTE The choice of the associated construction may be significant to the performance of the test specimen, and reference should be made to the guidance notes given in the appendices of BS 476-21 to BS 476-23 relevant to the element under test.

The test construction only represents the element of construction when the conditions of load, restraint and fixity used during the test are identical to, or typical of, those used in practice. If information is required to determine the behaviour of the construction under different end or edge conditions or to determine the effect of special aspects of the construction, which are not an essential or integral part of the element, then additional test(s) shall be carried out.

4.2 Design considerations

The test construction shall be designed so that the critical aspects of the element are incorporated in the specimen (see **A.3.1**). In designing a specimen and its associated construction the influence of joints, incorporated services, finishes, openings for access and vision, etc. shall be considered. Unless evidence exists indicating that these features will not have a deleterious effect, they shall be incorporated in the construction to be tested.

The influence and interactions between the element of construction and its adjacent supporting construction shall be carefully considered such that any associated construction used in conjunction with the test specimen shall have similar influences as in practice.

4.3 Manufacture of the test construction

All materials and constructional methods used in the manufacture of the test construction shall be representative of the intended use of the element, and shall be described in the report (see A.3.2).

If it is necessary to modify an element in order to produce a construction that will fit into the furnace or to facilitate an evaluation of a particular design feature, then full details of the design of the specimen and details of the modifications made shall also be included in the report.

The properties of any material component used in the test construction that have a significant effect on the fire resistance of the specimen shall be reported. The report shall include either the source of the information, or if particular properties are measured details of the method used (see A.3.3).

4.4 Number of specimens

For non-separating elements, separating elements that are only required to resist fire from one side in use, and for vertical symmetrical separating elements, one specimen shall be tested (see A.3.4).

For vertical asymmetrical separating elements that are required to resist fire from either side, the element shall be tested from each side using a separate specimen. However, if it is possible to ascertain the direction of exposure that will give the lesser fire resistance, one test may be carried out exposing the specimen to the furnace in its anticipated weaker direction, in which case the reasons for this shall be clearly stated in the report.

4.5 Size of specimen

Whenever possible, the test specimen and where appropriate any associated construction shall be a full sized element of building construction. Unless it is impossible, the individual components making up a test specimen shall be full size (see A.3.5).

When the element exceeds the size that can be accommodated by the furnace, the minimum size of element exposed to the heating conditions in the furnace shall be:

non-separating elements:	vertical	3 m high
	horizontal	4 m span
separating elements:	vertical	3 m high by 3 m wide
	horizontal	4 m span by 3 m wide

When the element, and hence the specimen, is smaller than the aperture available in the appropriate furnace, either an associated construction shall be provided with the specimen of such dimensions to give a test construction of the necessary size or furnace closures of the requisite size shall be used.

4.6 Condition of the test construction

When a test construction incorporates materials that are either time or moisture sensitive, these materials shall, at the time of test, be at a condition approximating to the state of strength and moisture content that would be expected in normal service.

NOTE Where this is not known or cannot be achieved, the moisture content levels given in A.3.6 should be used.

The moisture content of hygroscopic materials and the state of time sensitive materials shall, where accessible, be determined prior to test and shall be quoted in the test report together with the method used for their determination.

When it is not practicable to ascertain the condition of component material(s) of a test specimen, e.g. fully encapsulated materials, the report shall state that the condition has not been determined.

5 Selection of support and loading conditions

5.1 For non-loadbearing elements the test construction shall be mounted as realistically as possible using the fixing details employed in practice (see A.4.1).

5.2 For loadbearing elements, the condition at the ends or edges of the test construction through which the test loading is applied or reacted shall be selected to ensure that they represent the condition applicable to the element in practice. Any fixity shall be taken into account in calculating the test loading and, where possible, provision shall be made to measure the extent of any fixing moments or loads achieved. For loadbearing elements, those edges or ends through which no load is transmitted shall be totally unrestrained.

5.3 When the test construction is representative of a loadbearing element, it shall be subjected to a test loading (see A.4.2). The basis for selecting the test loading and the magnitude and direction of the loading shall be clearly stated in the report.

When an element in use is larger than the specimen for test, the nature, magnitude and the distribution of the test loading shall be carefully selected in order to subject the test construction to critical stress levels of the same nature and magnitude as those likely to be encountered by the element in practice. If the magnitude and the distribution of the load is different from that used in practice in order to achieve these requirements, the relationship between the stresses generated by the test loading and the stresses experienced by the element in use shall be explained in the test report.

6 Apparatus

6.1 Furnace

NOTE All dimensions given in the description of the furnace and its associated equipment are nominal unless tolerances are specified.

6.1.1 The furnace shall be of a design (see **A.5.1**) appropriate to the type of specimen being tested, as to allow:

- a) vertical separating elements to be exposed to the heating and pressure conditions on one face;
- b) horizontal separating elements to be exposed to heating and pressure conditions from the underside;
- c) beams normally to be exposed to the heating and pressure conditions on three faces, i.e. the soffit and two sides, but provision should be made to enable beams to be tested with all four faces exposed;
- d) free standing columns to be exposed to the heating and pressure conditions equally on all four faces.

6.1.2 The furnace shall be able to accommodate the full sized element of construction or the minimum size of test construction specified in **4.5** where the element is of a larger size. Reduced size furnaces can be used for testing small, but full sized elements. Where a reduced size furnace is used (i.e. a furnace with an opening not greater than $1.5\text{ m} \times 1.5\text{ m}$), the furnace aperture shall be greater in area than the exposed face of the specimen by a ratio of at least 1.5 : 1. The additional area between the element and the furnace aperture shall be filled by means of an associated construction or a furnace closure as appropriate.

6.1.3 Vertical furnaces shall have a chamber depth, i.e. the distance between the exposed face of the specimen and the face of the furnace lining immediately opposite the specimen, of not less than 600 mm and not more than 1 300 mm excluding any areas where flues or other openings enter the furnace chamber. The total area of such flues and other openings shall not exceed 25 % of the surface area of the wall in which they occur. Furnaces for testing columns shall have a minimum horizontal dimension of 1.4 m.

6.1.4 Horizontal furnaces shall have a chamber depth, i.e. the distance between the soffit of the floor or the beam and the face of the furnace floor below, of not less than 1 000 mm and not more than 2 000 mm excluding any areas where flues or other openings enter the furnace chamber. The total area of such flues and other openings shall not exceed 33 % of the floor area.

NOTE For smaller furnaces a small reduction in furnace depth to less than 1 m may be satisfactory provided uniform heating of the specimen can be obtained.

6.1.5 The furnace shall be heated with burners that are fired using either natural gas or liquefied petroleum gases. The heat output of the burners shall be controllable and shall be sufficient to expose the specimen to the heating and pressure requirements specified in **3.1** and **3.2** respectively.

NOTE The mixture of fuel and air to each burner should be nominally constant over the burner's operating range.

The furnace shall be provided with exhaust ports connected to a suitable exhaust gas handling and control system that allows control of the furnace pressure to comply with **3.2**.

6.1.6 The furnace shall be provided with thermocouples and linked to associated temperature measuring devices as specified in **C.1.2** and **C.2.2.2** for determining the temperatures at specified positions in the furnace as described for each type of specimen tested (see BS 476-21 to BS 476-23).

6.1.7 The furnace shall be provided with a pressure sensing probe as specified in **C.1.3** situated within the furnace at a specified position as described for each type of specimen evaluated (see BS 476-21 to BS 476-23). The pressure sensing probe shall be connected to a furnace pressure indicator (see **C.2.2.3**). The measurement of the static pressure within the furnace shall be made relative to the static pressure outside the furnace.

6.1.8 In order to define the start of the test the temperature shall be continuously indicated and the display shall be clearly visible to the furnace operator for the purpose of starting the timing device.

A timing device complying with C.2.3 shall be available for the furnace operator.

6.1.9 The furnace shall be located in a room of adequate size to allow easy access to the furnace and its associated equipment and safe handling of specimen constructions.

6.2 Loading equipment

6.2.1 General. The method of applying the test loading to the specimen shall be either by dead weights or by a hydraulic or mechanical jacking system, or by a combination of dead weights and a jacking system. The choice shall normally be dictated by practical convenience, considering the type of element and the type and magnitude of the loading required. Irrespective of the method chosen, the method of loading shall not significantly affect the natural thermal behaviour of the specimen. Similarly, the method of loading shall not limit the movement of the specimen nor in any other way influence the natural mechanical behaviour of the element.

6.2.2 Dead-weight loading. The uniformly distributed loading shall be simulated by at least four nominally equal point loads on every square metre of the specimen. The accuracy of the individual weights shall be within ± 2.5 % of their nominal value and they shall contact the surface of the specimen via legs that will not unduly impair the performing of such monitoring checks as are appropriate, e.g. the use of the cotton pad or the roving thermocouple. The total area of the contact points between the dead weights and the test specimen surface shall not exceed 10 % of the total area of the surface of the test specimen. The individual contact areas shall not be so small that they cause excessive localized stresses. The distribution of dead weights over the surface of a specimen shall be as uniform as possible.

For beams, the maximum value of any single dead weight (in kN) used to simulate a uniformly distributed load shall not exceed 25 % of the required uniformly distributed loading (in kN/m).

The loading of vertical separating elements shall not be applied by means of dead weight unless the value of the applied load is so low that the use of mechanical or hydraulic loading systems is impracticable.

6.2.3 Mechanical or hydraulic loading. The loading system shall be designed such that the loads are applied gradually to avoid shock loads and the direction and the magnitude of the force exerted by each individual loading unit remains constant (i.e. ± 2 % as specified in 9.1.2) throughout the duration of the test and is not changed by the deformation of the specimen. For horizontal elements, articulation and/or freedom for movement of the contact position shall be provided, either at the point of application of the loading or within the loading distribution system.

The load shall be applied uniformly over the surface so that at any single point the load does not exceed 10 % of the total load.

For beams that are hydraulically or mechanically loaded to simulate the uniformly distributed load, the load shall be applied by at least four nominally equal points.

NOTE When vertical separating elements are carrying a uniformly distributed load, the required total load may be applied through a suitable spreader beam.

When the element contains discrete loadbearing members, the loading system shall be designed so as to ensure that significant load sharing does not occur.

For horizontal elements, the mechanical or hydraulic loading system shall be capable of following a maximum rate of deformation of the test specimen of 50 mm/min with a maximum deformation of 250 mm. For vertical elements, the system shall be capable of following a maximum rate of deformation of 25 mm/min with a maximum deformation of 120 mm.

6.3 Specimen support systems

6.3.1 Provision of restraint. Any framework used to apply restraint at the edges or the ends of the test specimen shall have sufficient rigidity and stiffness to resist the forces exerted by any thermal movement induced during the test. It shall have provision for allowing the specimen edges or ends to be fixed in a manner representative of that used in practice.

6.3.2 Loading and fixity. Where the loading system requires the applied test loading to be reacted back to the specimen support positions, the furnace and/or the support/reaction frame shall have sufficient strength and stiffness to resist any distortion that may affect the performance of the test specimen or that may modify the applied loading.

6.4 Instrumentation

6.4.1 Measuring and control equipment, to monitor the test construction, the laboratory and the furnace environment and the behaviour of the test sample during the test.

NOTE Details of the instrumentation needed for the measurement of temperature, pressure and load are given in Appendix C.

6.4.2 Monitoring equipment

6.4.2.1 Fixed specimen surface thermocouples, constructed as shown in Figure 3, and consisting of either type T, type N or type K thermocouple wires complying with BS 4937-4 or BS 4937-5, with a maximum diameter of 0.5 mm, brazed to a 12 mm diameter, 0.2 mm thick copper disc. Each thermocouple shall be provided with a 30 mm square, 2 ± 0.5 mm thick pad of insulation material. This insulation material shall have a dry density of 900 ± 90 kg/m³, a thermal conductivity of 0.13 W/(m·K) $\pm 10\%$ at 100 °C, and shall be of a material capable of withstanding temperatures of 400 °C without any change in mechanical or physical properties. The insulation pads shall be slotted or provided with holes to accommodate the thermocouple wires.

The wires from the thermocouples shall be connected either directly or via compensating leads to an appropriate temperature indicator (see C.2.2.4).

6.4.2.2 Roving surface thermocouple, with a measurement junction consisting of either type T, type N or type K thermocouple wires complying with BS 4937-4 or BS 4937-5, with a diameter of 1.0 mm, brazed to a 12 mm diameter, 0.5 mm thick copper disc (a copper/constantan wire thermocouple with a diameter of 0.5 mm may also be used). The wires of the thermocouple shall be bent normal to the rear face of the copper disc to allow them to be inserted into separate holes in a porcelain insulator as shown in Figure 4. The porcelain insulator shall have a diameter of 6 mm to 10 mm and shall contain two holes of approximate 2 mm diameter. The distance between the rear face of the copper disc and the end of the insulator shall be 6 ± 1 mm.

The wires from the thermocouple shall be connected to an appropriate temperature indicator (see C.2.2.5).

6.4.2.3 Cotton pad, used for monitoring of permeability and consisting of new, undyed and soft cotton fibres, without any admixtures of man-made fibres, and shall be 100 mm square by 20 mm thick and shall have a mass of between 3 g and 4 g. It shall be dried in an oven at 105 ± 5 °C for at least 30 min and then stored in a desiccator to cool and until ready for use.

It shall be placed, immediately prior to use, in the wire holder shown in Figure 5.

6.4.2.4 Gap gauges (as shown in Figure 6), used for monitoring of impermeability. They shall be made of steel rod of the diameter specified to an accuracy of ± 0.5 mm. They shall be provided with handles that are of sufficient length to ensure operator safety without detracting from the accuracy and care which may be needed in determining the point of any failure.

6.4.2.5 Deformation measuring devices, for measuring deformation of the test specimen having a range sufficient to take account of any deformation due to the initial application of the test load, any creep experienced under the test load prior to the heating period, and any deformation that occurs during the heating period. The measurement shall be accurate to ± 1 mm.

Provision shall normally be made for the measured deformation to be indicated and recorded remote from the test specimen. The deformation indicated by the devices shall be displayed continuously or updated at intervals not exceeding 15 s. The deformation shall be displayed and logged at 1 min intervals from the commencement of the heating period, on the minute, for calculation of the rate of deformation of the specimen.

6.4.2.6 Radiometer. The radiometer shall be capable of measuring irradiance within the range 0 to 100 kW/m². The time constant shall be not more than 3 s (corresponding to a time to reach 95 % of final output in not more than 10 s). The instrument shall normally be calibrated with the target vertical in which case the sensitivity shall not change by more than 1 % when the instrument is used with the target horizontal. The target receiving radiation shall be circular, flat, not more than 10 mm diameter, and coated with a durable matt black finish. The target shall be within a water or air cooled body whose front face shall be flat and coincident with the plane of the receiving face of the target. Radiation shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, insensitive to draughts and stable in calibration. The instrument shall have an accuracy of within $\pm 3\%$ and a repeatability within $\pm 0.5\%$.

The output from the radiometer shall be measured on an appropriate millivolt measuring device (see C.2.2.6).

6.4.2.7 Specimen internal thermocouples, for measuring internal temperatures.

NOTE Determination of internal temperatures is not required. When these are to be determined for information purposes, the guidance given in A.6.2.5, A.8.2 and C.4.1.3 should be followed.

6.4.2.8 Recording and ancillary equipment, required for the following purposes:

- a) furnace temperature;
- b) furnace pressure;
- c) specimen interior temperature;
- d) fixed and roving furnace temperature devices;
- e) radiation measuring devices;
- f) timing devices.

NOTE The type of equipment suitable for such purposes is described in C.2.

7 Examination of specimen

A full and detailed specification of the test specimen shall be provided by the test sponsor prior to the installation of the test specimen at the laboratory. This specification shall be to a level of detail sufficient to allow the laboratory to conduct a detailed examination of the specimen in accordance with C.3 before the test and to agree with the sponsor the accuracy of the specimen specification.

NOTE A.7 provides guidance on the important characteristics to be noted.

8 Preparation of specimen

The procedure for fixing thermocouples, installing the specimen, applying restraint, measurement of radiation and other essential steps to be taken before a test can be undertaken shall be as given in C.4.

9 Test procedure

9.1 General

NOTE The procedure for conducting the test and measurements and observations to be made during the course of the test are defined in 9.1.1 to 9.1.3 and details are described in C.9 to C.11.

9.1.1 Ambient temperature measurements. Measure the ambient temperature, using the ambient temperature thermometer or thermocouple. Do not commence heating until the ambient temperature is within the specified limits.

9.1.2 Application of the test loading. For loadbearing elements, apply the test loading in such a way as to obtain stable conditions not less than 15 min before the commencement of the heating period. Maintain the load constant within $\pm 2\%$ until the test is terminated.

9.1.3 Establishment of datum values. Not more than 15 min before the commencement of heating take and record datum values for each individual temperature measurement, deflection measurement and any other supplementary measurement, e.g. radiation.

9.2 Heating procedure

Commence heating of the specimen and control the furnace temperature to comply with 3.1 and the furnace pressure to comply with 3.2.

9.3 Monitoring of criteria

Throughout the heating period monitor the behaviour of the specimen for compliance with the relevant criteria in clause 10 and the appropriate clauses of BS 476-21, BS 476-22 or BS 476-23.

9.4 Other observations

Monitor and record any significant deflection of the specimen even when not required as a criteria for failure. Monitor and record the radiation flux emitted from the unexposed face of separating elements using the radiometer specified in 6.4.2.6 (see A.9.4).

9.5 Termination of test (see also A.9.5)

9.5.1 Continue heating until failure occurs under one or more of the relevant performance criteria or at a time agreed between the sponsor and the test laboratory. If the heating is terminated before failure, the duration of heating is deemed to be the fire resistance of the specimen.

9.5.2 For non-loadbearing constructions, terminate the test at the end of the heating period.

9.5.3 For loadbearing constructions, terminate the test at the end of the heating period.

NOTE An evaluation of the residual loadbearing capacity may be carried out in which case terminate the test following completion of the procedure described in Appendix B.

10 Performance criteria

10.1 General

The fire resistance of the test construction shall be assessed against one or more of the criteria for loadbearing capacity, integrity and insulation, whichever are relevant to the elements used in practice (see A.10 and BS 476-21 to BS 476-23).

10.2 Loadbearing capacity

10.2.1 General. A failure of the test construction to maintain its loadbearing capacity (see 2.10) shall be deemed to have occurred when any of the requirements specified in 10.2.2 and 10.2.3 are exceeded.

10.2.2 Loadbearing vertical elements. Failure of the test construction shall be deemed to have occurred when the specimen fails to support the test loading (see A.10).

10.2.3 Loadbearing horizontal elements. The test specimen shall be deemed to have failed if it is no longer able to support the test load. For the purposes of this standard, this shall be taken as either of the following, whichever is exceeded first:

- a) a deflection of $L/20$; or
- b) where the rate of deflection (in mm/min), calculated over 1 min intervals, starting at 1 min from the commencement of the heating period, exceeds the limit set by the following equation:

$$\text{rate of deflection} = \frac{L^2}{9000d}$$

where

- L is the clear span of specimen (in mm);
- d is the distance from the top of the structural section to the bottom of the design tension zone (in mm).

However, this rate of deflection limit shall not apply before a deflection of $L/30$ is exceeded.

NOTE *Residual loadbearing capacity.* The residual loadbearing capacity of both vertical and horizontal loadbearing test constructions may be determined following the procedure described in Appendix B.

10.3 Integrity

10.3.1 General. A failure of the test construction to maintain integrity shall be deemed to have occurred when collapse or sustained flaming on the unexposed face occurs or the criteria given in 10.3.2 for impermeability are exceeded (see clause 2).

10.3.2 Impermeability. Failure shall be deemed to have occurred when one or other of the following conditions prevail.

- a) For situations where the cotton pad (6.4.2.3) is suitable (see C.10.3.2), failure shall be deemed to have occurred when flames and/or hot gases cause flaming or glowing of the cotton fibre pad.
- b) For situations where the use of the cotton pad is not suitable, failure shall be deemed to have occurred when either:
 - 1) the 6 mm diameter gap gauge can penetrate a through gap such that the end of the gauge projects into the furnace and the gauge can be moved in the gap for a distance of at least 150 mm; or
 - 2) the 25 mm diameter gap gauge can penetrate a through gap such that the end of the gauge projects into the furnace.

10.4 Insulation

Failure shall be deemed to have occurred when one of the following occurs:

- a) if the mean unexposed face temperature increases by more than 140 °C above its initial value;
- b) if the temperature recorded at any position on the unexposed face, either by a fixed thermocouple (see 6.4.2.1) or by the roving thermocouple subject to the following provisions (see 6.4.2.2) is in excess of 180 °C above the initial mean unexposed face temperature;
- c) when integrity failures as defined in 10.3 occur.

Temperatures measured by the roving thermocouple placed on a flat surface that has a minimum 12 mm diameter flat surface to which the disc can be applied shall be included in the evaluation of maximum temperature criterion.

Temperatures measured by the roving thermocouple, placed on small features that have a minimum 6 mm diameter flat surface, shall only be used in the evaluation of the maximum temperature criterion if the aggregate area of this or these features exceeds 0.1 % of the specimen surface area within any 1 m² of surface area.

11 Expression of results

11.1 The test results shall be stated in terms of the elapsed time rounded down, to the nearest minute, between the commencement of heating and failure under one or all of the criteria given in clause 10. If no integrity or insulation failure occurred in a separating element during the heating period, then the times stated for these criteria shall be the elapsed time between the commencement and the termination of the heating.

11.2 With respect to the loadbearing capacity of a loadbearing specimen, the time stated shall be the elapsed time between the commencement of heating and the termination of heating or failure to meet the loadbearing capacity criterion whichever is the sooner.

11.3 In no case shall the period taken for insulation failure to occur exceed the period given for integrity failure to occur.

NOTE An example of the method of expressing the results is given in A.11.

11.4 The results of the test shall be contained in a test report as specified in clause 12.

NOTE In the event of the test being performed to determine the residual loadbearing capacity of a test construction, a supplementary report should be prepared as stated in Appendix B.