BS ISO 834-10:2014

BSI Standards Publication

Fire resistance tests — Elements of building construction

Part 10: Specific requirements to determine the contribution of applied fire protection materials to structural steel elements

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 834-10:2014.

The UK participation in its preparation was entrusted to Technical Committee FSH/22/-/12, Fire resistance tests For Protection Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 78004 2

ICS 13.220.50

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2014.

Amendments issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 834-10

First edition
2014-03-01

Fire resistance tests — Elements of building construction —

Part 10: Specific requirements to determine the contribution of applied fire protection materials to structural steel elements

Essais de résistance au feu — Éléments de construction —

Partie 10: Exigences spécifiques pour déterminer la contribution des matériaux de protection appliqués aux éléments des structures en acier

Reference number
ISO 834-10:2014(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

ISO 834 consists of the following parts, under the general title *Fire resistance tests — Elements of building construction*:

— *Part 1: General requirements*

— *Part 2: Guidance on measuring uniformity of furnace exposure on test samples* [Technical Report]

— *Part 3: Commentary on test method and guide to the application of the outputs from the fire-resistance test* [Technical Report]

— *Part 4: Specific requirements for loadbearing vertical separating elements*

— *Part 5: Specific requirements for loadbearing horizontal separating elements*

— *Part 6: Specific requirements for beams*

— *Part 7: Specific requirements for columns*

— *Part 8: Specific requirements for non-loadbearing vertical separating elements*

— *Part 9: Specific requirements for non-loadbearing ceiling elements*

— *Part 10: Specific requirements to determine the contribution of applied fire protection materials to structural steel elements*

— *Part 11: Specific requirements for the assessment of fire protection to structural steel elements*

— *Part 12: Specific requirements for separating elements evaluated on less than full scale furnaces*

Introduction

This part of ISO 834 specifies a method for testing fire protection systems applied to structural steel members employed in buildings as beams, columns, or tension members. This part of ISO 834 is intended for use in conjunction with the assessment protocol described in ISO 834-11.

Fire resistance tests — Elements of building construction —

Part 10:
Specific requirements to determine the contribution of applied fire protection materials to structural steel elements

1 Scope

This part of ISO 834 specifies a method for testing fire protection systems applied to structural steel members used in buildings as beams, columns, or tension members. This part of ISO 834 is intended for use in conjunction with the assessment protocol described in ISO 834-11. It applies to steel sections (including hollow sections) and only considers sections without openings in the web. Results from analysis of I or H sections are directly applicable to angles, channels, and T-sections for the same section factor, whether used as individual members, e.g. bracing, or part of a fabricated structural system such as a steel truss construction. This part of ISO 834 does not apply to solid bar, rod, or concrete-filled hollow sections.

This part of ISO 834 describes the fire test procedures that specify the tests which should be carried out to determine the ability of the fire protection system to remain sufficiently coherent and in position for a well-defined range of deformations, furnace, and steel temperatures, such that the efficacy of the fire protection system is not significantly impaired, and to provide data on the thermal characteristics of the fire protection system when exposed to the standard temperature/time curve specified in ISO 834-1.

In special circumstances, where specified in National Building Regulations, there can be a requirement to subject reactive fire protection materials to a smouldering curve. The test and the requirements for its use are described in Annex G.

This part of ISO 834 is applicable to both passive and reactive fire protection systems as defined in the terms and definitions, which are installed or applied in such a way that they remain in place for the intended duration of fire exposure.

The fire test methodology makes provision for the collection and presentation of data which is then used as direct input into ISO 834-11 to determine the limits of direct application to steel sections of various shapes, sizes, and fire resistance periods.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO 834-6, *Fire-resistance tests — Elements of building construction — Part 6: Specific requirements for beams*

ISO 834-7, *Fire-resistance tests — Elements of building construction — Part 7: Specific requirements for columns*

ISO 1182:2010, *Reaction to fire tests for products — Non-combustibility test*

ISO 1716, *Reaction to fire tests for products — Determination of the gross heat of combustion (calorific value)*

ISO 8421-2, *Fire protection — Vocabulary — Part 2: Structural fire protection*

ISO 13943, *Fire safety — Vocabulary*

IEC 584-1, *Thermocouples – Part 1: Reference tables*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 834-1, ISO 13943, ISO 8421-2, and the following apply.

3.1
characteristic steel temperature
temperature of the structural steel member which is used for the determination of the correction factor for stickability calculated as (mean temperature + maximum temperature)/2

3.2
design temperature
temperature of the steel member for structural design purposes

3.3
fire protection
protection afforded to the steel member by the fire protection system such that the temperature of the steel member is limited throughout the period of fire exposure

3.4
fire protection system
fire protection material together with any supporting system including mesh reinforcement as tested

Note 1 to entry: The reactive fire protection materials system includes the primer and top coat if applicable.

3.5
fire protection thickness
dry thickness of a single-layer fire protection system or the combined thickness of all layers of a fire protection system

Note 1 to entry: The thickness of elements of the supporting system or joint cover strips are not included in the fire protection thickness.

Note 2 to entry: For reactive fire protection systems, the thickness is the mean dry film thickness of the coating excluding primer and top coat if applicable.

3.6
H section
steel member with wide flanges compared with the section depth whose main function is to carry axial loads parallel to its longitudinal axis which can be combined with bending and shear

3.7
I section
steel joist or girder with short flanges shaped like a letter "I" whose main function is to carry loads transverse to its longitudinal axis

Note 1 to entry: These loads usually cause bending of the beam member. The flanges may be parallel or tapered.

3.8
passive fire protection material
materials, which do not change their physical form on heating, providing protection by virtue of their physical or thermal properties

Note 1 to entry: They may include materials containing water or undergo endothermic reactions which, on heating, produce cooling effects. These may take the form of sprayed coatings, renderings, mat products, boards, or slabs.

3.9
reactive fire protection material
materials which are specifically formulated to provide a chemical reaction upon heating such that their physical form changes and in so doing provide fire protection by thermal insulative and cooling effects

3.10
reference section
steel section which is taken from the same length of steel as its equivalent loaded section

3.11
section factor (unprotected steel)
ratio of the fire exposed perimeter area of the structural steel member, per unit length, A_m, to its cross sectional volume per unit length, V

3.12
section factor (profiled fire protection systems):
ratio of the fire-exposed outer perimeter area of the steel structural member excluding the protection material, per unit length, A_m, to its cross-sectional volume per unit length, V

3.13
section factor (boxed fire protection systems)
ratio of the internal surface area of the smallest possible rectangle or square box encasement which can be measured around the steel structural member, A_m, to its volume per unit length, V

3.14
steel member
element of building construction, which is load bearing and fabricated from steel

Note 1 to entry: For the purpose of this part of ISO 834, the steel used in the testing must be of the same type.

3.15
steel temperature
overall mean temperature to be used as input data for the analysis which is calculated as follows:

— For I and H section beams, this refers to the mean of the upper flange temperatures plus the mean temperature of the web plus the mean temperature of the lower flange, divided by three.

— For I, H, and hollow section columns, this refers to the sum of the mean temperature of each measuring station divided by the number of measuring stations.

— For hollow section beams, this refers to the mean temperature of the sides of the section plus the mean temperature of the bottom face, divided by two

3.16
stickability
ability of a fire protection system to remain sufficiently coherent and in position for a well-defined range of deformations, furnace, and steel temperatures, such that its ability to provide fire protection is not significantly impaired

3.17
test package
set of steel sections which may include short or long specimens that is tested to demonstrate adequate stickability of the fire protection system and to provide thermal data over a range of protection thickness, steel section factor, and steel temperatures

3.18
test specimen
steel section plus the fire protection system under test

Note 1 to entry: The steel test section, representative of a steel member for the purposes of this test, comprises long and short steel columns or beams.

4 Symbols and abbreviated terms

Symbol	Unit	Description
A	m^2	area
A_m	m^2	exposed perimeter area of the structural steel member, per unit length
A_p	m^2	for profile protection: exposed outer perimeter area of the structural steel member excluding the protection material, per unit length for encased protection: the internal surface area of the smallest possible rectangle or square box encasement which can be measured around the structural steel member
b	m	breadth of the steel section
d	mm	thickness
d_{aver}	mm	average thickness
d_p	mm	thickness of fire protection material
$d_{p(max)}$	mm	maximum thickness of fire protection material
$d_{p(min)}$	mm	minimum thickness of fire protection material
h	mm	depth of the steel section
K_d	-	range factor for thickness
K_s	-	range factor for section factor
L_{exp}	mm	length of beam section exposed to heating
L_{spec}	mm	total length of specimen
L_{sup}	mm	length of beam section between supports
P	m	perimeter of the steel section exposed to fire
s_p	m^{-1}	section factor at factor K_s
s_{max}	m^{-1}	maximum section factor at K_s factor of 1
s_{min}	m^{-1}	minimum section factor at K_s factor of 0
t_f	mm	thickness of the flange of the steel section
t_w	mm	thickness of the wall of the hollow steel section or web thickness of an I section or H column
V	m^3/m	volume of the steel section per unit length
V_p	m^3/m	volume of the fire protection per unit length
LB	–	loaded beam
LC	–	loaded 3m column section
TC	–	unloaded tall (2 m) column section
LHB	–	loaded hollow beam
LHC	–	loaded hollow column
SIB	–	short I section beam

Symbol	Unit	Description
SIC	–	short I section column
TCHS	–	tall circular hollow beam
TRHS	–	tall rectangular hollow beam
SHB	–	short hollow beam
SHC	–	short hollow column
RB	–	reference beam

5 Test equipment

5.1 General

The furnace and test equipment shall conform to what is specified in ISO 834-1.

5.2 Furnace

The furnace shall be designed to accommodate the dimensions of the test specimens to be exposed to heating as specified in 7.2 and their installation either upon or within the test furnace as specified in Clause 8.

5.3 Loading equipment

Loading shall be applied according to ISO 834-1. The loading system shall permit loading to be applied to beams as specified in 6.2.2 and to columns as specified in 6.2.4.

6 Test conditions

6.1 General

The procedures given in ISO 834-1 shall be followed in the performance of the test unless specific contrary instructions are given.

A number of steel members "I", "H", and hollow test sections, protected by the fire protection system, are heated in a furnace according to the protocol given in ISO 834-1.

Loaded beams and loaded columns are heated to provide information on the ability of the fire protection system to remain intact and adhere to the steel members (stickability). Unloaded beams and unloaded columns are heated to provide information on the thermal characteristics of the fire protection system.

It is recommended that the tests be continued until the steel temperature reaches the maximum value commensurate with the application of the data.

The method of testing loaded beams in this part of the test method is designed to provide maximum deflection (span/30) under the influence of load and heating as defined in ISO 834-1. If this is not possible, then the rate of deflection exceeds what is given in ISO 834-1.

Where several test specimens are tested simultaneously, care shall be taken that each be similarly exposed to the specified test conditions.

6.2 Support and loading conditions

6.2.1 General

Details of the calculations made to define the test loads shall be included in the test report.

6.2.2 Loaded beams

For each loaded beam test specimen, provision shall be made for the proper support, positioning, and alignment in the furnace in accordance with ISO 834-6, subject to any amended requirements of this part of ISO 834.

The beam shall not be provided with additional torsional restraint except where deemed necessary as in 7.2.1. The simply supported span (L_{sup}) shall not be greater than the length exposed to heating by more than 400 mm at each end. The length of the specimen (L_{spec}) shall be the exposed length plus up to a maximum 500 mm at each end.

The loaded beam test specimens shall be subjected to a total load, which represents 60 % of the design moment resistance, calculated using the actual yield strength from the batch test certificate of conformity or the actual measured value.

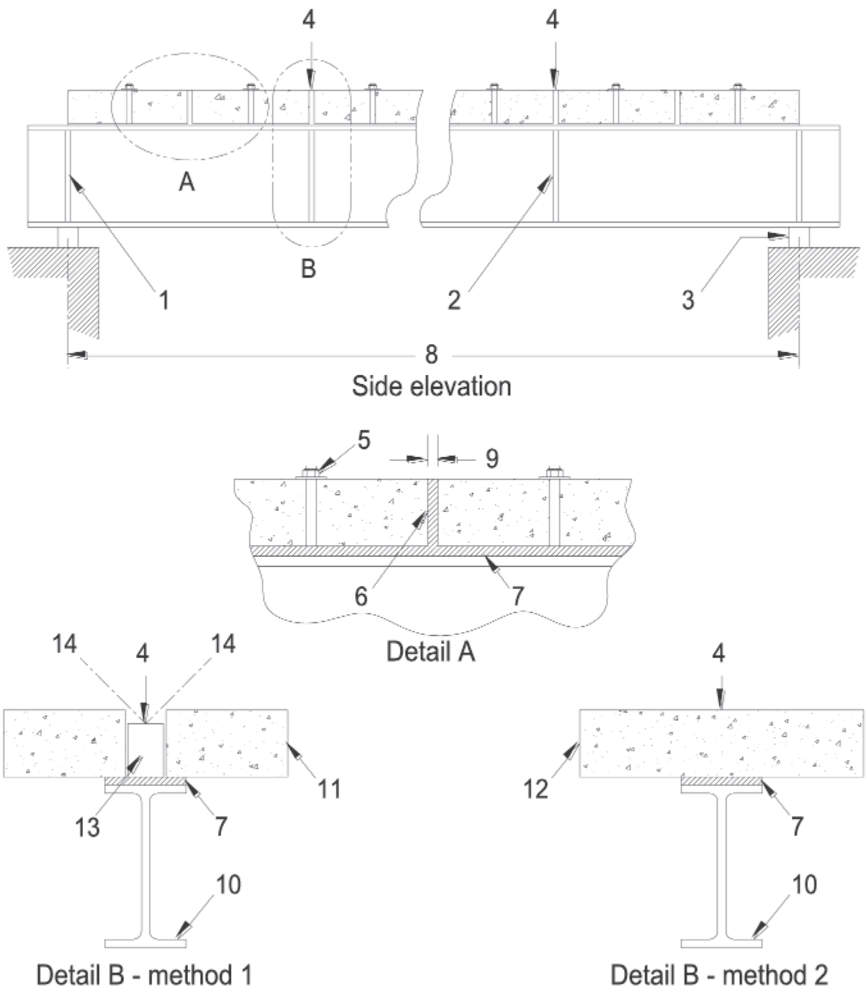
The actual load applied shall be the calculated total load less the dead weight of the beam, concrete topping, and fire protection system.

The method of loading shall be by a system which will produce a bending moment that is uniform over at least 20 % of the span of the beam around mid-span. The small increase in applied moment between jacks due to the cover slab may be ignored.

Loading shall be uniformly and symmetrically applied at two or more locations along its length.

The loading shall be applied using either of the two methods described in Figure 1.

The ends of loaded beams outside the furnace shall be insulated with a suitable insulation material.



Key

A detail A - fixing of beam topping

B detail B – beam loading method 1 or 2

1 web stiffener at end bearing – I or H section

2 web stiffener at load points – I or H section

3 provide sufficient clearance to ensure furnace lining does not interfere with protection

4 load applied centrally to top of beam via load spacer 13 or to concrete slab 12

5 stud/plate/locking nut

6 fibre insulation or equivalent

7 compressible fibre insulation to width of beam (see 7.1)

8 span

9 gap to be sufficient to ensure beam is able to bend without being restricted by the slab

10 steel beam – I section shown, hollow beam similar

11 aerated concrete slab sections of nominal density 500 kg/m3 retained as in 7.1; nominal size of slabs 600 mm (±100 mm) width × 625 mm maximum length × 150 mm to 200 mm thick

12 lightweight concrete slab section of nominal density 1500 kg/m3 retained as in 7.1; nominal size of slabs as 11

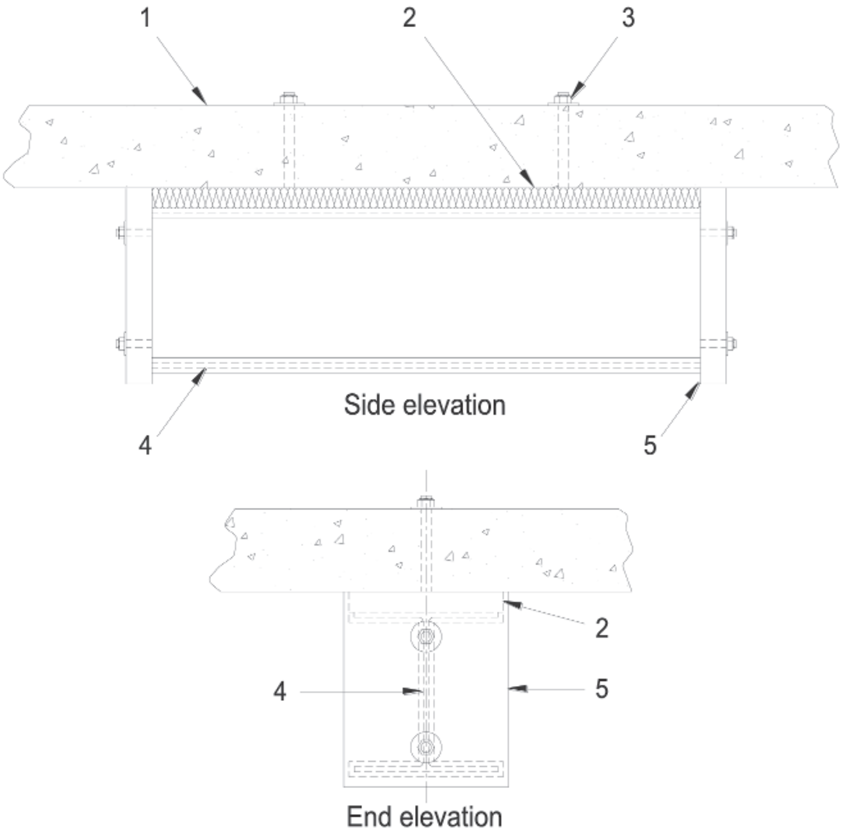
13 load spacer

14 additional bracing to prevent rotation of beam if necessary

Figure 1 — Construction arrangement options for loaded beams

6.2.3 Unloaded beams

Each unloaded beam test specimen shall be supported as shown in Figure 2.



Key

1 furnace cover

2 insulation board

3 stud/plate/locking nut

4 steel section

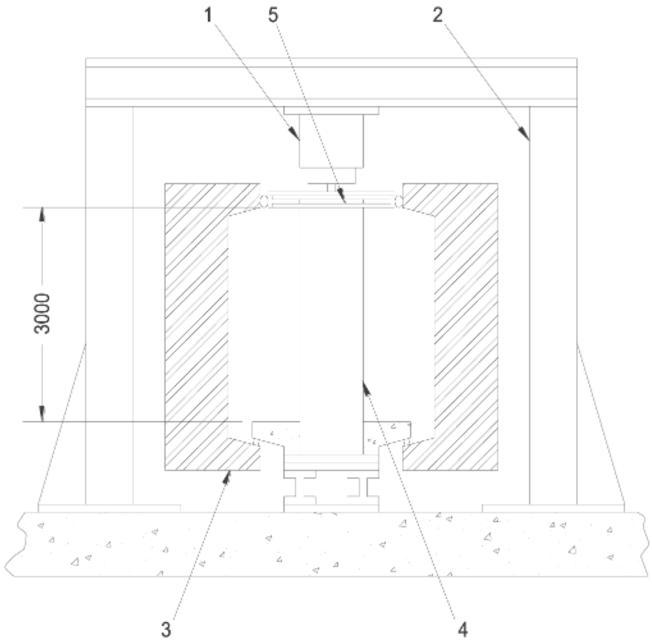
5 insulation board – end cap

Figure 2 — Support arrangement for unloaded beams

6.2.4 Loaded columns

For each loaded column, provision shall be made for the proper support, positioning, and alignment of the column test specimen in the furnace in accordance with ISO 834-7 subject to any amended or additional requirements of this part of ISO 834. An example of the test arrangement is given in Figure 3.

Dimensions in millimetres



Key

1 hydraulic jack

2 loading frame

3 furnace

4 loaded column

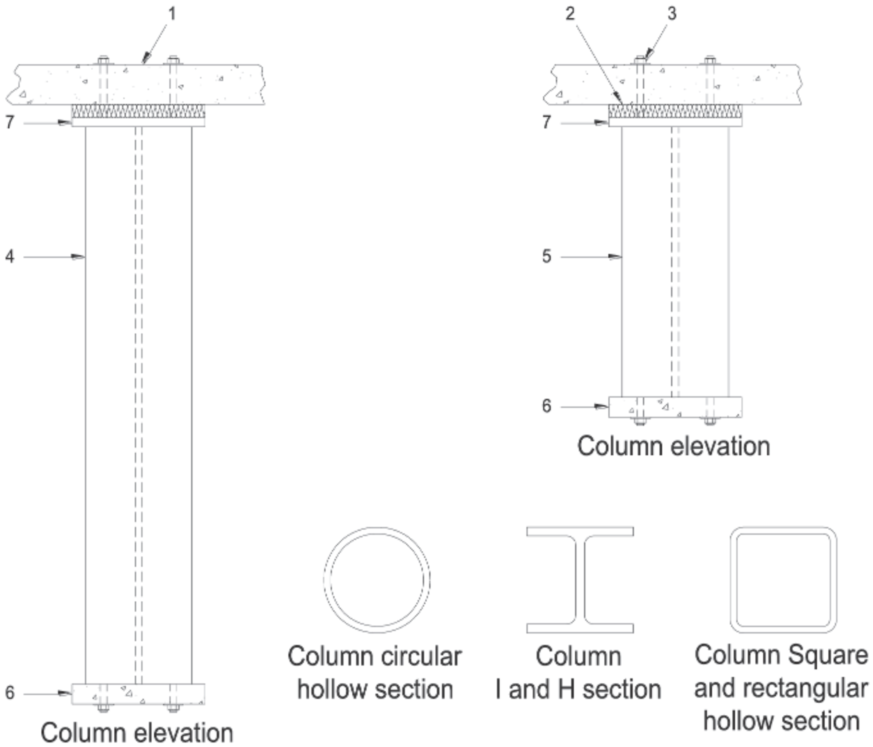
5 steel plate (only applies to reactive coatings)

Figure 3 — Loaded columns, example of general test arrangement

The loaded column shall be subjected to an applied test load which represents 60 % of the design buckling resistance calculated using the actual yield strength from the batch certificate of conformity or an actual measured value. Details of the calculation made to define the test load shall be included in the test report.

6.2.5 Unloaded columns

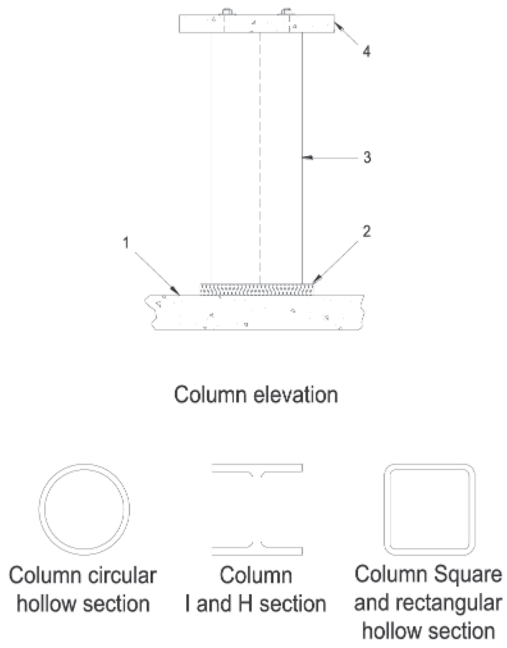
Unloaded column sections shall be supported vertically within the furnace; either installed to the soffit of the furnace cover slabs (see Figure 4) or stood directly on the furnace floor or on plinths (see Figure 5).



Key

1 furnace cover
2 insulation board
3 stud/plate/locking nut
4 tall column
5 short column
6 insulation board – end cap
7 steel plate (see Figure 7) to be applied to all columns with reactive protection systems whether situated on the floor or fixed to the furnace roof (steel plates are not used with passive protection systems)

Figure 4 — Support arrangement for unloaded columns



Key

1 furnace floor or plinth

2 insulation material sufficient to prevent heat transfer via end of section

3 short column

4 insulation board – end cap

Figure 5 — Installation of unloaded column on the furnace floor or on a plinth

When unloaded columns are tested simultaneously with beams, the columns shall be bolted to the underside of the furnace cover slab or stood on plinths or the furnace floor. When unloaded columns are tested simultaneously with a loaded column, the columns shall be stood on plinths or directly on the furnace floor.

7 Test specimens

7.1 General

The test sections should be chosen to suit the scope of the intended assessment and will include both loaded and unloaded sections. The testing of loaded tall and equivalent unloaded reference sections provides the basis for the stickability correction to be applied to the thermal data generated from the unloaded short sections

Depending upon the scope of the assessment, the principle of selecting the loaded and unloaded sections shall be based on the details presented in 7.4.

Whenever possible, for each test involving a loaded beam or column, an equivalent unloaded reference beam or column section respectively shall be included and tested in the furnace at the same time. Where it is not possible to test a loaded column and a reference column together in the furnace, then the reference section shall be tested separately in the same furnace in the same position as the loaded column. In the case of hollow sections protected with a reactive protection system, it shall be necessary to do this for both circular and rectangular columns.

For both the maximum and the minimum thickness of the fire protection system, a loaded beam shall be tested to examine stickability during maximum deflection of the steel section, up to a maximum anticipated steel temperature. The two loaded steel beams do not have to be the same size as each other.

If the assessment is to be confined to four-sided protection of columns, the loaded beam tests shall be replaced by loaded column tests. In this case, the unloaded reference beam sections shall be replaced by unloaded reference column sections.

The data from the loaded and equivalent unloaded reference sections shall be used to determine the correction factor for stickability across the range of fire protection thickness.

For passive protection systems, it shall be necessary to consider loaded tests on both beams and columns if the supporting systems are different for each type of structural element. In the case of stapled board systems, the above rule applies only to the minimum thickness tested with staples.

7.2 Specimen design and preparation

7.2.1 Loaded beam sections

Loaded beam test sections shall have an I or H cross-sectional shape or hollow rectangular section.

Steel test sections used in loaded beam tests shall be constructed according to Figure 6 and tested in accordance with ISO 834-6 subject to any amendments given in this part of ISO 834.

Each beam shall have a total length, which provides an exposed length for heating, of not less than 4 000 mm.

The supported length and specimen length shall be specified as follows:

The span between the supports (L_{sup}) shall be the exposed length plus up to a maximum of 400 mm at each end. The length of the specimen (L_{spec}) shall be the exposed length plus up to a maximum of 500 mm at each end (see Figure 6).

The additional length, required for installation purposes, shall be kept as small as practically possible.

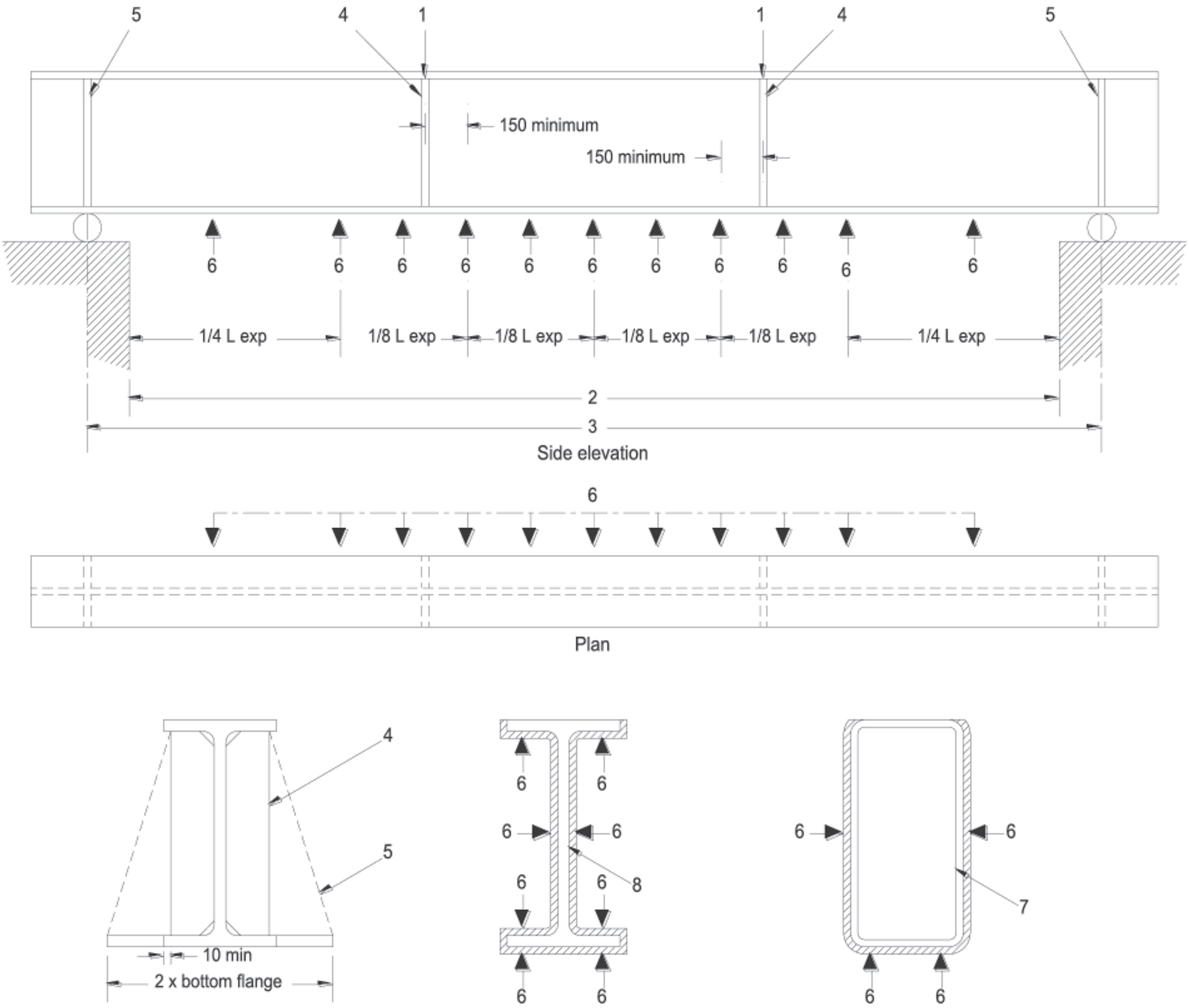
Where the span of these beams is such that additional restraint is required, provide web stiffeners as follows subject to agreement with the sponsor and as reported:

To give web stiffness and torsional restraint, the beams may be provided with

a) web stiffeners in the form of steel plates or triangular gussets, welded at each loading point; these shall have a thickness at least equal to the thickness of the web and a depth of at least 10 mm less than the depth of the beam flange (details are shown in Figure 6) and

b) web stiffeners in the form of steel plates or channels, welded at each support point; these shall have thickness at least equal to the thickness of the web; web stiffeners comprising steel plates shall be trapezoidal in shape to provide additional torsional restraint (details are shown in Figure 6).

Dimensions in millimetres



Key

1 load

2 exposed length, L_{exp}

3 span

4 web stiffener at load points if required – I or H section

5 web stiffener at bearing positions if required – I or H section

6 measuring points for sprayed coating

7 hollow section beam

8 I or H section

Figure 6 — Construction of loaded beam with web stiffeners and thickness measuring points

7.2.2 Unloaded beam sections

Steel sections used in unloaded beam test shall be constructed according to Figure 2.

The minimum length of unloaded short beam sections shall be 1 000 mm ± 50 mm. For board systems, joints in the protection should not be included unless the maximum board length is less than 1 000 mm

To minimize heat transfer at the ends of the unloaded beams, the ends shall be protected with insulation board or similar, which at elevated temperatures is capable of providing equivalent or greater insulation than that of the fire protection material provided over the length of the test specimen (see Figure 2).

The size of the end protection shall be greater than the total overall dimensions of the fire protection.

7.2.3 Unloaded reference sections

Where practical, each unloaded reference test section shall be taken from the same length of steel as its equivalent loaded section, thereby ensuring that it is of the same dimensions and characteristics. If this cannot be achieved, the test laboratory should ensure that the reference section is of similar dimensions and characteristics.

The minimum length of short beams and columns used as reference sections shall be 1 000 mm ± 50 mm. For board systems, joints in the protection should not be included unless the maximum board length is less than 1 000 mm.

7.2.4 Loaded column sections

A loaded column test specimen shall have a minimum height exposed to heating of 3 000 mm and be prepared as shown in Figure 3 and described in ISO 834-7.

7.2.5 Unloaded tall column sections

Unloaded tall column sections shall have a height of 2 000 mm ± 50 mm and be constructed according to Figure 4.

7.2.6 Unloaded short column sections

Short steel column test sections shall be constructed according to Figures 4 and 5.

The minimum length of unloaded short column sections shall be 1 000 mm ± 50 mm. For board systems, joints in the protection should not be included unless the maximum board length is less than 1 000 mm.

Short columns may be tested on the floor of the furnace or suspended from the ceiling or on plinths.

To minimize heat transfer from the ends of short steel column sections, the ends shall be protected with insulation board or similar which, at elevated temperatures, is capable of providing equivalent or greater insulation performance than the fire protection material provided over the height of the column.

The size of the end protection shall be greater than the total overall dimensions of the fire protection (see Figure 4).

7.2.7 Loaded tall and short column sections – upper plate (reactive fire protection)

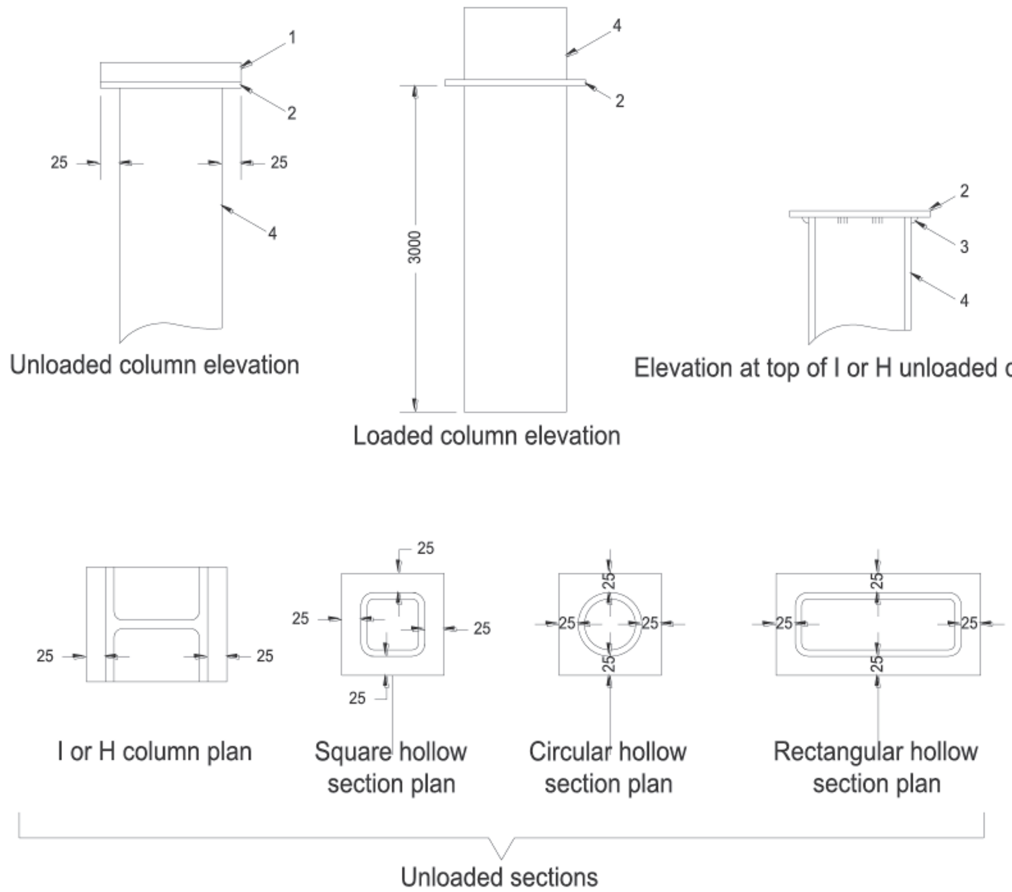
In order that the thermal insulation performance of an intumescent coating applied to a tall column may be accurately determined, the top edge of the column undergoing the test shall be adequately insulated to prevent inappropriate heat transfer to the section at this location

A 6-mm steel plate shall be fixed directly to the top edge of the unloaded columns at a distance of 3 m from the base of the loaded column. The plate shall be welded to the section and coated with the reactive material to all exposed areas (except the top face) to a thickness similar to that applied to the main section. The upper edge of the plate shall be protected with an insulation board or similar, which at elevated temperatures, is capable of providing equivalent or greater insulation than that of the fire protection.

This arrangement should allow the intumescent char to form in a more realistic manner and prevent false temperature data being recorded in this critical area. Figure 7 shows the details.

The arrangement may also be applied to the loaded column except that the plate may be positioned below the top edge to avoid interference with the loading equipment. In this case, the minimum exposed height shall be maintained.

Dimensions in millimetres



Key

1 insulation board fixed to plate

2 6-mm steel plate

3 continuous welds along outer flange of I or H column with 30 mm welds staggered elsewhere, continuous welds for hollow sections

4 column section

5 continuous welds

NOTE Intumescent at similar thickness to main section to exposed areas of plate, these areas of plate prepared as for main section.

Figure 7 — Steel capping to tall columns protected with an intumescent coating

7.2.8 Application of the fire protection to the steel section (all materials)

The surface of the steel sections shall be prepared and the fire protection system applied to the beams and columns in a manner representative of practice. The method of applying the protection system to columns shall not be different to that for beams; otherwise, separate tests and assessment shall be required incorporating loaded columns.

7.2.8.1 Passive protection

Any variability of density of the fire protection system applied to the loaded and equivalent unloaded beams shall be within the limits specified in 7.3.2.3.

For board and slab fire protection systems, the loaded beams and loaded steel column section shall incorporate an example of any constructional or peripheral joint that may be used in practice.

In the case of beams, the fire protection system shall be supported from the steel test section or the concrete deck as appropriate. Where the fire protection system is to be fixed to the lightweight concrete deck by artificial means, e.g. bolting through, the assessment should take into account the intended method of fixing to the supporting structure used in practice.

The fire protection material shall be applied to loaded steel test sections before the load is applied. In the case of loaded beams protected by board or slab fire protection systems, see 11.3 for additional guidance.

The fire protection material shall extend beyond the heated length and shall extend the full height of each column section. In addition and for loaded beams, sufficient clearance should be provided to ensure that the furnace walls cannot interfere with the protection material. This clearance is required to ensure that the fire protection material is not adversely affected when the beam deflects.

Where the fire protection system is of the box type, the ends of the cavity between the material and the steelwork shall be sealed at the point where the test specimen exits the furnace wall. This is to prevent any flow of gases beyond the heated length of the specimen.

Care shall be taken to ensure that during installation of the test specimens into the furnace, or as a result of any movement of the test specimens during the test, the fire protection system is not subjected to any expansion or restraint stresses contrary to its use in practice.

7.3 Composition of test component materials

7.3.1 Steel sections

The grade of structural steel shall be any hot rolled structural mild steel grade (non-alloyed, non-heat treated steel) with a yield strength of 200 N/mm^2 to 290 N/mm^2.

The dimensions and cross-sectional areas of the steel members shall be measured, neglecting any internal and external radii. These values shall be used to determine the section factors (A_m/V) according to the equations given in Figure 8.

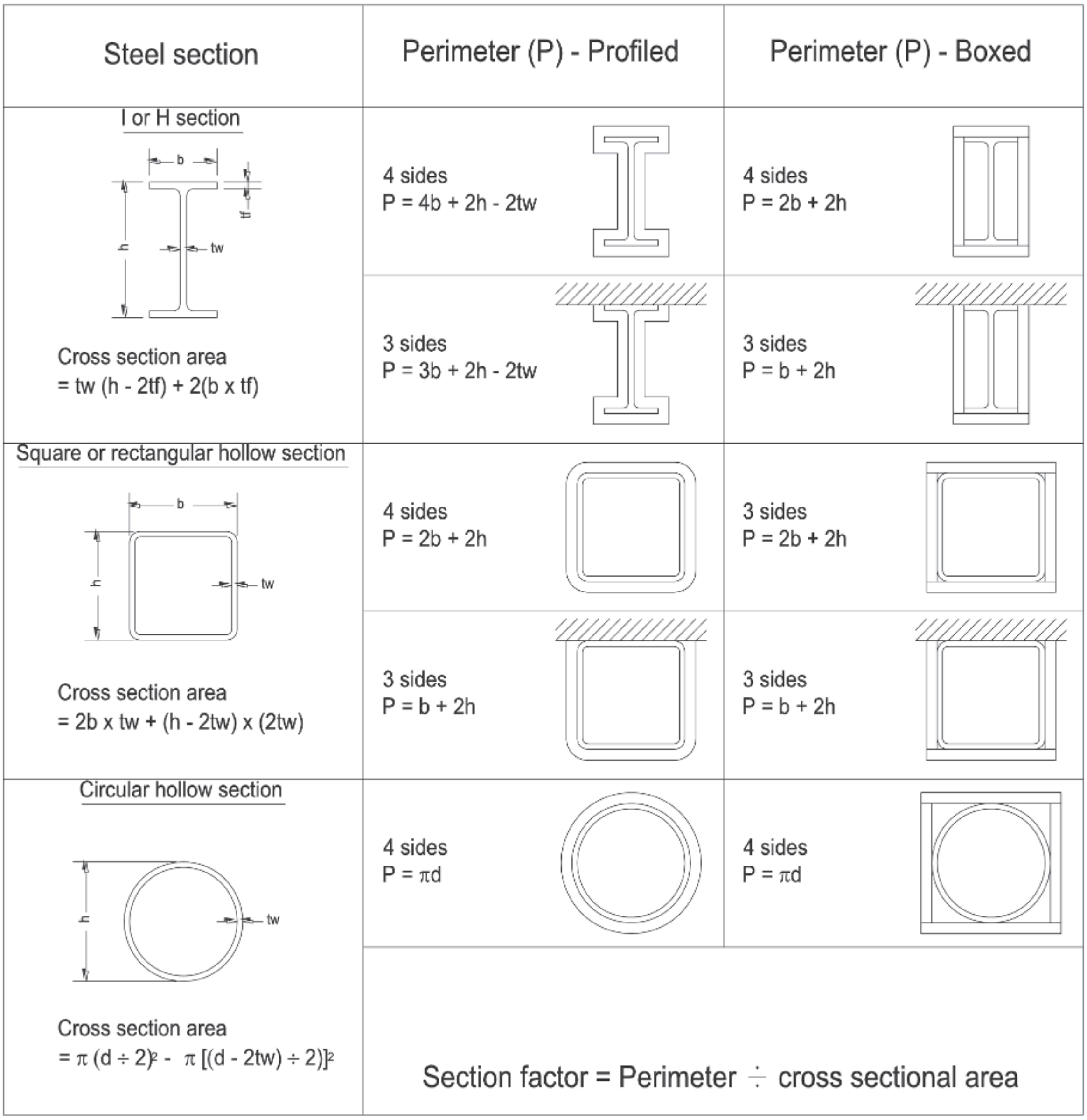


Figure 8 — Calculation of the section factor, A_m/V

7.3.2 Fire protection systems

7.3.2.1 General

The composition of the fire protection system shall be specified by the sponsor and shall include at least its expected nominal density and moisture content. Additional information may be required relative to the heat capacity for the purpose of the assessment.

For confidentiality reasons, the sponsor may not wish detailed formulation or composition details to be reported in the test report.

For reactive coatings, the dry film thickness of the coating shall be measured at the time of the test. The appropriate procedures and verification process are given in Annex B.

For passive fire protection materials like boards, slabs, and sprays, the actual thickness, density, and moisture content of the material shall be measured at the time of test for each specimen. The procedures appropriate to different types of fire protection material are given in Annex A.

The dimension for boards and slabs shall be determined in accordance with national standards and be within the tolerances defined in these standards.

Similarly, the thickness for boards and slabs shall be determined in accordance with national standards and be within the tolerances defined in these standards.

7.3.2.2 Thickness of fire protection material

7.3.2.2.1 Slabs and boards

The thickness of slab or board fire protection materials should not deviate by more than 15 % of the mean value over the whole of its surface. The mean value shall be used in the assessment of the results and in the limits of applicability of the assessment. If the board thickness varies by more than 15 %, then the maximum thickness recorded shall be used in the assessment.

The mean shall be the mean of all measurements in accordance with Annex A.

7.3.2.2.2 Spray renderings and passive coatings

The thickness of sprayed renderings and passive protection materials shall be measured at the locations specified in Annex A. The thickness measuring points shall not be closer than 150 mm to web stiffeners in loaded beams.

The measurement shall be taken between 50 mm and 100 mm away from each thermocouple positions.

The thickness of spray-applied fire protection coatings should not deviate by more than 20 % of the mean value. The mean value shall be used in the assessment of the results and in the limits of applicability of the assessment. If it deviates by more than 20 %, then the maximum thickness shall be used in the assessment.

The mean thickness (or maximum thickness according to the above criteria for permitted deviation in thickness) of the fire protection material applied to each loaded beam and loaded column section, where used, shall be the same as that applied to its reference beam or short column section. In each case, the difference shall not be greater than 10 % of the maximum value or ±5mm, whichever is the lesser.

7.3.2.2.3 Reactive coatings

For reactive fire protection materials, the average primer thickness shall be measured first and subtracted from the total average primer and reactive coating thickness. The resulting permitted thickness tolerances excluding primer and topcoat (assuming normal distribution of measured thickness) shall be as follows:

a) at the temperature measurement stations:

— A minimum of 68 % of readings shall be within ±20 % of the mean.

— A minimum of 95 % of readings shall be within ±30 % of the mean.

— All readings shall be within ±45 % of the mean.

b) overall:

— A minimum of 68 % of readings shall be within ±20 % of the mean at the temperature measurement stations.

— A minimum of 95 % of readings shall be within ±30 % of the mean at the temperature measurement stations.

— All readings shall be within ±45 % of the mean at the temperature measurement stations.

If the thickness is outside these limits, the test specimens shall be adjusted to comply with above requirements.

7.3.2.3 Density of passive fire protection materials

The density of the fire protection material (where appropriate) applied to each section shall be measured according to Annex A and recorded.

At each thickness of fire protection material, the density of each should not deviate by more than 15 % of the mean value. The mean value shall be used in the assessment of the results and in the limits of applicability of the assessment. If it deviates by more than 15 %, then the maximum density recorded shall be used.

The mean density of fire protection material (or maximum density according to the above criteria for permitted deviation in density) applied to each loaded beam and to the loaded steel column section, where used, shall be the same as that applied to its equivalent unloaded beam or short steel column section. The difference between the densities in each case shall not be greater than 10 % of the maximum mean value at that thickness. The test laboratory shall confirm equilibrium values of loaded and reference sections are within 10 % of each other.

7.3.2.4 Verification of the test specimen

An examination and verification of the test specimen for conformity to specification shall be carried out as described in ISO 834-1.

The properties of the fire protection materials used in the preparation of the test specimens shall be measured, using special samples where necessary the methods given in Annex A or B.

The sponsor shall be responsible for verification that the fire protection material has been applied correctly, and in the case of sprayed or coated materials, to ensure, by methods appropriate to the material, that it is of design composition and specification.

The gap between the internal face of a board or slab system and the steel section must be recorded. For beams, measurements should be taken at approximately mid-span and at both ends of a beam casing. For columns, measurements should be taken at approximately mid-height and at the top of a column casing.

7.4 Selection of test specimens

7.4.1 Principle of selection

The scope of the assessment will determine the selection of the test specimens.

For passive protection materials, guidance on the selection of test pieces is given Annex C. For reactive protection materials, guidance on the selection of test pieces is given in Annex D.

Annexes C and D allow for various assessments to be carried out, depending upon whether the manufacturer wishes to carry out limited or extensive testing. Each test package indicates the minimum number of test specimens required for the given scope.

7.4.2 Test sections for evaluation of stickability

The methodology for determining the stickability correction is dependent upon the scope of the test package and the fire protection system.

Guidance for passive protection materials is given in Annex C. Guidance for reactive protection materials is given in Annex D.

7.4.3 Sections required for thermal analysis

In addition to the requirements in 7.4.2, a range of unloaded I sections will be required whichever analysis method is used. These will be selected to cover the range of protection thickness, section factor, and fire resistance period and will include the short reference section equivalent to the loaded section or tall section.

Additional short and tall sections will be required for the analysis of hollow sections similarly chosen to cover the range of protection thickness, section factor, and fire resistance period.

The selection of the specimens will be determined by the scope of the assessment required for the protection product. This will be on the basis of section factor range (maximum and minimum) and thickness range (maximum and minimum) for each fire resistance period. The range factors will be 1,0 for maximum and 0,0 for minimum and will be determined by the manufacturer.

For passive protection materials, guidance is provided in Annex D. For reactive protection materials, guidance is given in Annex E.

8 Installation of the test specimens

8.1 Loaded beams

Lightweight or aerated concrete slabs shall be provided for the concrete topping which are bolted to the beam using 12-mm diameter bolts. Only the two sides and the soffit of the beams are exposed to heating, as shown in Figure 1. The slabs shall have the following properties:

a) the width measures across the beam shall be 600 mm ± 100 mm;

b) the thickness shall be within the range of 150 mm to 200 mm;

c) the maximum length shall be 625 mm;

d) the nominal density of aerated slabs shall be 500 kg/m^3;

e) the nominal density of lightweight concrete slabs shall be 1 500 kg/m^3;

f) the concrete slabs shall have a gap between them sufficient to allow the beam to bend.

There shall be a layer of compressible ceramic fibre insulation material placed between the lightweight concrete and the top flange of the beam. The insulation material shall be a Class A1 insulation material determined in accordance with EN 13501-1 and have an operating temperature of at least 1 000 °C. It will have an uncompressed thickness of 30 mm ± 5 mm and a nominal density of 125 ± 25 kg/m^3. The insulation shall have a width equal to the width of the top surface of the steel beam (see Figure 1).

Alternative Class A1 insulation materials determined in accordance with ISO 1182:2010, (1) and ISO 1716 may be used provided they have similar thermal properties and thickness to the specified ceramic fibre insulation.

The elements of the lightweight concrete topping shall be secured to the beam by bolting to studs of an appropriate diameter welded to the beam. There shall be a suitable steel plate beneath the locking nut. These studs may be situated within the junction between each element of the concrete topping or within the length of the concrete topping (see Figure 1; fixing within the length of the topping shown).

Each element of the concrete topping shall be secured by at least two fixings. The gap between the elements of the concrete topping shall be filled with fire-resistant packing.

At the commencement of the test, the soffit of the concrete topping to the loaded beam shall be nominally flush with the soffit of the adjacent furnace cover slabs.

Arrangements, appropriate to laboratory practice, shall be made to ensure that the gap between the concrete topping to the loaded beam and the adjacent furnace cover slabs is sealed to prevent escape of furnace gases, especially when the beam is subject to deformation during the test. The loaded beam shall be installed, with special attention taken to insulate the bearings of the beam from the influence of heat.

In addition, the ends of the loaded beam outside the furnace should be insulated and sufficient clearance should be provided between the underside of the protection system and the furnace walls to prevent interference.

8.2 Unloaded beams

Each unloaded beam test specimen shall be bolted to the soffit of the furnace cover slabs comprising the same concrete as that used as topping to the loaded beam. There shall be a suitable steel plate beneath the locking nut.

Each specimen shall be provided with a layer of ceramic fibre insulation fibre placed between the soffit and the top flange of the beam as specified in 8.1 for the loaded beam and Figure 2.

Alternative insulation materials (Class A1) may be used provided they have similar thermal properties and thickness to the specified ceramic fibre insulation.

The ends of the beam shall be insulated with a layer of rigid or flexible insulation material. See Figure 2 for a typical construction detail.

8.3 Loaded columns

A loaded column test specimen shall be installed as shown in Figure 3 and described in ISO 834-7.

8.4 Unloaded columns

The tall column and short column test specimens shall be either bolted to the underside of the lightweight concrete furnace cover slab [described in 6.2.5, using 10-mm diameter studs welded to the column section and (100 × 100 × 6) mm plates beneath the locking nut] or stood on the furnace floor (directly or on plinths).

Sufficient fibre insulation as described in 8.1 shall be used between all contact surfaces of the columns and the cover slab, or the furnace floor, or plinth to avoid heat transfer via the ends of the sections.

The linear dimensions of the fibre insulation material shall be greater than the total overall dimensions of the fire-protected steel section.

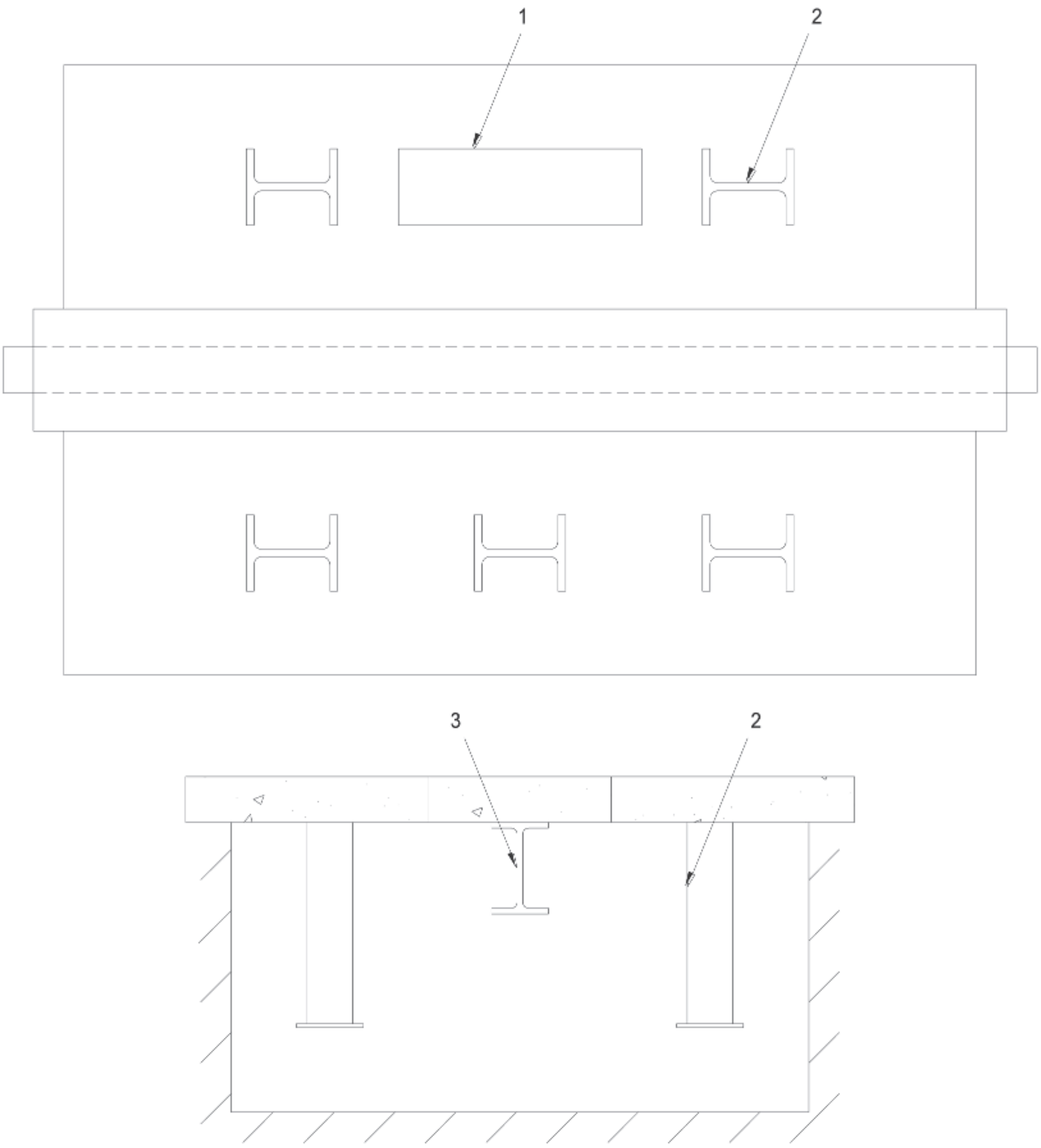
8.5 Test specimen installation patterns

For each test involving a loaded beam or column, an equivalent unloaded beam or column section shall be included and tested in the furnace at the same time.

For each loaded beam, the equivalent reference beam shall be positioned parallel to and at mid span of the loaded beam.

Each tall column and its equivalent unloaded reference column section shall be installed within the furnace at the same time and tested together wherever possible.

The sections should be positioned in the furnace to ensure they are not shielded or affected by the furnace walls, other test specimens, and obstacles. A minimum distance of separation of 300 m is recommended or a distance equal to the depth of the web if the beam depth is greater than 300 mm. A typical test specimen installation pattern useable in a 4 m × 3 m furnace is given in Figure 9.



Key

1 position of unloaded short reference beam (parallel to loaded beam)

2 unloaded short column

3 loaded beam

Figure 9 — Typical test specimen installation pattern

8.6 Furnace load

In order to ensure that the specified furnace temperature/time relationship is complied with, it may be necessary to control the amount of steel sections within the furnace and their location.

Typically, a furnace size 4 m × 3 m by about 2 m deep can accommodate up to 45 kg/m^3 without adverse affect.

9 Conditioning of the test specimens

All test specimens, their components, and any test samples taken for determination of material properties shall be conditioned in accordance with ISO 834-1.

10 Application of instrumentation

10.1 General

The instrumentation for measurement of temperature, furnace pressure, applied load, and deformation shall comply with the requirements of ISO 834-1.

10.2 Instrumentation for measurement of furnace temperature

10.2.1 General

Plate thermometers, of the type specified in ISO 834-1, shall be provided to measure the temperature of the furnace and shall be uniformly distributed to give a reliable indication of the temperature in the region of the test specimens. They shall not be placed in positions where they are unable to measure the furnace temperature correctly because they are obstructed by test specimens.

It is likely that the test series will involve at least one test where only short sections are included.

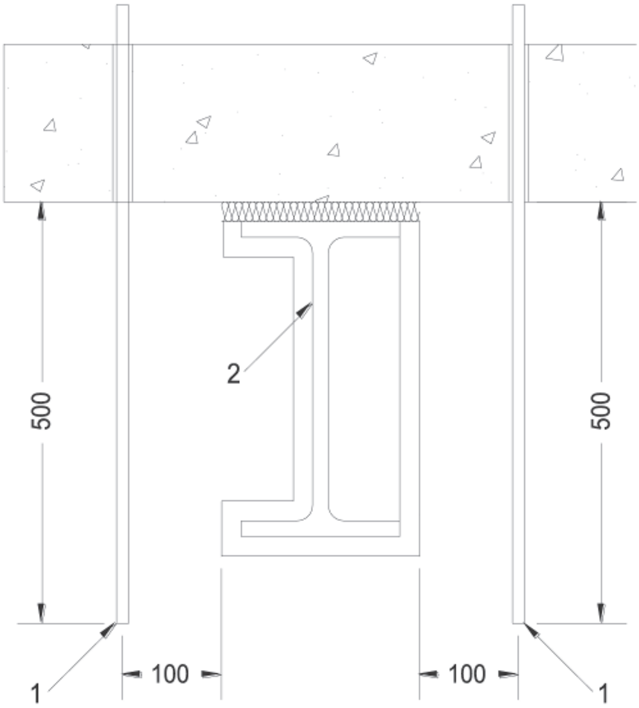
10.2.2 Furnace temperature in the region of loaded beam test specimens

The furnace temperature in the region of each loaded beam test specimen shall be measured by plate thermometers, placed at locations at 1/5, 2/5, 3/5, and 4/5 of the heated length of the loaded beam, there being two plate thermometers at each location, one on each side of the beam. The plate thermometers shall be positioned at a distance of 500 mm below the soffit as shown in Figure 10.

The plate thermometers shall be oriented so that for half their number, side "A" faces the floor of the furnace, and for the other half, side "A" faces the longer side walls of the furnace. The distribution of the different orientations shall be such that there shall be equal numbers facing the floor and the wall on each side of the beam.

At the commencement of the test, these thermocouples shall be positioned as specified in ISO 834-1 and shown in Figure 10.

Dimensions in millimetres



Key

1 plate thermometer

2 I or H section beam shown, hollow beam similar

NOTE For illustrative purposes only, the beam is shown with profile protection on the left and boxed protection on the right.

Figure 10 — Location of furnace control plate thermometers for loaded beams

10.2.3 Furnace temperature in the region of loaded column test specimens

Where a loaded column is tested in isolation, the furnace temperature in the region of the column section shall be measured using two plate thermometers placed on either side of the column at 1/4, 1/2, and 3/4 column height and at a distance of 100 mm from the column.

The plate thermometers shall be oriented so that side "A" faces the side walls of the furnace. The insulated parts shall face towards the column.

At the commencement of the test, the hot junctions of these thermocouples shall be positioned and maintained throughout the test as specified in ISO 834-1.

10.2.4 Furnace temperature in the region of unloaded test specimens

10.2.4.1 Columns on furnace floor with or without a loaded beam

In the case where short or tall columns are included in the same furnace as a loaded beam or a loaded column and they are placed on the floor of the furnace, the furnace temperature in the region of each column section shall be measured using two plate thermometers placed, on either side of the column, at a distance of 0,5 m from the top of the column and shall be used to control the furnace temperatures as given in ISO 834-1. These thermometers shall be placed as evenly as possible taking into account the location and number of test specimens.

The plate thermometers shall be oriented so that side “A” faces the side walls of the furnace. The insulated parts shall face towards the column.

At the commencement of the test, the hot junctions of these thermocouples shall be positioned and maintained throughout the test as specified in ISO 834-1.

Short columns on plinths (height > 500 mm) are equivalent to the fixing at the ceiling and therefore do not require additional plate thermometers

10.2.4.2 Tall and short sections fixed to furnace roof with a loaded beam

Where the short beams, short columns, or tall columns are included in the same furnace as a loaded beam and they are fixed to the roof of the furnace, the temperature shall be measured using the plate thermometers positioned as given in 10.2.2.

10.2.4.3 Tall and short sections fixed to furnace roof without a loaded beam

It is likely that the test series will include at least one test where only short or tall sections are installed in the furnace. In such tests, the furnace temperature will be measured by plate thermometers situated in the same position as if a loaded beam was installed as given in 10.2.2.

10.3 Instrumentation for measurement of steel temperatures

10.3.1 General

Thermocouples for measurement and recording of steel temperatures, of the type and fixing given in Annex E, shall be located at measurement stations and other points as specified below (see 10.3.1.1 to 10.3.5) and shown in Figures 11 to 14.

10.3.1.1 I or H sections

The thermocouples on the flanges shall each be fixed mid-way between the toe of the flange and the web; the thermocouple on the web shall be fixed mid-way between the two flanges

10.3.1.2 Rectangular hollow columns and beams

The thermocouples on the appropriate face shall each be fixed mid-way between the adjacent corners.

10.3.1.3 Circular hollow columns

The thermocouples at each measuring station on shall each be fixed equidistant around the circumference.

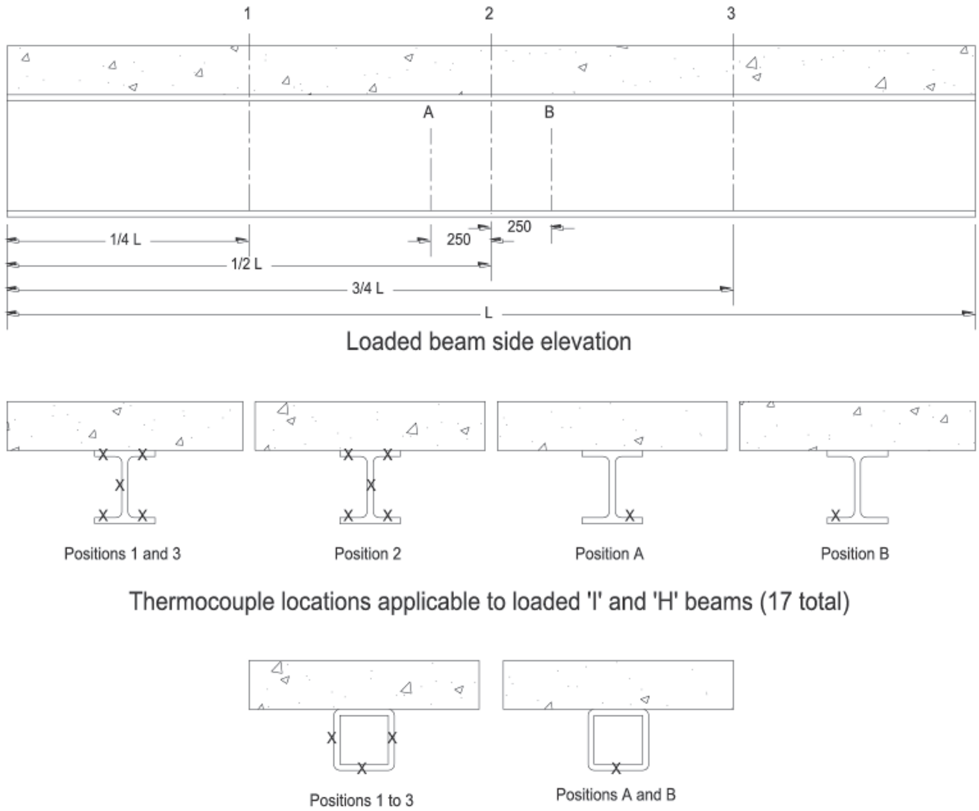
10.3.2 Loaded beams

For each loaded beam test specimen, there shall be three measurement stations each consisting of five thermocouples at 1/4, 1/2, and 3/4 of the length of the beam exposed to heating.

For I and H sections, the thermocouples shall be attached to the lower flange on alternate sides of the web at a distance of 250 mm from the central measuring station. For hollow beams, these additional thermocouples shall be on the lower face.

Temperature measuring points shall be separated from loading points by at least 150 mm and shall not be closer than 150 mm to web stiffeners where fitted. The thermocouples on the web shall be positioned on alternate sides of the web (see Figure 11).

Dimensions in millimetres



Key

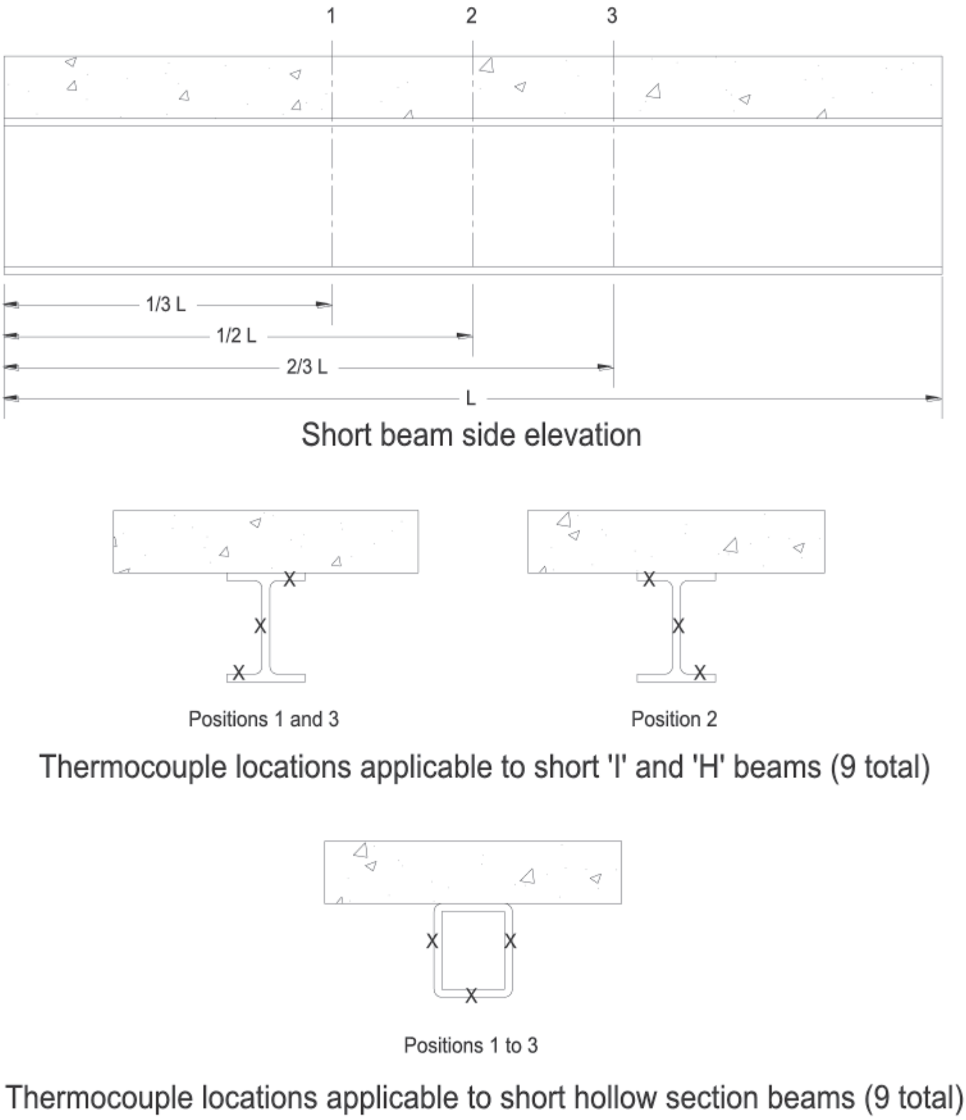
1 position 1
2 position 2
3 position 3
A position A
B position B
L span of beam

Figure 11 — Thermocouple position/orientation for loaded beams

10.3.3 Unloaded beams

For each beam test specimen, there shall be three measurement stations each consisting of five thermocouples at 1/3, 1/2, and 2/3 of the length of the beam exposed to heating. The thermocouples on the web and flanges shall be positioned on alternate sides for adjacent measuring stations for I and H sections (see Figure 12).

Similarly, for hollow sections, the thermocouples shall be at a similar measuring stations and at the centre of each face.



Key

1 position 1

2 position 2

3 position 3

L length

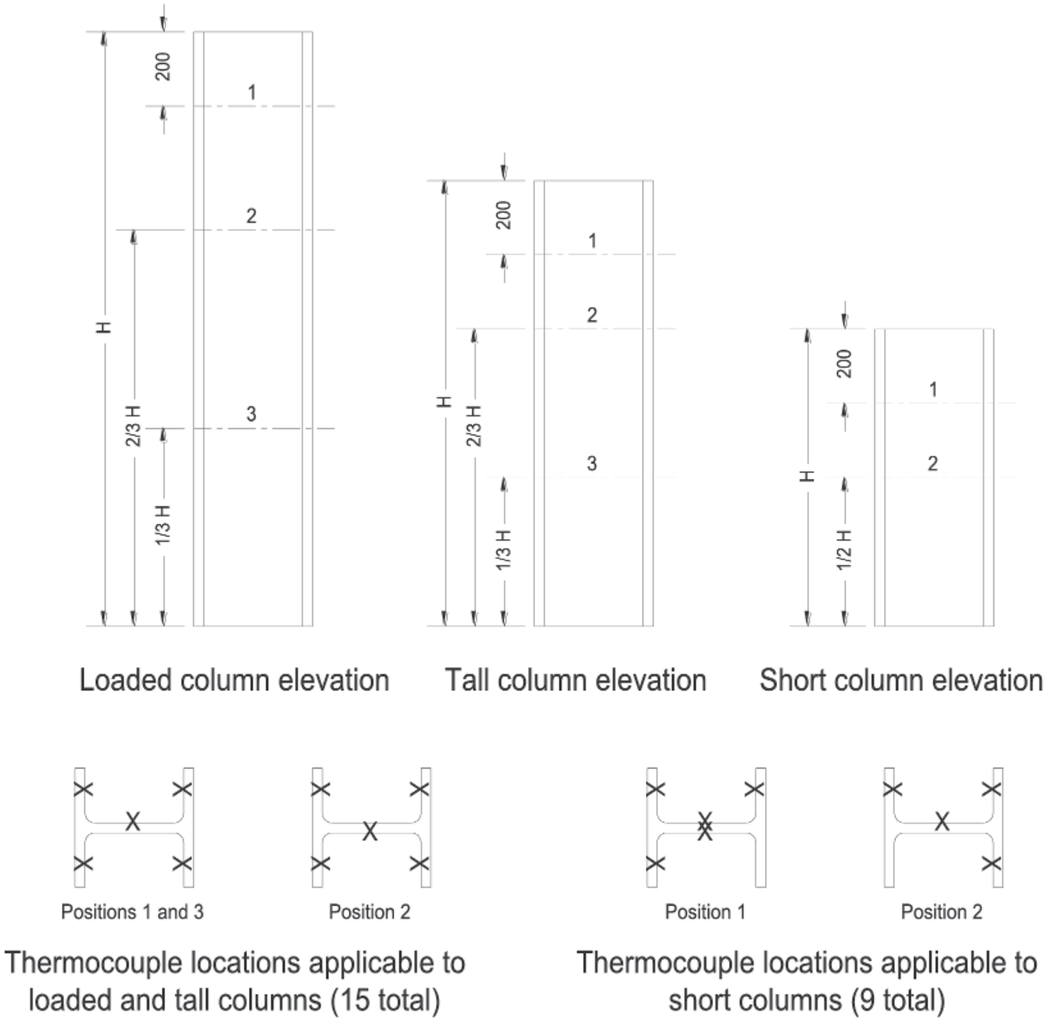
Figure 12 — Thermocouple locations/orientation for short beams

10.3.4 Loaded columns and unloaded tall columns

For each loaded and unloaded column test specimen, there shall be a measurement station consisting of five thermocouples located at a distance of 200 mm from the top of the column and also at 1/3 and 2/3 of the heated length of the column (see Figure 13).

Thermocouples on the web shall be positioned on alternate sides of the web.

Dimensions in millimetres



Key

1 position 1

2 position 2

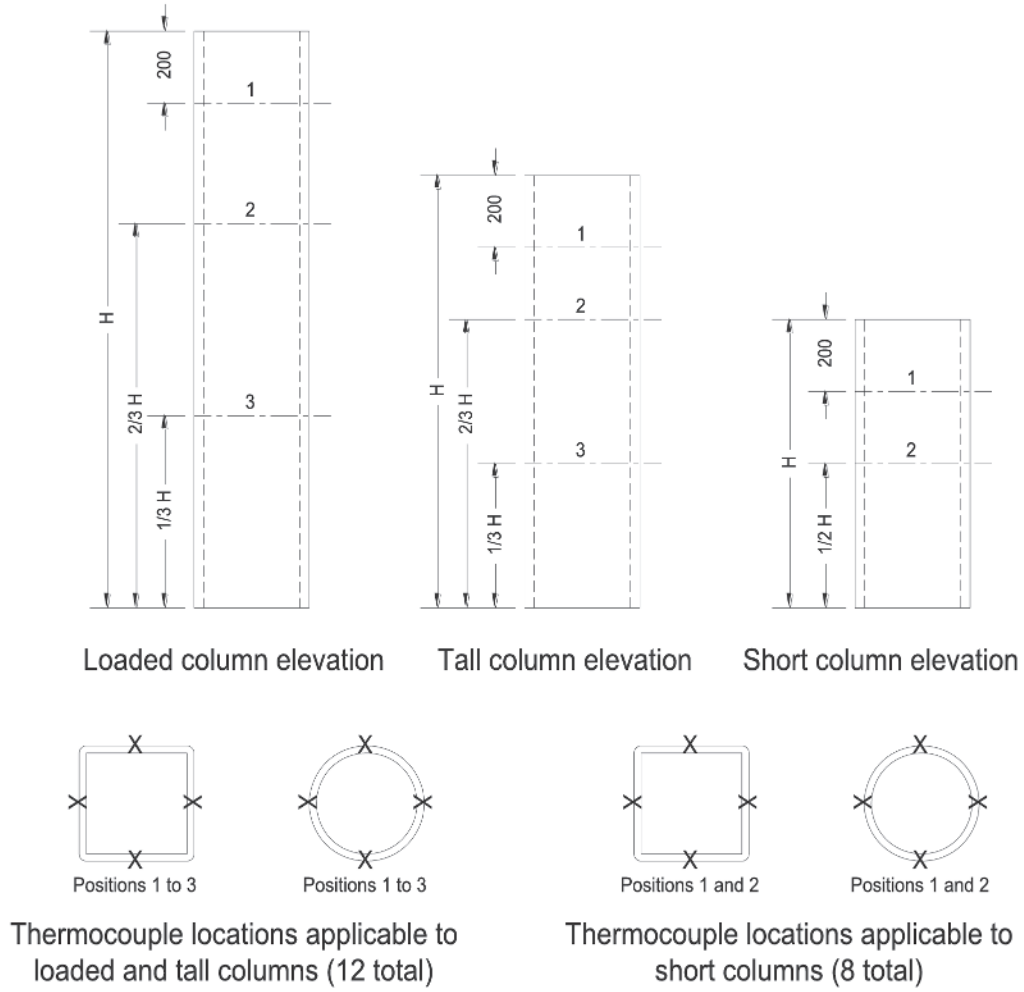
3 position 3

H height

Figure 13 — Thermocouple locations/orientation for I and H section columns

Similarly, for hollow sections, the thermocouples shall be at similar measuring stations and at the centre of each face (see Figure 14).

Dimensions in millimetres



Key

1 position 1
2 position 2
3 position 3
H height

Figure 14 — Thermocouple locations/orientation for hollow sections

10.3.5 Unloaded short columns

For each short I or H column, there shall be a measurement station consisting of five thermocouples located at a distance of 200 mm from the top of the column and four located at mid-height of the column (see Figure 13). Thermocouples on the web and flanges shall be positioned on alternate sides for adjacent measuring stations for I or H sections.

For hollow section columns, there shall be four thermocouples at each measuring station and at the centre of each face (see Figure 14).

10.4 Instrumentation for measurement of furnace pressure

The vertical deformation at mid-span relative to the supports, for loaded beams, and the axial deformation, for loaded steel columns, shall be measured as specified in ISO 834-1.

10.5 Instrumentation for measurement of deformation

The vertical deformation at mid-span relative to the supports, for loaded beams, and the axial deformation, for loaded steel columns, shall be measured as specified in ISO 834-1.

10.6 Instrumentation for measurement of load

Instrumentation for the measurement of applied load shall be provided and used as specified in ISO 834-1.

11 Test procedure

11.1 General

Assemble the required number of test specimens forming the testing package as detailed in Clause 7.

Incorporate these in several tests according to the capacity of the furnace and the criteria in 8.5.

Conduct tests on a loaded beam together with its equivalent unloaded beam and, when possible, include unloaded column specimens. Whenever possible, conduct tests on a loaded column together with its equivalent unloaded short column specimen.

Carry out checks for thermocouple consistency and establish data points for temperature before commencement of the test and the procedures defined in 11.2 to 11.4.

11.2 Furnace temperature and pressure

Measure and record the furnace temperature in the region of the test specimens using the plate thermometers defined in 10.2 and the furnace pressure in accordance with ISO 834-1.

The location of plate thermometers to be used to control the furnace temperature is dependent upon the specimens incorporated within the furnace.

The plate thermometers as specified in 10.2.2 to 10.2.4 will be used to control the furnace to the criteria of ISO 834-1.

Some National Bodies may require tests on the fire protection to be carried out under a smouldering fire (slow heating curve). Where this is necessary, the test procedure is described in Annex F.

11.3 Application and control of load

11.3.1 Loaded beams

Using the procedures of ISO 834-1, apply a constant load to the loaded beam, of magnitude derived in accordance with 6.2.2, throughout the test period until after a deformation of $L_{sup}/30$ is reached or a rate of deflection of $L^2/9\,000\,d$ mm/min, at which point the load shall be removed.

$L_{sup}/30$ shall be reached in the range of 500 °C to 600 °C. If this is not achieved after reaching 575 °C, then the load shall be increased gradually and carefully until $L_{sup}/30$ is reached. The temperature used shall be the mean of the bottom flange temperatures. In the case of the maximum thickness loaded beam, $L_{sup}/30$ shall be reached within 85 % of the maximum fire resistance period within the scope of the assessment.

For board or slab fire protection systems, it is possible that applying the required load to an already protected beam may lead to disruption of the protection material. Therefore, up to 50 % of the required load may be applied prior to the installation of the fire protection.

11.3.2 Loaded columns

Using the procedures of ISO 834-1, apply a constant load to the loaded column, of magnitude derived in accordance with 6.2.4, throughout the test period until the point of maximum elongation is reached and the column has returned to its original height at which point the load shall be removed.

In the case of the maximum thickness loaded column, this shall be reached within 85 % of the maximum fire resistance period within the scope of the assessment.

11.4 Measurements and observations

11.4.1 Temperature of steelwork

Measure and record the temperature of the loaded and unloaded sections using the thermocouples attached to the steelwork as specified in 10.3 at intervals not exceeding 1 min.

11.4.2 Deflection

Identify an initial deflection datum point, relative to the supports, before application of the test load. Then, using the procedures of ISO 834-1, apply the test load, measure the zero point for deformation, and monitor the deformation of the loaded beam and the axial contraction of the loaded column, if used, continuously throughout the test, at intervals not exceeding 1 min.

11.4.3 Observations

Monitor the general behaviour of each of the specimens throughout the test and record the occurrence of cracking, fissuring, delamination, or detachment of the fire protection material and similar phenomena as described in ISO 834-1.

11.4.4 Termination of the test

All tests should provide thermal data up to the maximum temperature required for the scope of the assessment.

For tests that include loaded specimens when the load has been removed, it may be necessary to continue the test until the mean temperature recorded on all the steel sections exceeds the maximum temperature and the duration of the test exceeds the maximum time period for which the sponsor requires approval. Otherwise, terminate the test when one or more of the reasons for termination which are specified in ISO 834-1 occur.

12 Test results

12.1 Acceptability of test results

It is possible that within any test package, apparently, erroneous results may occur through failure of thermocouples, abnormal behaviour of fire protection, incorrect assembly of the test specimen, etc. If any results are to be disregarded, the laboratory, in consultation with the sponsor, shall justify this and apply the following rules:

12.1.1 I and H sections

12.1.1.1 Loaded I or H beams

— From the 6 thermocouples on the upper flange, at least 4 results shall be valid.

— From the 3 thermocouples on the web, at least 2 results shall be valid.

— From the 8 thermocouples on the lower flange, at least 6 results shall be valid.

12.1.1.2 Unloaded I or H beams

— From the 3 thermocouples on the upper flange, at least 2 results shall be valid.

— From the 3 thermocouples on the web, at least 2 results shall be valid.

— From the 3 thermocouples on the lower flange, at least 2 results shall be valid.

12.1.1.3 Loaded I or H columns and unloaded tall columns

— From the 15 thermocouples on the column, at least 9 results shall be valid, with at least 3 valid results at each temperature measurement station.

12.1.1.4 Unloaded short I or H columns

— From the 3 thermocouples on the each flange, at least 2 results shall be valid.

— From the 3 thermocouples on the web, at least 2 results shall be valid.

12.1.2 Hollow sections

12.1.2.1 Loaded hollow beams

— From the 11 thermocouples on the beam, at least 9 results shall be valid, with at least 2 valid results at each temperature measurement station.

12.1.2.2 Unloaded hollow beams

— From the 9 thermocouples on the beams, at least 7 results shall be valid, with at least 2 valid results at each temperature measurement station.

12.1.2.3 Loaded and unloaded tall hollow columns

— From the 12 thermocouples on the column, at least 9 results shall be valid, with at least 3 valid results at each temperature measurement station.

12.1.2.4 Unloaded short hollow columns

— From the 8 thermocouples on the column at least 6 results shall be valid, with at least 2 valid results at each temperature measurement station.

13 Presentation of test results

The following shall be reported within the test report:

a) the results of measured dimensions especially the thickness of the fire protection, as well as the density and moisture content for passive protection, together with those values to be used in the assessment, according to 7.3;

b) the individual results of all furnace temperature measurements and the mean of all individual furnace temperature measurements, taken as specified in ISO 834-1, graphically presented and compared with the specified requirements and tolerances given in ISO 834-1;

c) the individual results of all furnace pressure measurements and the mean of all individual furnace pressure measurements, taken as specified in ISO 834-1, graphically presented and compared with the specified requirements and tolerances given in ISO 834-1;

d) the individual results and the mean temperature of each of the flanges, the mean of the web, and the overall mean determined as given in (terms and definitions) and all individual results of all steel temperature measurement thermocouples at the locations given in 10.3, all graphically presented (evidence of compliance with the validity criteria of 12.1);

e) the deflection measurements on loaded beams specified in 11.4.2, all graphically presented (if the load is removed according to 11.3.1, the time at which this occurred);

f) the individual results of the axial contraction measurements on loaded columns specified in 11.4.2, all graphically presented (if the load is removed according to 11.3.2, the time at which this occurred);

g) observations made and times at which they occur.

The results b) to f) may be presented as a selection of the measured data sufficient to give a history of the performance of the test specimen according to ISO 834-1.

The results b) to f) may also be prepared and printed in tabular form and/or presented electronically. In the latter case, this should be prepared in the appropriate, secure, "read only" format to prevent alteration. Only legitimate data maintained in the laboratory files shall be used in the assessment.

14 Test report

14.1 General

The test report shall include the following statement.

"This report provides the constructional details, the test conditions, and the results obtained when the specified fire protection system described herein was tested following the procedures of ISO 834-10. Any deviation with respect to thickness and density of fire protection material and constructional details, loads, stresses edge or end conditions other than those allowed under the field of application could invalidate the test result".

In addition to the items required by ISO 834-1, the following information shall be included in the test report:

a) generic description and accurate details of the fire protection system;

b) name of the manufacturer or the product or products and the manufacturer or manufacturers of the construction;

c) full details of the test specimen preparation including the method of installation/ application of the fire protection system and surface preparation (for reactive coatings, this also includes the thickness of primer, reactive coating – brush/spray applied, number of coats, and top coating);

d) description of the fabrication of the test construction (a description of the conditioning of the test construction and its installation into the test furnace);

e) results of the measurements obtained using the measuring devices in Clause 13 b) to f) during the tests presented in graphical format (and any other optional format), as required in Clause 13;

f) description of significant behaviour of the test specimen observed during the test period, including observation(s) and magnitude of any detachment of the fire protection material.

g) magnitude of the load applied to each test specimen, as a function of time, and if removed (loaded beams and columns), the time at which this occurred;

h) elapsed time at which the test was terminated and the reason, on the basis of 11.4.4, for the termination;

i) results of any test carried out using the smouldering fire (slow heating curve), as described in Annex F, should be reported separately;

j) details of the calculations used to determine the test load.

Annex A
(normative)

Measurement of properties of passive fire protection materials

A.1 Introduction

Determination of the thickness, density, and moisture content of the fire protection materials and other materials used in fire resistance tests is important to the accurate prediction of required fire protection thicknesses from the test result.

The methods used to establish these properties shall, therefore, be consistent and this annex gives guidance on appropriate procedures to be used.

Any special test samples to determine thickness, density, and moisture content shall be conditioned with the actual fire test specimen under the conditions described in Clause 9.

Any specific product standard existing for the measurement of such properties shall be followed. The procedures given in ISO 834-1 shall be followed together with the following.

A.2 Thickness of fire protection materials

A.2.1 Measurement

For board or slab/mat fire protection materials, the nominal thickness of each material shall be measured using suitable gauges or calipers in accordance with national standards. The measurement shall be carried out either on the actual materials during assembly of the test specimen or on a representative special test sample, the minimum linear dimensions of which shall be 300 mm × 300 mm. At least nine measurements shall be made including measurements around the perimeter and over the surface of the material.

The design thickness used in the assessment shall be as described in 7.3.2.2.

For sprayed passive fire protection materials, the thickness shall be measured using a 1-mm diameter probe or drill bit, which shall be inserted into the material at each measurement position until the tip of the probe or drill touches the surface of the building element. The probe or drill shall carry a circular steel plate of diameter 50 mm upon it, for accurate determination of the surface level.

The number and location of thickness measurement points shall be as given in A.2.2.

The design thickness used in the assessment shall be as defined in 7.3.2.2.

For sprayed fire protection materials, of thickness very much greater than 5 mm (i.e. where the mean thickness of the fire protection is greater than 15 % of the height of the test member), the mean thickness shall be given by

$$d_{av} = A_p + \left(\frac{A_p^2 + 16V_p}{8} \right) \tag{A.1}$$

For sprayed fire protection materials and coatings of thickness less than 5 mm applied to the surface of steel beam and column test members, the material thickness shall be determined directly upon the test member, once the coating is fully dried.

The thickness shall be measured using an instrument employing either the electromagnetic induction principle or the eddy current principle with a probe contact diameter of at least 2,5 mm.

The number and location of thickness measurement points shall be as described in A.2.2. The design thickness used in the assessment shall be as described in 7.3.2.2.

A.2.2 Measuring positions renderings

The number and location of thickness measurement points (which shall be regarded as the minimum required) shall be as follows:

A.2.2.1 Loaded beams

A minimum number of 88 measurements should be taken spread over the measuring stations indicated in Figures 6 and 11.

— the measurement stations at which temperature measurements are made on the surface of the test beam;

— the positions at which temperature measurements are made on the upper surface of the bottom flange of the beam, or bottom surface of hollow beams, halfway between each temperature measurement station;

— the positions halfway between the outermost temperature measurement stations and the outermost points on the upper surface of the bottom flange of the beam or the bottom surface of hollow beams.

A.2.2.2 Unloaded beams

A minimum number of 24 measurements at positions on the exposed surfaces of the beam (web and flanges; see Figure 12) at locations in the proximity of

— the temperature measurement stations (between 50 mm to 100 mm away from) at which temperature measurements are made on the surface of the test beam.

A.2.2.3 Loaded columns

A minimum number of 50 measurements should be taken spread evenly over the measuring stations indicated in Figure 13 for I or H sections and Figure 14 for hollow sections.

— the temperature measurement stations (between 50 mm to 100 mm away from) at which temperature measurements are made on the surface of the test column;

— the positions halfway between each temperature measurement station.

A.2.2.4 Unloaded short columns

A minimum number of 24 measurements should be taken spread evenly over the measuring stations indicated in Figure 13 for I or H sections and Figure 14 for hollow sections.

— the temperature measurement stations (between 50 mm to 100 mm away from) at which temperature measurements are made on the surface of the test column.

A.3 Density of applied fire protection materials

The density of each fire protection material shall be determined from measurements of mass and dimensions using the following:

For board or panel passive fire protection materials, the density can be obtained from values of mass, mean thickness (from nine measurements), and area measured either on the actual materials during assembly or on a representative special test sample which shall be at least 300 mm × 300 mm. The mass of the board shall be obtained using a balance having an accuracy equivalent to 0,1 % of the total mass of the sample being weighed or 0,1 g (the sample size shall be sufficient such that the minimum sample mass is 100 g), whichever is the greater.

The density of fibrous or similar compressible fire protection material shall be related to the nominal thickness.

For spray applied fire protection materials, the density of the material shall be determined from samples sprayed, from beneath, into metal trays, horizontally orientated. This should be carried out at the same time as the fire protection system is applied to the steel test specimens. These trays shall be of size 300 mm × 300 mm and made from 1-mm thick steel plate.

The depth of the trays shall be the same as the design thickness of the fire protection material.

For each thickness of material, two such trays shall be prepared with the material applied to the same thickness as that applied to the steel. One of these trays is dried to provide a reference for dry density and moisture content. The second tray shall be used to determine the density at the time of test.

The thickness of the specimen within the trays shall be determined at nine positions over the surface of the trays according to

— one at the centre (one total) and

— two along each centre to corner axis, equidistant from each other, the centre and the corner (eight in total).

The mass of the fire protection within the tray shall be obtained using a balance having an accuracy equivalent to 0,1 % of the total mass of the sample being weighed or 0,1 g (the sample size shall be sufficient such that the minimum sample mass is 100 g), whichever is the greater.

The design density used in the assessment shall in all cases be as described in 7.3.2.2

A.4 Moisture content of applied fire protection materials

The samples and materials used to measure moisture content shall be stored together with and under the same conditions as the test specimens. The measurement of final moisture content shall be made on the day that fire testing takes place.

For board or slab passive fire protection materials, special test samples shall be taken measuring minimum 300 mm × 300 mm and of each thickness of the material used. They shall be weighed and dried in a ventilated oven, using the temperatures and techniques specified in ISO 834-1. The moisture content of the specimen shall be calculated as a percentage of its moisture equilibrium weight.

For spray applied passive fire protection materials, the moisture content of the material shall be determined from oven drying of one of the sample trays referred to in A.3, for each thickness tested. They shall be weighed and dried in a ventilated oven, using the temperatures and techniques specified in ISO 834-1. The moisture content of the specimen shall be calculated as a percentage of its moisture equilibrium weight.

Annex B
(normative)

Measurement of properties of reactive protection materials

B.1 Introduction

Determination of the thickness of the fire protection materials and other materials used in fire resistance tests is important to the accurate prediction of required fire protection thickness from the test result.

The methods used to establish these properties shall therefore be consistent and this Annex gives guidance on appropriate procedures to be used.

Any test samples used to determine thickness shall be conditioned with the actual fire test specimen under the conditions described in Clause 8.

The procedures given in EN 1363-1 shall be followed together with the following.

B.2 Thickness of fire protection materials

B.2.1 Dry film thickness

The dry film thickness shall be determined directly upon the test member, once the coating is fully dried as defined by the sponsor.

The thickness shall be measured by the test laboratory using an instrument employing either the electro-magnetic induction principle or the eddy current principle with a probe contact diameter of at least 2,5 mm.

B.2.2 Measuring positions

The number and location of thickness measurement points (which shall be regarded as the minimum required) shall be as follows:

B.2.2.1 Loaded beams

A minimum number of 88 measurements should be taken spread over the measuring stations indicated in Figures 6 and 13.

— the measurement stations at which temperature measurements are made on the surface of the test beam;

— the positions at which temperature measurements are made on the upper surface of the bottom flange of the beam or the bottom surface of hollow beams, halfway between each temperature measurement station;

— the positions halfway between the outermost temperature measurement stations and the outermost points on the upper surface of the bottom flange of the beam or the bottom surface of hollow beams.

B.2.2.2 Unloaded beams

A minimum number of 24 measurements at positions on the exposed surfaces of the beam (web and flanges or faces of hollow beams; see Figure 12) at locations in the proximity of

— the temperature measurement stations (between 50 mm and 100 mm away from) at which temperature measurements are made on the surface of the test beam.

B.2.2.3 Loaded tall columns

A minimum number of 50 measurements should be taken spread over the measuring stations indicated in Figure 13 for I or H sections and Figure 14 for hollow sections.

— the temperature measurement stations (between 50 mm and 100 mm away from) at which temperature measurements are made on the surface of the test column;

— the positions halfway between each temperature measurement station.

B.2.2.4 Unloaded short columns

A minimum number of 24 measurements should be taken spread over the measuring stations indicated in Figures 13 for I or H sections and Figure 14 for hollow sections.

— the temperature measurement stations (between 50 mm and 100 mm away from) at which temperature measurements are made on the surface of the test column.

B.3 Identification

Identification of the coating shall be in accordance with the ETAG 018-Part 2.

The properties of the material should be unambiguously characterized/identified (formulation).

Annex C
(normative)

Selection of test specimens - passive fire protection

C.1 Principle of selection

The scope of the assessment will determine the selection of the test specimens. Table D.1 allows for various assessments to be carried out depending upon whether the manufacturer wants to carry out limited or extensive testing. Each test package indicates the minimum number of test specimens required for the given scope.

Loaded beam testing of a particular fire protection supporting system is applicable also to columns using the same supporting system. The same protection system is defined as a system that identically reflects the bottom half of the beam protection system. It must also use the same fixing method in the upper half of the beam. For example, if the beam system only uses support noggins, then the column protection system can be regarded as being the same if the noggins are also used in the column protection system and they are located at the same spacing. If the beam system uses angles in the upper part of the beam casing but not in the lower part, then the same angles must be used in the column casing system. Otherwise, the two systems are regarded as different and a loaded column must be tested.

Fire protection systems that include a different number of layers of board, slab, or mat must be regarded as more than one system. Therefore, a single-layer system requires a separate package of tests and assessment from the multi-layered system. For example, if a board system requires up to three layers of board, then two test and assessment packages are required, i.e. one for the single-layer system and one for the two- and three-layer systems combined.

If fire protection render systems are tested without any reinforcing mesh, then mesh can be added in practice. If mesh is used in the tested system, then it must be used in practice.

Table C.1 applies to boards, slabs, or mats and sprayed coatings. In the case of boards, slabs, or mats, the column and beam fire protection systems must be the same for the combined columns and beams option (test packages 3 and 4).

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table C.1 — Principle of selection - open sections

Scope	Test package	Loaded beams selected from C.2	Loaded columns selected from C.2	Reference beams[b]	Reference columns[c]	Short I - sections beams	Short I - section columns[b]	Total short sections	Correction procedures from ISO 834-11, Table B.2
I beams[a]	1	✓		2		11		13	a)
I columns	2		✓		2		11	13	b)
I beams[a] + I columns	3	✓		2			13	15	d)
I beams[a] + I columns	4	✓		2		111	13	26	c)

[a] I means both I and H shapes.

[b] This beam shall be included in the thermal analysis.

[c] This column shall be used in the thermal analysis.

The sponsor can adopt the principles given in Annex A for structural hollow sections. If this is the case, testing of the appropriate I or H sections in accordance with this document must be carried out.

In the case of board, slab, or mat protection where the fixing method for hollow sections differs from that of I or H sections or where a separate assessment of hollow sections is required, Table C.2 applies.

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table C.2 — Principle of selection, hollow sections

Scope	Test package	Loaded beams selected from C.2	Loaded columns selected from C.2	Reference sections	Short hollow beams	Short hollow columns	Total short sections	Correction procedures from ISO 834-11, Table B.2
Rectangular beams	1	✓		2	4		6	e)
Hollow columns	2		✓	2		4	8	f)

A test programme for unloaded sections is required to explore the relationship between fire resistance, protection thickness, and section factor. A typical programme will include at least six sections where a range of thickness is required.

C.2 Test sections for correction for stickability

To take into account the stickability performance of the fire protection product, the temperature data for the short sections are to be corrected against the loaded beams and loaded columns depending upon the selected test programme. The methodology for determining the stickability correction is dependent on the scope of the test package selected from Tables C.3 and C.4 and is described in ISO 834-11.

The mathematical process for the correction of stickability is given in ISO 834-11. Guidance for the selection of loaded sections for evaluating stickability is given in Tables C.3 and C.4.

Table C.3 — Selection of test sections for renderings

Loaded section	Protection thickness	Section factor	Minimum depth or width mm
Beam 1	Maximum	Maximum to suit scope of assessment	300
Beam 2	Minimum	Maximum to suit scope of assessment	300
Column 1	Maximum	Maximum to suit scope of assessment	200
Column 2	Minimum	Maximum to suit scope of assessment	200

Table C.4 — Selection of test specimens for boards/mats/slab – single-layer systems

Loaded section	Protection thickness	Section factor	Minimum depth mm
Beam 1	Maximum	Maximum to suit scope of assessment	300
Beam 2	Minimum	Maximum to suit scope of assessment	300
Column 1	Maximum	Maximum to suit scope of assessment	200
Column 2	Minimum	Maximum to suit scope of assessment	300

Not all loaded sections will be required to demonstrate stickability; therefore, refer to C.1 for the selection of tests required.

The methodology for determining stickability correction is dependent on the scope of the test package selected from Table C.1 and Table C.2 and is described in ISO 834-11.

Correction factors for single-layer systems shall apply only to thermal data from single-layer testing.

Correction factors for multiple-layer systems shall apply only to thermal data from multiple-layer testing.

For multiple-layer systems tested on beams and columns, the section with the minimum protection thickness shall use two layers of the thinnest board, slab, or mat and the section with the maximum thickness shall use two or more layers of the maximum thickness board, slab, or mat. In the latter case, the outer layer of the board, slab, or mat may be replaced by a thinner layer to produce the maximum thickness to meet the scope of the assessment.

The location of the thinnest layer must be the same as in practice. For example, if the thinnest layer is tested as the outer layer of the system, then it must be the outer layer in practice.

C.3 Sections required for thermal analysis

C.3.1 Short I and H sections

The sections will be selected to cover the range of protection thickness, section factor, and fire resistance period and will include the short reference section equivalent to the loaded section. Tables C.5 and C.6 give the minimum number of sections required. Additional sections can be tested to allow curve fitting as described in ISO 834-11 (graphical method)

Additional short sections will be required for the analysis of hollow sections similarly chosen to cover the range of protection thickness, section factor, and fire resistance period.

The short, unloaded test specimens for fire protection systems with joints must not include joints unless the system would normally have joints at less than 1 m centres.

The selection of the specimens will be determined by the scope of the assessment required for the product. This will be on the basis of section factor range (maximum and minimum) and thickness range (maximum and minimum) for each fire resistance period. The range factors will be 1,0 for maximum and 0,0 for minimum and will be determined by the manufacturer.

For short I or H sections, Table C.5 applies.

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table C.5 — Fire protection thickness and section range factors for thermal analysis (short I or H sections)

Section range factor K_s	Thickness range factor K_d			
	0,0 (d_{min})	0,2 – 0,5	0,5 – 0,8	1,0 (d_{max})
0,0 (s_{min})	✓	✓	✓	
	✓ptp			
0,2 – 0,5	✓		✓	✓
	✓ptp			
	✓ptp	✓ptp		✓ptp
0,5 – 0,8	✓	✓	✓	✓
		✓ptp	✓ptp	✓ptp
		✓ptp	✓ptp	✓ptp
1,0 (s_{max})		✓	✓	✓

Table C.5 applies to beams and columns separately.

The above is an example – in any choice there must be at least three sections in each row and three sections in each column except in the case of the additional ptp sections.

The loaded beam or column at maximum thickness must be in the section factor range (0,2-1,0).

The loaded beam or column at minimum thickness must be in the section factor range (0,2-0,8).

Actual section factor and thickness are calculated in accordance with the formulas in Figure 8.

The scope of the assessment will be limited to beams with a maximum depth equal to two times that of the tested loaded beam protected with the appropriate protection thickness.

The scope of the assessment will be limited to columns with a maximum depth equal to two times that of the tested loaded beam or loaded column up to a maximum of 600 mm.

Minimum total number of short sections is 13 for beams and 1 for columns. If the system uses less than four thicknesses in practice, these thicknesses are tested and each thickness must be tested at every range of section factor.

If only short columns are used to assess beams, then reference beams must also be included for both minimum and maximum loaded beam tests.

If only short I or H sections are to be used to assess beams, then the maximum web depth will be limited to the web depth of the loaded beam plus 50 %.

If short I or H sections are to be used to assess the performance of hollow sections, then this shall be in accordance with Annex A of ISO 834-11.

The sections indicated in Table C.5 with a ptp reference are required as additional sections which are intermediate to the section factor ranges on either side when using a point-to-point graphical assessment for a particular nominal thickness line.

C.3.2 Hollow sections

If hollow sections are to be tested and assessed separately, i.e. when Annex A of ISO 834 Part 11 is not being used, then Table C.6 applies:

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table C.6 — Fire protection thickness and section range factors for thermal analysis (hollow sections)

Section range factor K_s	Thickness range factor K_d		
	0,0 (d_{min})	0,4–0,6	1,0 (d_{max})
0,0 (s_{min})	✓	✓	
0,4–0,6	✓		✓
1,0 (s_{max})		✓	✓

The table applies to hollow beams and columns separately.

The above is an example – in any choice there must be at least two sections in each row and two sections in each column.

The loaded beam at maximum thickness must be in the section factor range (0.5-1.0).

The loaded hollow column at maximum thickness must be in the section factor range (0.5-1.0).

Actual section factor and thickness are calculated in accordance with Formulae C.1 and C.2.

Minimum total number of short sections is 6 for beams and 6 for columns = 12 in total. If the system uses less than three thicknesses in practice, these thicknesses are tested and each thickness must be tested at every range of section factor.

This lower number of sections than in Table C.5 only allows for a limited assessment, i.e. a fixed protection thickness for each section factor with no interpolation between the tested thickness ranges.

For a full assessment, the same approach and number of sections given in Table C.5 shall be used.

The scope of the assessment will be limited to beams with a maximum depth equal to 1,5 times that of the tested loaded beam protected with the appropriate protection thickness.

The scope of the assessment will be limited to columns with a maximum depth equal to two times that of the tested loaded beam or loaded column up to a maximum of 600 mm.

For some fire resistance periods, the loaded section may not be the maximum section factor but it must be protected by the maximum thickness.

The actual values of the range factor may be derived from Formulae C.1 and C.2.

For thickness

$$d_p = K_d (d_{max} - d_{min}) + d_{min} \tag{C1}$$

where

d_p is the thickness at factor K_d;

d_{max} is the maximum thickness at K_d factor of 1;

d_{min} is the minimum thickness at K_d factor of 0.

For example: Thickness range 0,2 mm to 1,2 mm

Then thickness for a K_s factor of 0,5 is [(1,2 − 0,2) × 0,5] + 0,2 = 0,7 mm.

For section factor

$$s_p = K_s (s_{max} - s_{min}) + s_{min} \tag{C2}$$

where

s_p is the section factor at factor K_s;

s_{max} is the maximum section factor at K_s factor of 1;

s_{min} is the minimum section factor at K_s factor of 0.

For example: Section factor range 60 m^{-1} to 300 m^{-1}

Then section factor for a K_s factor of 0,5 is [(300 − 60) × 0,5] + 60 = 180 m^{-1}.

The section factor may be determined by the manufacturer subject to the selection of the actual test profile by the test laboratory.

The test specimens used shall be selected from the tables in Annex G.

Annex D
(normative)

Principle of selection of test specimens - reactive fire protection

D.1 Principle of selection

The scope of the assessment will determine the selection of the test specimens. Table D.1 allows for various assessments to be carried out depending upon whether the manufacturer wants to carry out limited or extensive testing. Each test package indicates the minimum number of test specimens required for the given scope.

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table D.1 — Selection of test specimens

Scope	**Test package**	**LB** min + **LB** max	**LC** min + **LC** max	**TC** max	**LHB** max	**LHB** min	**LHC** max	**LHC** min	**RB**	**SIB**	**SIC**	**TCHS**	**TRHS**	**SHB**	**SHC**	**Total short sections**	**Correction procedures from Table B.1**
I beams	1	✓								13						13	a)
I columns	2		✓								13					13	b)
I beams + I columns	3	✓		✓						13	13					26	a), c)
I beam + I columns	3A	✓		✓					2		13					15	d)
I beams + I columns + hollow columns	4	✓		✓			✓			13	13	✓	✓		6	32	a), c), e)
I beams + I columns + hollow columns	4A	✓		✓			✓		2		13	✓	✓		6	21	d), e)
I beams + I columns + hollow columns	5	✓		✓	✓					13	13			6		32	a), c), f)

Table D.1 *(continued)*

Scope	**Test package**	**LB** min + **LB** max	**LC** min + **LC** max	**TC** max	**LHB** max	**LHB** min	**LHC** max	**LHC** min	**RB**	**SIB**	**SIC**	**TCHS**	**TRHS**	**SHB**	**SHC**	**Total short sections**	**Correction procedures from Table B.1**
I beams + I columns + hollow columns	5A	✓		✓	✓				2		13			6		21	d), f)
I beams + I columns + hollow beams + hollow columns	6	✓		✓	✓		✓			13	13	✓	✓	6	6	38	a), c), e), f)
I beams + I columns + hollow beams + hollow columns	6A	✓		✓	✓		✓		2		13	✓	✓	6	6	27	d), e), f)
I beams + hollow beams + hollow columns	7	✓			✓		✓			13		✓	✓	6	6	25	a), e), f)
I columns + hollow columns + hollow beams	8		✓		✓		✓				13	✓	✓	6	6	25	b), e), f)
hollow beams + hollow columns	9				✓	✓	✓	✓				✓	✓	6	6	12	g), h)
I beams + hollow beams	10	✓			✓	✓				13				6		19	a), g)

Table D.1 *(continued)*

Scope	Test package	LB min + LB max	LC min + LC max	TC max	LHB max	LHB min	LHC max	LHC min	RB	SIB	SIC	TCHS	TRHS	SHB	SHC	Total short sections	Correction procedures from Table B.1
I columns + hollow columns	11		✓				✓	✓			13	✓	✓		6	19	b), h)
I beams + hollow columns	12	✓					✓	✓		13		✓	✓		6	19	a), h)
I columns + hollow beams	13		✓		✓	✓					13			6		19	b), g)
hollow beams	14				✓	✓								6		6	g)
hollow columns	15						✓	✓				✓	✓		6	6	h)

The test programmes for unloaded sections are required to explore the relationship between fire resistance, dry film thickness, and section factor.

Where the column referring to reference beams is only relevant to test packages where a beam assessment is carried out using short column data, then reference beams at minimum and maximum are required in addition to the short column test sections. In all other cases, the reference beams and columns shall be included in the selected short sections.

Testing of circular and rectangular hollow columns protected with reactive coatings does not conclusively demonstrate that one particular shape is more onerous than another. To allow test data to be used for both types, testing should be undertaken to adequately demonstrate which particular shape is more onerous prior to assessing both hollow shapes on the basis of testing one shape only.

To determine whether the coating performs differently on circular or rectangular hollow columns, a tall column of each type with a nominal section factor of 130 m^{-1} to 160 m^{-1} protected with the same coating thickness that relates to the nominal maximum should be tested or the maximum section factor to suit the scope of the assessment.

The nominal section size for tall circular and rectangular hollow columns should be 168,3 mm diameter × 6,3 mm wall thickness and 160 mm × 160 mm by 8,0 mm wall thickness respectively, or the minimum wall thickness to suit the scope of the assessment. In this case, it may be necessary to select the loaded hollow specimen with the same wall thickness as the tall column so that data correction can be carried out using the same reference section.

A comparison of the steel temperature profiles with respect to time to reach each of the design temperatures to be included in the assessment shall be made and the most onerous performance determined.

Once the determination of the most onerous hollow type has been made the loaded hollow column and short sections may be selected accordingly.

Alternatively tests on both circular rectangular hollow sections may be conducted and assessed separately. In each case, a loaded section will be required with the maximum thickness

D.2 Test sections for correction for stickability

To take into account the stickability performance of the fire protection product the temperature data for the short sections is to be corrected against the loaded beams and loaded columns depending upon the selected test programme. The methodology for determining the stickability correction is dependent on the scope of the test package selected from Table D.1 and is described in ISO 834-11.

D.3 Sections required for thermal analysis

D.3.1 Short and H sections

The sections will be selected to cover the range of protection thickness, section factor, and fire resistance period and will include the short reference section equivalent to the loaded section or tall section. Tables D.2 and D.3 give the minimum number of sections required. Additional sections can be tested to allow curve fitting as described in ISO 834-11, Annex C (graphical method).

Additional short and tall sections will be required for the analysis of hollow sections similarly chosen to cover the range of protection thickness, section factor, and fire resistance period.

The selection of the specimens will be determined by the scope of the assessment required for the product. This will be on the basis of section factor range (maximum and minimum) and thickness range (maximum and minimum) for each fire resistance period. The range factors will be 1,0 for maximum and 0,0 for minimum and will be determined by the manufacturer.

For short I or H sections, Table D.2 applies.

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table D.2 — Fire protection thickness and section range factors for thermal analysis (short I or H sections)

Section range factor K_s	**Thickness range factor** K_d			
	0,0 (d_{min})	0,2 – 0,5	0,5 – 0,8	1,0 (d_{max})
0,0 (s_{min})	✓	✓	✓	
	✓ptp			
0,2 – 0,5	✓		✓	✓
	✓ptp			
	✓ptp	✓ptp	✓ptp	✓ptp
0,5 – 0,8	✓	✓	✓	✓
		✓ptp	✓ptp	✓ptp
		✓ptp	✓ptp	✓ptp
1,0 (s_{max})		✓	✓	✓

If the graphical method of analysis according to Annex C of ISO 834-11 is to be used, then reference shall be made to Table C.3 to ensure that the correct number of thickness steps is included in the selection of the test specimens.

The table applies to beams and columns separately.

The above table is an example and in any choice there shall be at least three sections in each row and three sections in each column except in the case of the additional ptp sections.

The loaded beam at maximum thickness shall be in the section factor range of 0,2-1,0 and the loaded beam at minimum thickness shall be in the section factor range of 0,2-0,8.

Actual thicknesses and section factors are calculated in accordance with Formulae D.1 and D.2 respectively.

At least one short beam section shall have a minimum web depth of 600 mm.

The minimum number of short sections is 13 for beams and 13 for columns.

The section factors indicated in Table E.2 with a ptp reference are required as additional sections which are intermediate to the section factor ranges on either side when using a point-to-point graphical assessment for a particular nominal thickness line.

If only short columns are used to assess beams, then reference beams shall also be included for both minimum and maximum loaded beam tests.

If only short columns are used to assess beams, then the maximum web depth will be limited to the web depth of the loaded beam plus 50 %.

D.3.2 Hollow sections

For short hollow sections, Table D.3 applies.

NOTE Additional specimens may be needed for heavier steel sections as identified by local needs.

Table D.3 — Fire protection thickness and section range factors for thermal analysis (hollow sections)

Section range factor K_s	**Thickness range factor** K_d		
	0,0 (d_{min})	0,4–0,6	1,0 (d_{max})
0,0 (s_{min})	✓	✓	
0,4–0,6	✓		✓
1,0 (s_{max})		✓	✓

Table D.3 applies to hollow beams and columns separately.

Table D.3 is an example and in any choice there shall be at least two sections in each row and two sections in each column.

The loaded hollow beam at maximum thickness shall be in the section factor range of 0,5-1,0 and the loaded hollow beam at minimum thickness shall be in the section factor range of 0,5-1,0.

Actual thickness and section factor are calculated in accordance with Formulae (D.1) and (D.2) respectively.

The minimum number of short sections is six for beams and six for columns.

This lower number of sections than in Table D.2 only allows for a limited assessment i.e. a fixed protection thickness for each section factor with no interpolation between the tested thickness ranges. For a full assessment, the same approach and number of sections given in Table D.2 shall be used.

The actual values of the range factor may be derived from Formulae (D.1) and (D.2).

For thickness

$$d_p = K_d\ (d_{max} - d_{min})) + d_{min} \quad \text{(D1)}$$

where

d_p is the thickness at factor K_d;

d_{max} is the maximum thickness at K_d factor of 1;

d_{min} is the minimum thickness at K_d factor of 0.

For example: Thickness range 0,2 mm to 1,2 mm

Then thickness for a K_s factor of 0,5 is [(1,2 − 0,2) × 0,5] + 0,2 = 0,7 mm.

For section factor

$$s_p = K_s\ (s_{max} - s_{min})) + s_{min} \quad \text{(D2)}$$

where

s_p is the section factor at factor K_s;

s_{max} is the maximum section factor at K_s factor of 1;

s_{min} is the minimum section factor at K_s factor of 0.

e.g. Section factor range 60 m^{-1} to 300 m^{-1}

Then section factor for a K_s factor of 0,5 is [(300 − 60) × 0,5] + 60 = 180 m^{-1}.

The section factor may be determined by the manufacturer subject to the selection of the actual test profile by the test laboratory. The test specimens used shall be selected from the tables in Annex G.

Annex E
(normative)

Fixing of thermocouples to steelwork and routing cables

E.1 Introduction

The accurate measurement of steel temperatures is fundamental to the assessment methodology. The type of thermocouple and the method of attachment and routing, protection, and connection to suitable compensating cables or extensions shall therefore be considered carefully. This Annex offers guidance on suitable procedures.

E.2 Types of thermocouples

Several different kinds of thermocouple wire are suitable, including types “T”, “N”, “K”, and “J” as specified in IEC 60584-1.

It is preferred that mineral-insulated stainless steel sheathed thermocouples with an isolated hot junction are used. The overall diameter over the sheath shall be at least 1,5 mm.

Other thermocouples may be used subject to consultation between the laboratory and the test sponsor regarding their suitability. Suitable thermocouples shall be provided with individual wires at least 0,5 mm in diameter and be provided with insulation between the two wires and between each wire and any external conducting material such that there is no failure during test.

E.3 Fixing of thermocouples

The hot junction of the thermocouple shall be attached to the steelwork by peening or other methods that do not affect the response or accuracy of the thermocouple. Mechanical attachment using screws or bolts shall not be permitted.

Irrespective of the fixing methodology, it is essential that the thermocouples do not make contact beyond the hot junction which shall be in or at the steel surface; a thermocouple hot junction shall always be made at the position which creates the shortest loop between it and the cold junction. The thermocouple shall be fixed to ensure that it remains at that position.

E.4 Routing of thermocouple wires

Every attempt shall be made, whenever possible, to ensure that the wire from the hot junction follows a route to the cold junction which does not expose it to a temperature in excess of the hot junction temperature. The wires shall be routed behind the fire protection material and out of the furnace without passing through the furnace environment.

It may be necessary to protect the thermocouple wires by use of a channel or conduit prior to the application of the fire protection material. This is to be constructed from light gauge steel and is spot welded to the corners of the web and flange.

It shall be remembered that the claimed temperature performance of the thermocouple insulation material will relate to the thermocouple being in an environment where the wires are not subjected to movement or other strain.

It is possible that thermocouple wires will need to be supported to ensure that failure of the insulation material does not occur.

E.5 Connection of thermocouples

No connections shall be made between the thermocouple wire and any extension or compensating cable within any region of high temperature.

Compensating leads shall always be of a type appropriate to the thermocouple wire.

E.6 Thermocouple failures

Thermocouple failures are not always easily identifiable. Failure may be caused by a break within the wires or by failure of the electrical insulation between wires, thereby short circuiting the hot junction.

Obvious signs of failure, however, are

— a sudden decrease of indicated temperature from that previously recorded,

— a sudden increase in indicated temperature to a value representing the maximum range of the recording device, and

— a "floating or wandering" indicated temperature inconsistent with anticipated values.

A common sign of electrical insulation failure may be the observation of an indicated temperature value inconsistent with that of the furnace.

Annex F
(informative)

Test method to the smouldering fire (slow heating curve)

F.1 Introduction

Fire protection products activated by the heat flux of the fire may be required to be subjected to a test to a smouldering curve (slow heating curve as defined in ISO 834-2), with a rate of temperature increase less than that of the standard temperature/time curve.

This exposure, applicable to reactive fire protection materials, is used only in special circumstances, where it might be expected that the performance of the product when exposed to a smouldering fire might be substantially less than when it is exposed to the standard temperature/time curve and where such a test is specified in the national building regulations of the Member State of destination.

It is not intended to be mandatory for all fire protection materials applied to structural steel members.

F.2 Test equipment

The furnace and test equipment shall be designed to permit the test specimens to be exposed to heating as specified within F.5.

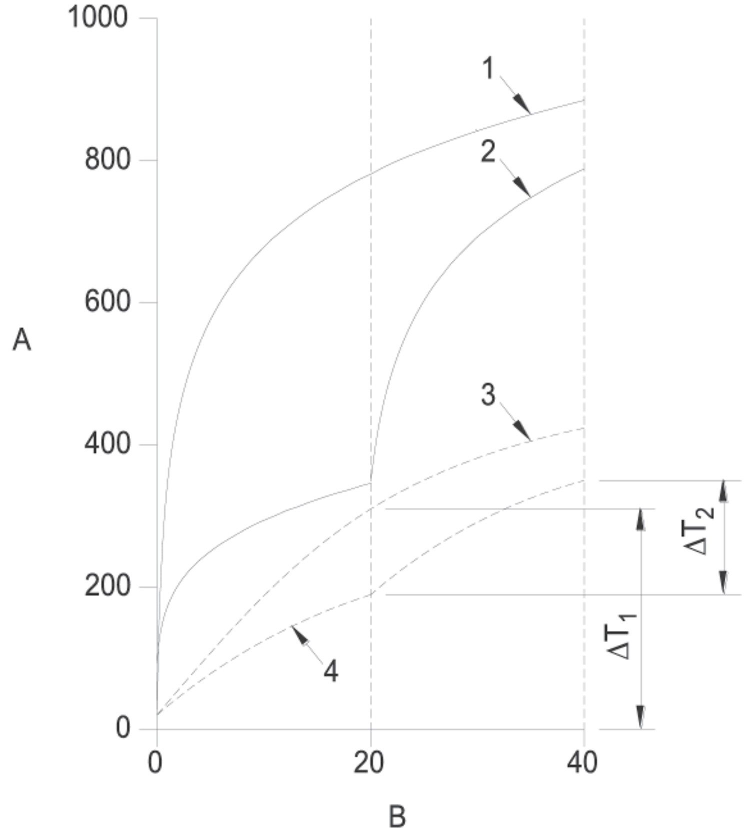
The smouldering curve (slow heating curve) shall be as specified in ISO 834-2, where it provides a heating regime wherein during the period t = 0 min to 20 min the furnace temperature (T) follows the relationship

$$T = 154\sqrt[4]{t} + 20 \tag{F.1}$$

After t = 20 min and for the remainder of the test, the furnace temperature (T) follows the temperature/time relationship

$$T = 345\log_{10}[8(t-20)+1] + 21 \tag{F.2}$$

This heating protocol is shown graphically in Figure F.1.



Key

1 standard temperature/time curve

2 smouldering (slow heating) curve

3 test element temperature to standard temperature/time curve

4 test element to smouldering (slow heating) curve

A temperature, in °C

B time, in min

Figure F.1 — Comparison of performance to the standard and smouldering fire curves

F.3 Test specimens

Four short steel columns shall be specified, e.g. as in Table F.1, which are duplicates of four of the sections from the tables given in D.3.

Table F.1 — Test specimens

Section range factor K_s	**Thickness range factor** K_d			
	0,0 (d_{min})	0,2 – 0,5	0,5 – 0,8	1,0 (d_{max})
0,0 (s_{min})	✓			
0,2 – 0,5				
0,5 – 0,8		✓	✓	
1,0 (s_{max})				✓

F.4 Termination of test

Terminate the test after 40 min or if it becomes unsafe to continue according to ISO 834-1.

F.5 Evaluation of the results

The characteristic temperature test data for each of the four defined short columns when subjected to both the standard temperature/time curve (according to the principal test) and the smouldering curve (this test) shall be compared each with the other.

The results from all thermocouples in each comparable location shall be examined and recorded by tabulation. The results from each comparable location shall be presented graphically, in a manner similar to that given in Figure F.1, and the performance of the fire protection material to the two fire sources compared and recorded.

The values of ΔT_1 and ΔT_2 shall be measured and recorded for all comparable locations.

Annex G
(informative)

Tables of section factors

The following tables list section factors for various sizes of steel members.

Table G.1 — Section factors for profile I and H shaped beam sections

UK beam section size mm × mm × kg/m	**Nominal profiled section factor** m^{-1}	**Euro beam section size** mm × mm × kg/m	**Euro beam designation**	**Nominal profiled section factor** m^{-1}
914 × 419 × 388	60	814 × 303 × 317	HEM 800	63
610 × 305 × 238	70	900 × 300 × 291	HEB 900	73
610 × 305 × 179	90	540 × 300 × 166	HEA 550	95
254 × 254 × 89	110	240 × 240 × 83	HEB 240	116
457 × 152 × 82	130	500 × 200 × 91	IPE 500	141
356 × 171 × 67	140			
533 × 210 × 92	140			
406 × 178 × 67	155	400 × 180 × 66	IPE 400	164
610 × 229 × 101	145			
406 × 178 × 60	175	330 × 160 × 49	IPE 330	188
406 × 178 × 54	190	300 × 150 × 42	IPE 300	200
356 × 171 × 45	210	240 × 120 × 31	IPE 240	223
356 × 127 × 39	215			
254 × 146 × 31	230	200 × 100 × 22	IPE 200	253
305 × 102 × 28	245	180 × 91 × 19	IPE 180	268
254 × 102 × 22	275	160 × 82 × 16	IPE 160	287
305 × 102 × 25	285	140 × 73 × 13	IPE 140	306
102 × 44 × 7,4	320	120 × 64 × 10,4	IPE 120	331
		100 × 55 × 7,8	IPE 100	360
			IPE 80	390

Table G.2 — Section factors for boxed I and H shaped beam sections

Section factors for profile	Nominal boxed section factor m^{-1}	Euro beam section size mm × mm × kg/m	Euro beam designation	Nominal boxed section factor m^{-1}
914 × 419 × 388	45	814 × 303 × 317	HEM 800	49
610 × 305 × 238	50	900 × 300 × 291	HEB 900	58
610 × 305 × 179	70	540 × 300 × 166	HEA 550	67
254 × 254 × 89	70	240 × 240 × 83	HEB 240	71
457 × 152 × 82	105	500 × 200 × 91	IPE 500	107
356 × 171 × 67	105			
533 × 210 × 92	110			
406 × 178 × 67	115	400 × 180 × 66	IPE 400	121
610 × 229 × 101	110			
406 × 178 × 60	130	330 × 160 × 49	IPE 330	137
406 × 178 × 54	145	300 × 150 × 42	IPE 300	145
356 × 171 × 45	155	240 × 120 × 31	IPE 240	161
356 × 127 × 39	170			
254 × 146 × 31	160	200 × 100 × 22	IPE 200	184
305 × 102 × 28	200	180 × 91 × 19	IPE 180	194
254 × 102 × 22	215	160 × 82 × 16	IPE 160	207
305 × 102 × 25	225	140 × 73 × 13	IPE 140	221
102 × 44 × 7,4	260	120 × 64 × 10,4	IPE 120	239
		100 × 55 × 7,8	IPE 100	258
			IPE 80	277

Table G.3 — Section factors for profile I and H shaped column sections

UK column section size mm × mm × kg/m	Nominal profiled section factor m^{-1}	Euro column section size mm × mm × kg/m	Euro column designation	Nominal profiled section factor m^{-1}
356 × 406 × 634	30			
305 × 305 × 283	55	432 × 307 × 256	HEM 400	64
356 × 406 × 340	55			
305 × 305 × 198	75	270 × 248 × 157	HEM 240	76
		310 × 288 × 189	HEM 280	74
254 × 254 × 132	90	240 × 226 × 117	HEM 220	92
356 × 368 × 177	95	450 × 300 × 171	HEB 450	98
254 × 254 × 107	110	320 × 300 × 127	HEB 320	117
305 × 305 × 118	120	300 × 300 × 117	HEB 300	125
		390 × 300 × 125	HEA 400	128
254 × 254 × 89	130	240 × 240 × 83	HEB 240	139
356 × 368 × 129	130	330 × 300 × 105	HEA 340	145
203 × 203 × 60	160	180 × 180 × 51	HEB 180	168
305 × 305 × 97	145	290 × 300 × 88,3	HEA 300	166
203 × 203 × 52	180	230 × 240 × 60	HEA 240	192
203 × 203 × 46	200	210 × 220 × 51	HEA 220	209
		190 × 200 × 42	HEA 200	229

Table G.3 *(continued)*

UK column section size mm × mm × kg/m	**Nominal profiled section factor** m⁻¹	**Euro column section size** mm × mm × kg/m	**Euro column designation**	**Nominal profiled section factor** m⁻¹
152 × 152 × 30	235	152 × 160 × 34	HEA 160	253
		133 × 140 × 25	HEA 140	259
203 × 102 × 23	270	114 × 120 × 20	HEA120	290
		200 × 100 × 22,4	IPE 200	290
152 × 152 × 23	300	180 × 91 × 19	IPE 180	307
178 × 102 × 19	305	160 × 82 × 16	IPE 160	329
			IPE 100	424
			IPE 80	450

Table G.4 — Section factors for boxed I and H shaped column sections

UK column section size mm × mm × kg/m	**Nominal boxed section factor** m⁻¹	**Euro column section size** mm × mm × kg/m	**Euro column designation**	**Nominal boxed section factor** m⁻¹
356 × 406 × 634	20			
305 × 305 × 283	40	432 × 307 × 256	HEM 400	46
356 × 406 × 340	35			
305 × 305 × 198	50	270 × 248 × 157	HEM 240	53
		310 × 288 × 189	HEM 280	51
254 × 254 × 132	65	240 × 226 × 117	HEM 220	64
356 × 368 × 177	65	450 × 300 × 171	HEB 450	71
254 × 254 × 107	75	320 × 300 × 127	HEB 320	80
305 × 305 × 118	85	300 × 300 × 117	HEB 300	84
		390 × 300 × 125	HEA 400	90
254 × 254 × 89	90	240 × 240 × 83	HEB 240	94
356 × 368 × 129	90	330 × 300 × 105	HEA 340	99
203 × 203 × 60	110	180 × 180 × 51	HEB 180	114
305 × 305 × 97	100	290 × 300 × 88,3	HEA 300	110
203 × 203 × 52	125	230 × 240 × 60	HEA 240	129
203 × 203 × 46	140	210 × 220 × 51	HEA 220	140
		190 × 200 × 42	HEA 200	153
152 × 152 × 30	160	152 × 160 × 34	HEA 160	169
		133 × 140 × 25	HEA 140	174
203 × 102 × 23	210	114 × 120 × 20	HEA120	194
		200 × 100 × 22,4	IPE 200	220
152 × 152 × 23	205	180 × 91 × 19	IPE 180	233
178 × 102 × 19	230	160 × 82 × 16	IPE 160	250
			IPE 100	313
			IPE 80	339

Table G.5 — Section factors for rectangular hollow sections

Column section size mm × mm × mm	**Nominal section factor** m^{-1}
400 × 400 × 20	55
200 × 200 × 16	70
200 × 200 × 12,5	85
200 × 200 × 10	100
200 × 200 × 8	130
160 × 160 × 8	135
90 × 90 × 8	140
200 × 200 × 6,3	165
150 × 150 × 5	210
100 × 100 × 4	260
90 × 90 × 3,6	290
80 × 80 × 3,6	295
100 × 50 × 3,2	330
50 × 50 × 2,5	425

Table G.6 — Section factors for circular hollow sections

Column section size mm × mm	**Nominal section factor** m^{-1}
244,5 × 25	45
323,9 × 25	45
355,6 × 20	55
219,1 × 12,5	85
219,1 × 10	100
219,1 × 8	130
168,3 × 8	130
168,3 × 6,3	165
139,7 × 5	205
219,1 × 5	205
114,3 × 3,6	285
88,9 × 3,2	325
42,4 × 2,6	410

Section factors can also be selected from Table G.5 if testing rectangular beams. In this case, the section factor is calculated on the basis of three-sided exposure.

Bibliography

[1] ISO/TR 834-3, *Fire-resistance tests — Elements of building construction — Part 3: Commentary on test method and guide to the application of the outputs from the fire-resistance test*

[2] ISO/TR 12470, *Fire-resistance tests — Guidance on the application and extension of results*

ICS 13.220.50

Price based on 61 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™