INTERNATIONAL STANDARD ISO 834

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Fire-resistance tests — Elements of building construction

Essais de résistance au feu — Éléments de construction

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 834 was drawn up by Technical Committee ISO/TC 92, *Fire tests on building materials and structures*, and circulated to the Member Bodies in September 1973.

It has been approved by the Member Bodies of the following countries :

Australia	Hungary	Romania
Belgium	India	South Africa, Rep. of
Bulgaria	Ireland	Spain
Canada	Israel	Sweden
Czechoslovakia	Italy	Thailand
Denmark	Mexico	Turkey
Egypt, Arab Rep. of	New Zealand	U.S.A.
France	Norway	Yugoslavia
Germany	Portugal	

The Member Body of the following country expressed disapproval of the document on technical grounds :

United Kingdom

This International Standard cancels and replaces ISO Recommendation R 834-1968, of which it constitutes a technical revision.

The revision has been made with the intention of specifying the test conditions more precisely in order to improve the reproducibility of the test results.

Guidance on the planning, performance and reporting of fire-resistance tests in accordance with this International Standard is given in annex A.

Reference should also be made to Technical Report ISO/TR 3956, *Principles of structural fire-engineering design with special regard to the connection between real fire exposure and the heating conditions of the standard fire-resistance test (ISO 834).*

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CONTENTS

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Fire-resistance tests – Elements of building construction

1 SCOPE

This International Standard specifies standard heating and pressure conditions, a test method and criteria for the determination of the fire resistance of elements of building construction of various categories.

The test provides for the determination of fire resistance of elements of building construction on the basis of the length of time for which the test specimens, of specified dimensions, satisfy the criteria laid down under the prescribed test conditions during the period of fire exposure.

2 FIELD OF APPLICATION

This International Standard is applicable to such structural elements of building construction as

- walls and partitions;
- columns;
- beams;
- floors (with or without ceilings);[1]
- roofs (with or without ceilings).[1]

This list is not exhaustive. Elements which fall into none of these categories may be tested by analogy with a similar element.

This fire-resistance test should not be used for classification of discrete materials or single components as such of an element of building construction. Tests for doors, shutters and glazing are dealt with in ISO 3008, *Fire-resistance tests on door and shutter assemblies*, and ISO 3009, *Fire-resistance tests on glazed elements.*

3 APPARATUS

The main items of apparatus are :

3.1 Furnace, capable of subjecting a specimen element to the standard heating and pressure conditions specified in clause 4.

3.2 Loading equipment (if necessary).

3.3 Thermocouples for measuring the internal temperature of the furnace and the surface and internal temperatures of the test specimens in conformity with the requirements of 4.1.2, 4.1.3 and 4.1.4.

3.4 Equipment for measuring overpressure in furnaces for testing walls and floors.

4 STANDARD HEATING AND PRESSURE CONDITIONS

4.1 Standard heating conditions

4.1.1 *Temperature rise*

The temperature rise within the furnace shall be controlled so as to vary with time within the limits specified in 4.1.3 according to the following relationship :

$$T - T_0 = 345 \log_{10} (8t + 1)$$

where

t is the time, expressed in minutes;

T is the furnace temperature at time t, expressed in degrees Celsius;

T_0 is the initial furnace temperature, expressed in degrees Celsius.

The curve representing this function, known as the "standard time-temperature curve", is shown in figure 1.

1) An annex concerning the testing of suspended ceilings without roof or floor is in preparation.

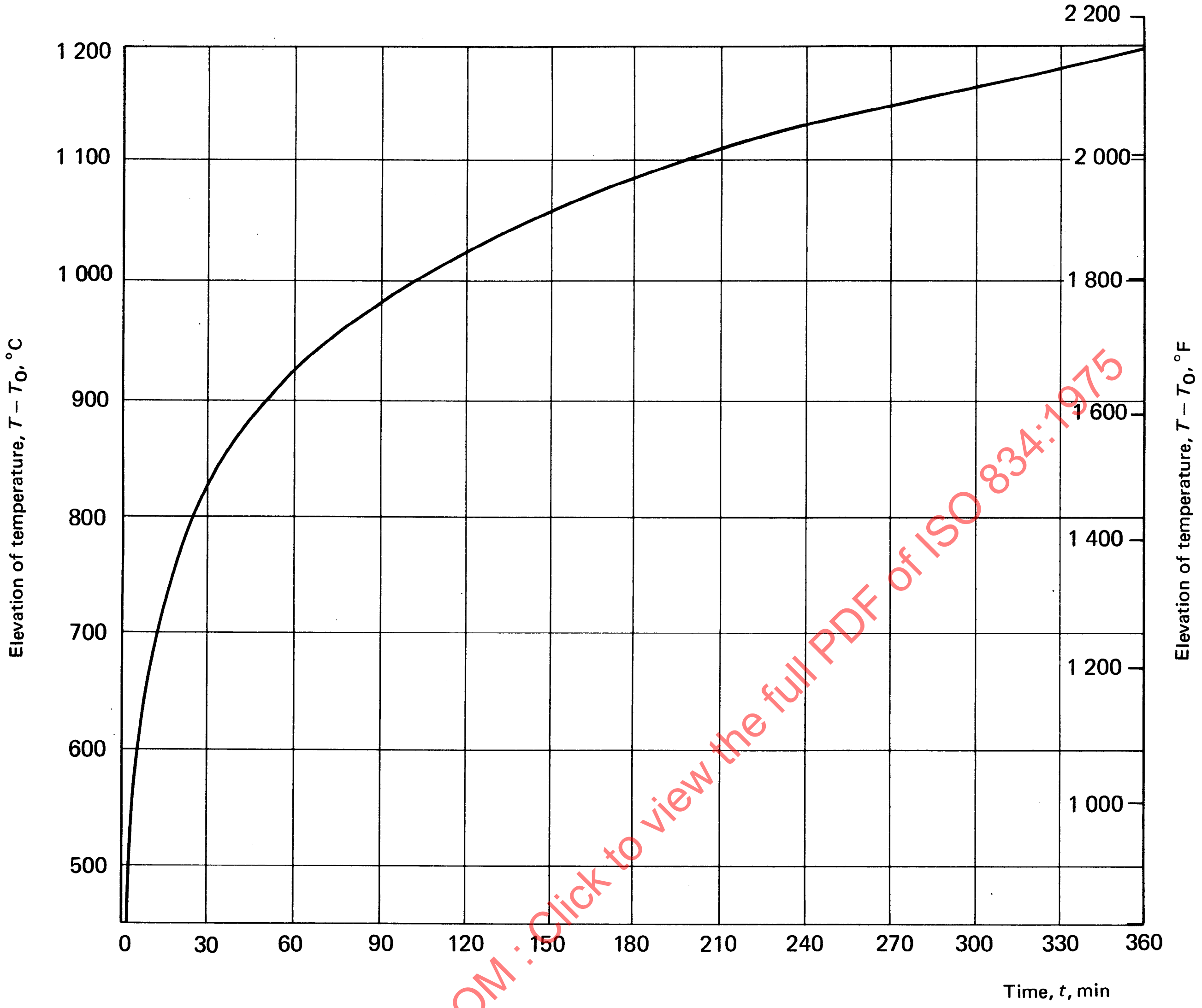

FIGURE 1 — **Standard time-temperature curve**

The relationship expressed above gives the values shown in the following table.

TABLE — **Temperature rise as a function of time**

Time, t	Elevation of furnace temperature, $T - T_0$	
min	°C	°F
5	556	1 001
10	659	1 186
15	718	1 292
30	821	1 478
60	925	1 665
90	986	1 775
120	1 029	1 852
180	1 090	1 962
240	1 133	2 039
360	1 193	2 147

4.1.2 *Measurement of furnace temperature*

4.1.2.1 The furnace temperature is deemed to be the average of the temperatures recorded by thermocouples arranged within the furnace to give an approximation to its average temperature.

4.1.2.2 These thermocouples shall not be fewer than

— one to each 1,5 m^2 of surface for walls and floors;

— two to each 1 m of length for beams;

— two to each 1 m of height for columns.

In any case, the number of thermocouples shall be not less than five.

4.1.2.3 Bare wire thermocouples of wire diameter not less than 0,75 mm and not more than 1,5 mm shall be arranged so that the hot junction is 100 mm from the nearest point of the test specimen. This distance shall be kept as constant as possible during the test.

Sheathed thermocouples may be used provided that they have a sensitivity not less than and time-constant not greater than those of bare wire thermocouples.

The wires of the thermocouples shall be placed in open tubes of heat-resistant material, for example porcelain, within approximately 25 mm from the hot junction.

4.1.3 *Tolerances*

4.1.3.1 FOR MEAN DEVIATION OF FURNACE TEMPERATURE RISE

The mean deviation of the furnace temperature rise is given, as a percentage, by the following expression :

$$\left| \frac{A-B}{B} \times 100 \right|$$

where

A is the integral value of the average furnace temperature as a function of time;

B is the integral value of $T - T_0$ from the equation defined in 4.1.1.

The tolerances on the mean deviations shall satisfy the following conditions :

1) ± 15 % during the first 10 min of test;

2) ± 10 % during the first 30 min of test;

3) ± 5 % after the first 30 min of test.

4.1.3.2 FOR TEMPERATURE DISTRIBUTION WITHIN THE FURNACE

At any time after the first 10 min of test, the temperature, recorded by any thermocouple, shall not differ from the corresponding temperature of the standard time-temperature curve by more than ± 100 °C (180 °F).

For specimens incorporating a significant amount of combustible material, the deviation of any one thermocouple shall not exceed 200 °C (360 °F).

4.1.4 *Measurement of temperature of test specimens*

Surface temperatures of test specimens shall be measured by means of thermocouples with a wire diameter of not more than 0,7 mm.

Each thermocouple junction shall be attached to the centre of the face of a copper disk 12 mm in diameter and 0,2 mm thick, which is secured to the surface of the specimen at the required position.

The disks shall be covered with oven-dry square asbestos pads 30 mm × 30 mm and 2 mm thick. The asbestos material shall have a density of 1 000 kg/m³.

The disk and the pad may be fixed to the surface of the specimen by pins, tape or a suitable adhesive, depending on the nature of the material forming the side of the specimen.

For thermocouples for measuring the temperature in the interior of the test specimen, the wires shall, if possible, follow the isotherm through the hot junction as closely as possible along a distance of at least 30 mm from this junction.

4.2 Pressure conditions

An over-pressure[1)] of 10 ± 5 Pa (1,0 ± 0,5 mmH_2O or 0,04 ± 0,02 inH_2O)[2)] shall exist in the furnace during the whole heating period of fire-resistance tests on separating elements of building construction. For vertical separating elements, this over-pressure shall exist over at least the upper two-thirds of the height of the test specimen. This over-pressure shall be measured and monitored :

a) for horizontal elements — 100 mm from the underneath surface of the specimen;

b) for vertical elements — at a point located approximately at three-quarters of the height of the element under test.

NOTE — The pressure difference may also be achieved by lowering the pressure on the unexposed face.

5 PREPARATION OF TEST SPECIMENS

5.1 Dimensions

5.1.1 The test specimens should be full size.

5.1.2 Where this is not possible, the following shall be the minimum dimensions[3)] of the parts of a test specimen exposed in the furnace :

Walls and partitions	height 3 m width 3 m
Floors and roofs : Supported on two sides	span 4 m width 2 m
Floors and roofs : Supported on four sides	span 4 m width 3 m
Beams	span 4 m
Columns	height 3 m

1) This condition is not mandatory for the first 10 min of the test.

2) 1 Pa = 1 N/m²

3) For a limited time, tests on walls and partitions of a slightly smaller size are allowed provided that the advice given in A.5 is taken into account.

5.2 Construction

5.2.1 The test shall be made on a test specimen representative of the complete element of construction on which information is required. Each type of element requires a different approach and an attempt shall be made to reproduce the boundary conditions and the method of fixing or support representative of that used in practice.

A test specimen shall include at least one of each representative type of joint. A specimen wall may include a beam or columns which form an integral part of the element to establish the performance of the composite assembly. A specimen may also include a door or glazing to establish the performance of the whole assembly.

When a ceiling treatment or a suspended ceiling is designed to contribute to the fire-resistance of a floor or a flat roof, the specimen shall incorporate the ceiling installed as in service.

When a specimen represents a column forming the side of an opening in a wall, it shall be suitably shielded on the unexposed face or faces to represent the protection provided by the wall.

5.2.2 The materials and standard of workmanship of the test specimen shall be representative of those applying in good practice, as defined by existing national codes and standards.

5.3 Conditioning

The test specimen shall be conditioned in such a way that it corresponds as closely as possible, in temperature, moisture content and mechanical strength, to the expected state of a similar element in service.

5.3.1 *Moisture content*

The test specimen shall not be tested until its moisture content is in dynamic equilibrium with an ambient atmosphere approximating to that expected in service. This dynamic equilibrium may be checked either on the test specimen itself or on a representative sample.

The drying of the test specimen may be by natural or artificial means, but a temperature shall not be reached which could impair the fire-resisting properties of the element. It is recommended that a temperature of 60 °C (140 °F) should not be exceeded.

When possible, the moisture content of the principal materials of the element shall be measured at the time of the test and the values shall be stated in the test report.

5.3.2 *Mechanical strength*

For load-bearing elements, the constituent materials of the specimen shall have attained a mechanical strength close to that expected for a similar element in service.

6 PROCEDURE

6.1 Test conditions

6.1.1 *Restraint and loading*

6.1.1.1 The role of the element in service shall be analysed so that the methods adopted for supporting or restraining the ends or sides of a test specimen during a test are, as far as possible, similar in nature to those which would be applied to a similar element in service. If restraint is applied in the test, then the restraint conditions shall be specified with regard to free movements of the element and, so far as possible, those external forces and moments which are transmitted to the element by restraint during the test.

6.1.1.2 For floors and beams with uncertain or variable boundary service conditions, the test specimen shall be simply supported all round the edges or at the ends.

For columns and walls with complete or partial restraint to longitudinal elongation, for a full evaluation of the structural behaviour, it may be necessary to conduct a complementary test under longitudinal restraint conditions which are as close as possible to conditions in practice.

6.1.1.3 At least 30 min before heating, the load-bearing test specimen shall be subjected to a loading which, in the critical regions of the element, produces stresses of the same magnitude as would be produced normally in the full-size element when subjected to the design load.

When it seems appropriate, a preloading shall be applied to the test element to guarantee a stabilization of the deformation and of the support and load equipment. The load application may be repeated a number of times for this stabilization.

6.1.1.4 The level and distribution of the applied loading shall be maintained constant during the test period.

6.1.1.5 Test specimens of non-load-bearing elements shall not be subjected to any external loading in the fire-resistance test. (See annex A).

6.1.2 *Exposure to heat*

6.1.2.1 Free-standing columns shall be tested by applying heat on all sides over their whole height.

6.1.2.2 Separating elements represented by test specimens of elements which have the function of separating spaces shall be heated over the whole of one face only.

Those which may be required to resist fire in one direction only shall be tested in that direction.

Those which may be required to resist fire in either direction shall be tested in the direction considered to possess the lower resistance by the testing authority. When this cannot be prejudged, each face shall be tested on separate test specimens.

6.2 Observations during test

The fire resistance of a load-bearing structure or structural element shall be judged by the criterion of load-bearing capacity, that of a separating element by the criteria of insulation and integrity, and that of a load-bearing and separating element by the criteria of load-bearing capacity, insulation and integrity. In most cases, only a small loss of integrity (initial integrity failure) can be accepted; in other cases, a larger loss of integrity (ultimate integrity failure) can be accepted.

In all cases of separating structural elements, the initial integrity failure shall be determined.

6.2.1 *Load-bearing capacity and deformation*

6.2.1.1 For a load-bearing test specimen, the time at which the specimen can no longer support the test load shall be measured and used to assess the performance.

6.2.1.2 Where possible, the following properties and characteristics shall also be noted during the whole test period :

a) deformations which can facilitate an analysis of the structural behaviour of the element and an application of the test results;

b) free movements of the element;

c) forces and moments transmitted to the element by restraint, according to 6.1.1.1;

d) other phenomena which are of importance for the load-bearing capacity of the element, such as cracking, splitting and structural transformations of materials.

When needed for an application of the test results, the temperature distribution in the interior of the test specimen shall be determined by means of thermocouples placed in such a manner that they provide a satisfactory basis for estimating the function and the behaviour of the specimen during the test.

6.2.1.3 For a separating element, such deformations as may have substantial effects on the function of the element shall be measured and noted during the whole test period. Note shall be made of the time when the test specimen no longer fulfils its functional requirements.

6.2.2 *Insulation*

6.2.2.1 AVERAGE TEMPERATURE OF UNEXPOSED FACE

In the case of elements with an unheated surface, the temperature of the unexposed face shall be measured by means of not fewer than five thermocouples, one placed approximately at the centre of the face and the others approximately at the centres of the straight lines joining the centre and the corners. Any additional thermocouples shall be disposed as uniformly as possible over the unexposed face of the specimen.

None of these thermocouples intended for measurement of mean temperature rise shall be fixed in position with through-metal connections or closer than 100 mm to the edge of the test specimen.

In the case of structures comprising composite elements, the arrangement of the test specimen shall ensure that the joints do not coincide with the points of measurement specified above.

The average of the temperatures measured at the points specified above, omitting temperatures measured at joints, is deemed to be the temperature of the unexposed face.

6.2.2.2 MAXIMUM TEMPERATURE OF UNEXPOSED FACE

In addition, the temperature shall be measured at the point that appears to be the hottest at any time during the test. This temperature shall not be used in the calculation of average temperature, unless the point at which this temperature occurs corresponds to one of the locations specified in 6.2.2.1, but shall be taken into account in determining whether the maximum temperature criterion has been complied with.

6.2.3 *Integrity*

6.2.3.1 For the determination of the time of initial integrity failure, a pressure difference according to 4.2 shall exist between the side of the furnace and the unexposed side of the test element. Observations shall be made of any sustained flaming on the unexposed face and of the ignition of a cotton pad held for not less than 10 s and not more than 30 s at a distance of between 20 and 30 mm from any opening on the unexposed side, indicating the ignition by hot gases. The pad shall not be re-used if it has absorbed any moisture or become charred during a previous application.

The cotton pad, measuring approximately 100 mm square × 20 mm thick, shall consist of new, undyed soft cotton fibres, without any admixture of artificial fibres, and shall have a mass between 3 and 4 g. The pad shall be conditioned by drying in an oven at 100 °C for at least 0,5 h. The pad shall be attached by wire clips to a 100 mm × 100 mm frame of 1 mm diameter wire to which a wire handle approximately 750 mm long is fixed. Note shall be made of the time when the first ignition of the cotton pad occurs and the position where this takes place.

6.2.3.2 To obtain the time of ultimate integrity failure, the test shall be continued beyond the initial integrity failure and further observations and measurements made of enlargement of cracks, holes or other openings through which flames or gases could pass. The full or partial collapse of non-load-bearing separating elements shall be noted as this will constitute ultimate integrity failure (see 7.2.3.2).

6.2.4 *Additional observations*

Throughout the test, observations shall be made of all changes and occurrences which are not criteria of performance but which could create hazards in a building, including, for example, the emission of smoke or noxious vapours from the unexposed face of a separating element.

6.3 Duration of test

6.3.1 Normally, the test specimen shall be heated in the prescribed manner until failure occurs under any one of the relevant test requirements, namely

- load-bearing capacity (see 7.2.1);
- insulation (see 7.2.2);
- integrity (see 7.2.3).

6.3.2 In tests other than those on test specimens judged only by the criterion of load-bearing capacity (see 7.2.1), the testing may be continued after failure under either of the other two conditions (see 7.2.2 and 7.2.3) by prior agreement between the sponsor of the test and the testing authority, until failure occurs under the other condition, provided that collapse of the specimen has not already occurred.

6.3.3 Alternatively, the test may be concluded after a period determined by prior agreement between the sponsor and the testing authority, even if no failure under any of the conditions has occurred at the end of that time.

6.3.4 The length of time from the commencement of heating for which the test specimen complies with the relevant requirement(s) shall be expressed in minutes.

7 PERFORMANCE CRITERIA

7.1 Fire resistance

The fire resistance of test specimens shall be the time, expressed in minutes, of the duration of heating in accordance with 4.1.1 until failure occurs, under the conditions — load-bearing capacity, insulation, integrity — appropriate to the specimen.

7.2 Criteria of fire resistance

The functional criteria of fire resistance comprise requirements with regard to load-bearing capacity for a load-bearing structural element, insulation and integrity for a separating element, and load-bearing capacity as well as insulation and integrity for a load-bearing and separating element.

7.2.1 *Load-bearing capacity*

For load-bearing elements of structure, the test specimen shall not collapse in such a way that it no longer performs the load-bearing function for which it was constructed.[1]

7.2.2 *Insulation*

For elements of structure such as walls and floors which have the function of separating two parts of a building,

a) the average temperature of the unexposed face of the specimen shall not increase above the initial temperature by more than 140 °C (252 °F);

b) the maximum temperature at any point of this face

- shall not exceed the initial temperature by more than 180 °C (324 °F) and
- shall not exceed 220 °C (428 °F) irrespective of the initial temperature.

7.2.3 *Integrity*

7.2.3.1 For elements of structure such as walls and floors which have the function of separating two parts of a building, the presence and formation in the test specimen of cracks, holes or other openings through which flames or hot gases can pass so as to cause initial integrity failure, shall not occur.

7.2.3.2 Initial integrity failure shall be deemed to have occurred when the cotton pad referred to in 6.2.3.1 is ignited or when sustained flaming, having a duration of at least 10 s, appears on the unexposed face of the test element.

Ultimate integrity failure shall be deemed to have occurred when collapse of the specimen takes place or at an earlier time on the basis of criteria stipulated from case to case.

NOTE — The words "insulation", "integrity" or "load-bearing capacity" shall follow the time, expressed in minutes, denoting the period of successful compliance under each of these headings.

8 TEST REPORT

The test report shall include the following information :

a) name of testing laboratory;

b) name of sponsor;

c) date of test;

d) name of manufacturer and the trade-name (if any) of the product;

e) details of construction and conditioning of the test specimens, including detailed information on the relevant physical and mechanical properties of the materials used, together with drawings illustrating the essential features;

f) methods of fixing, support and restraint as appropriate for the type of specimen;

g) for load-bearing specimens, the methods used for calculating the test load and its relationship to the maximum permissible load;

h) for asymmetrical separating elements, the direction in which the specimen was tested and the reason for adopting this procedure;

i) observations made during the test according to 6.2;

j) test results as required by 7.1. Where the test is terminated before the occurrence of failure under the relevant criteria, this shall be reported.

1) National standards may specify a value for the limiting deflection for beams and floors.

ANNEX A

COMMENTARY

A.0 INTRODUCTION

NOTE — So that suitable precautions to safeguard health may be taken, the attention of all persons concerned in fire tests is drawn to the possibility that toxic or harmful gases may be evolved in combustion of test elements.

This annex has been drafted to provide a commentary on the body of this International Standard, with the intention of giving guidance on the planning, performance and reporting of results of the test specified therein.

The possibilities of predicting the fire behaviour of a structure on the basis of data from a standard fire-resistance test is discussed in ISO/TR 3956.

This International Standard and the corresponding national standards concerning fire-resistance tests on elements of building construction have been developed on the basis of the classification requirements stipulated in national building codes and regulations.

A fundamental requirement for fire-resistance tests carried out according to this International Standard is that the test results shall be reproducible. This requirement necessitates very accurate detailed specification of the test conditions for the preparation of the test specimens and the characteristics of heating, loading and restraint during the test.

The test results obtained may be used as data for a structural design taking into account real conditions. This presupposes that the test characteristics and results have to be specified, measured and reported with a degree of accuracy and in sufficient detail so that the element of building construction, corresponding to the test specimen, can be analysed with regard to its functional behaviour in the complete structure.

Such detailed data from a fire-resistance test will also facilitate a classification and an international utilization of the test data in countries with different classification requirements. For a satisfactory analysis of the test results, it may be necessary to complement a fire-resistance test by other tests for determination of relevant material properties, for example thermal conductivity, specific heat and strength and deformation properties in the temperature range associated with fires.

The following explanatory notes are intended to serve as guidance for the planning, performance and reporting of a fire-resistance test in conformity with the principles outlined above. The clause numbers correspond to those in the body of this International Standard.

A.1 SCOPE

The fire resistance of an element of building construction is defined as the period of time from the beginning of a heating process fixed in accordance with clause 4 to an instant when the element no longer complies with the functional requirements that is has to fulfil.

These functions can be

a) a load-bearing function (for example a column or a beam);

b) a separating function (for example a partition or a non-load-bearing wall);

c) a load-bearing and separating function (for example a load-bearing wall or a floor).

For a load-bearing element, it is to be shown that the load-bearing capacity during the fire action does not decrease below a prescribed level multiplied by a stipulated safety factor. This factor depends, among other things, on the probability of the occurrence of a fire, the probability of the presence of the prescribed load at a fire outbreak and the statistical characteristics of the fire load and the load-bearing capacity. Unfortunately, the present state of knowledge is inadequate to enable a statistical approach to be made to this essential problem in ordinary cases. Consequently, a simplified routine is applied as a temporary solution of the problem, characterized by putting the test load equal to the design load and the corresponding safety factor required just in excess of unity.

For a separating element, it is to be shown that during the fire action the increase of the average temperature of the unexposed face and the maximum temperature at any point of this face do not exceed specified values (insulation; see 7.2.2) and that neither any sustained flaming nor any ignition of hot gases occurs on the unexposed face of the element (integrity; see 7.2.3). With regard to integrity, the requirements then can be differentiated. In most cases, only a small loss of integrity can be accepted, limited by the criteria of "initial integrity failure" according to 7.2.3.2.

In a fire-resistance test of a separating element, this type of integrity failure should always be determined. In some cases, a larger loss of integrity can be permitted without an unacceptable risk of fire spread through the separating element to an adjacent compartment. For a limitation of this risk, the concept "ultimate integrity failure" is introduced and defined according to criteria, stipulated from case to case, for instance on the basis of the canopy test, described in annex B of ISO 3008. The concept "ultimate integrity failure" replaces the former concept of "loss of stability" for non-load-bearing elements.

Finally, a load-bearing and separating element shall be judged by the criteria of load-bearing capacity, insulation and integrity (initial and ultimate integrity failure).

A.2 FIELD OF APPLICATION

This International Standard is limited in application to an experimental determination of the fire-resistance of those elements of building construction which either are located in a fire compartment or constitute parts of the structures enclosing a fire compartment.

In the latter case, only structural elements exposed to a fire on their internal face are included in the field of application.

This standard specification is not directly applicable to load-bearing walls which may be attacked by fire simultaneously on both sides; however, in particular cases, they may be treated as wall-shaped columns.

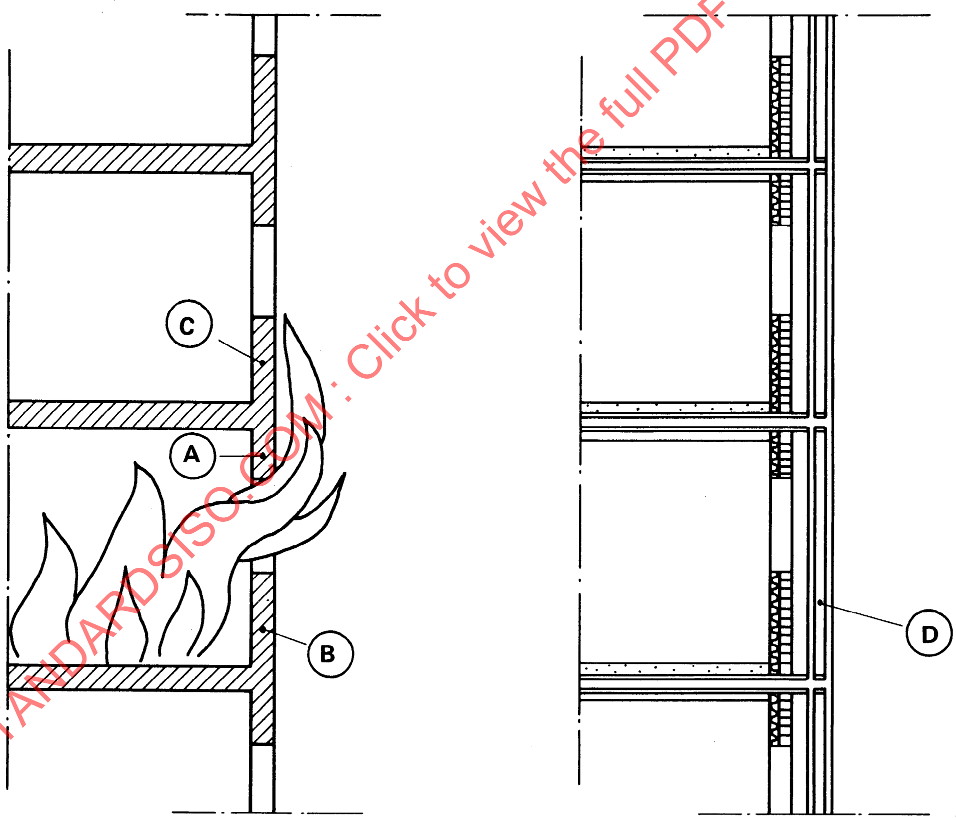

FIGURE 2 – **Example of fire exposure of structural elements**

This International Standard may not be directly applied to, for instance, external walls, columns and beams, for example as shown by items A, B, C and D in figure 2, or roofs under exterior fire exposure. According to figure 2, a structural element of type A will be directly exposed on the internal as well as on the external surface with different heating conditions for the two surfaces. A structural element of type B will be directly exposed to fire on its internal surface and simultaneously exposed on its external surface to a radiation from flames and combustion gases issuing from the fire compartment. In those cases in which this effect of radiation is unimportant, the structural element can be tested according to this International Standard.

For a structural element composed of the two structural details A and B functionally acting together, a compartment fire will lead to complicated heating conditions, which differ from the conditions specified in clause 4. Characteristic of a structural element of type C is fire exposure on the external surface only – provided that the windows above the element are intact – with heating conditions which cannot be described by the time-temperature curve, given in 4.1.1. For an external column of type D, a compartment fire will give rise to a fire exposure with varying heating conditions along the column.

It is essential to emphasize that the fire-resistance test according to this International Standard can be used only for a classification of a complete element of building construction and not for a classification of individual components or discrete materials of the element. This means, for instance, that a complete structural element of the type given in figure 3, composed of a reinforced concrete slab, load-bearing steel beams and an insulating ceiling, can be classified on the basis of the results of a fire-resistance test but not the steel beams or the insulating ceiling separately, unless they form part of a complete, fixed assembly.

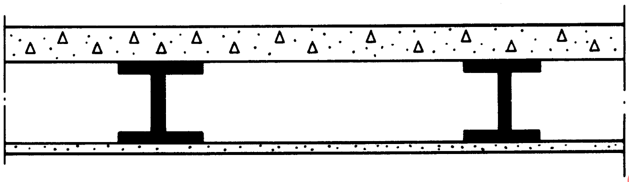

FIGURE 3 – **A typical structural element**

A.3 APPARATUS

A.3.1 Furnace

An accurate description of a time-temperature curve for a fire-resistance test according to 4.1.1 is not sufficient as the sole characteristic for the determination of the temperature fields in an element of building construction exposed to a fire. Another essential factor which is important in this connection is the coefficient of heat transfer for the surfaces of the element exposed to the fire. This coefficient is primarily influenced by the convection and radiation conditions.

For a prescribed time-temperature curve, the convection and radiation characteristics can vary considerably from one furnace to another, depending on the detailed design of the furnace and the type of fuel. For this reason, test results obtained in different laboratories may be difficult to correlate. In order to facilitate such comparisons of test results, it is recommended that the thermal properties of the furnace be calibrated with reference to a well-defined standard test specimen and be described in terms of that variation in the coefficient of the average heat transfer with the time which is associated with the time-temperature curve given in 4.1.1. It is also recommended that this calibration curve of the furnace be included in the test report.

For vertical and horizontal furnaces, such a standard test specimen can be constituted by, for instance, reinforced concrete elements, 150 mm in thickness, having a dry density of 2 400 kg/m^3.

An additional factor, which can also influence the test results and make comparative estimations more difficult – but to a lesser degree than the convection and radiation conditions within the furnace – is the characteristics of the environment of the furnace. In order to avoid too great variations of the temperature during a test within the space outside the furnace, it is necessary that the volume of the building containing the furnace be large, unless the environment is ventilated, and that the surrounding structure of this building have a comparatively high degree of thermal inertia. If possible, the ambient temperature, at a distance of more than 250 mm from the furnace, should not lie outside the range of 25 ± 15 °C. In testing elements which include combustible material, the oxygen content in the furnace can considerably influence the test results. It should be sufficient to ensure combustion and usually should be within the range of 5 to 10 %.

A.4 STANDARD HEATING AND PRESSURE CONDITIONS

A.4.1 Standard heating conditions

The time-temperature curve for the furnace given by the relationship

$$T - T_0 = 345 \log_{10} (8t + 1)$$

constitutes a simplification of real conditions in a fire.

In reality, the time-temperature relation which represents the development of a fire in an enclosed room depends on several factors. The most important of these are

a) the amount and type of combustible materials in the room (the fire load);

b) the distribution of the fire load in the room;

c) the porosity and particle shape of the fire load;

d) the amount of air per unit time supplied to the room;

e) the geometry of the room;

f) the thermal characteristics of the structures which enclose the fire chamber or are contained in it.

For a discussion of this problem and the question concerning the connection between a real fire exposure and the heating conditions according to the standard fire-resistance test, reference should be made to [1] and [2] in the Bibliography.

At the international level, the principles governing the need for fire-resistance tests and, consequently, the utilization of the test results, vary from country to country. At present, in different countries a classification system and a fire-engineering design of an element of building construction are characterized by one of the following :

a) only the heating period is considered;

b) the whole process of theoretical fire development is taken into account;

c) the test is limited to the heating period but the effect of the subsequent cooling period is included by a prolongation of the heating period;

d) the test is limited to the heating period and the capacity of the test element to resist the subsequent cooling period is estimated on the basis of the results of a residual load test of the element at the end of the heating period.

As a consequence of the varying classification requirements, the following additional recommendations can be given for a fire-resistance test of elements of building construction.

When an element of building construction has to fulfil certain functions during the heating period and during the subsequent cooling period, the loading of the test specimen should be maintained constant also during the cooling period.

If such a test is to be performed, the temperature within the furnace should be controlled so as to have a linear rate of decrease during the cooling period according to the following relationships (see figure 4) :

$dT/dt = 625\ ^\circ C/h$ for $t_h \leqslant 0{,}5$ h
$dT/dt = 250\ (3 - t_h)\ ^\circ C/h$ for $0{,}5\ h < t_h < 2$ h
$dT/dt = 250\ ^\circ C/h$ for $t_h \geqslant 2$ h

where

t is the time, expressed in hours;

t_h is the duration of the heating period, expressed in hours;

T is the furnace temperature, at time t, expressed in degrees Celsius.

At the end of the cooling period the furnace temperature should have decreased to an average temperature not exceeding 200 °C. During the cooling period the recorded mean value of the mean furnace temperature should not differ from the mean value of the specified time-temperature curve by more than ± 10 % and the mean furnace temperature at any time should not differ from the specified temperature by more than 100 °C.

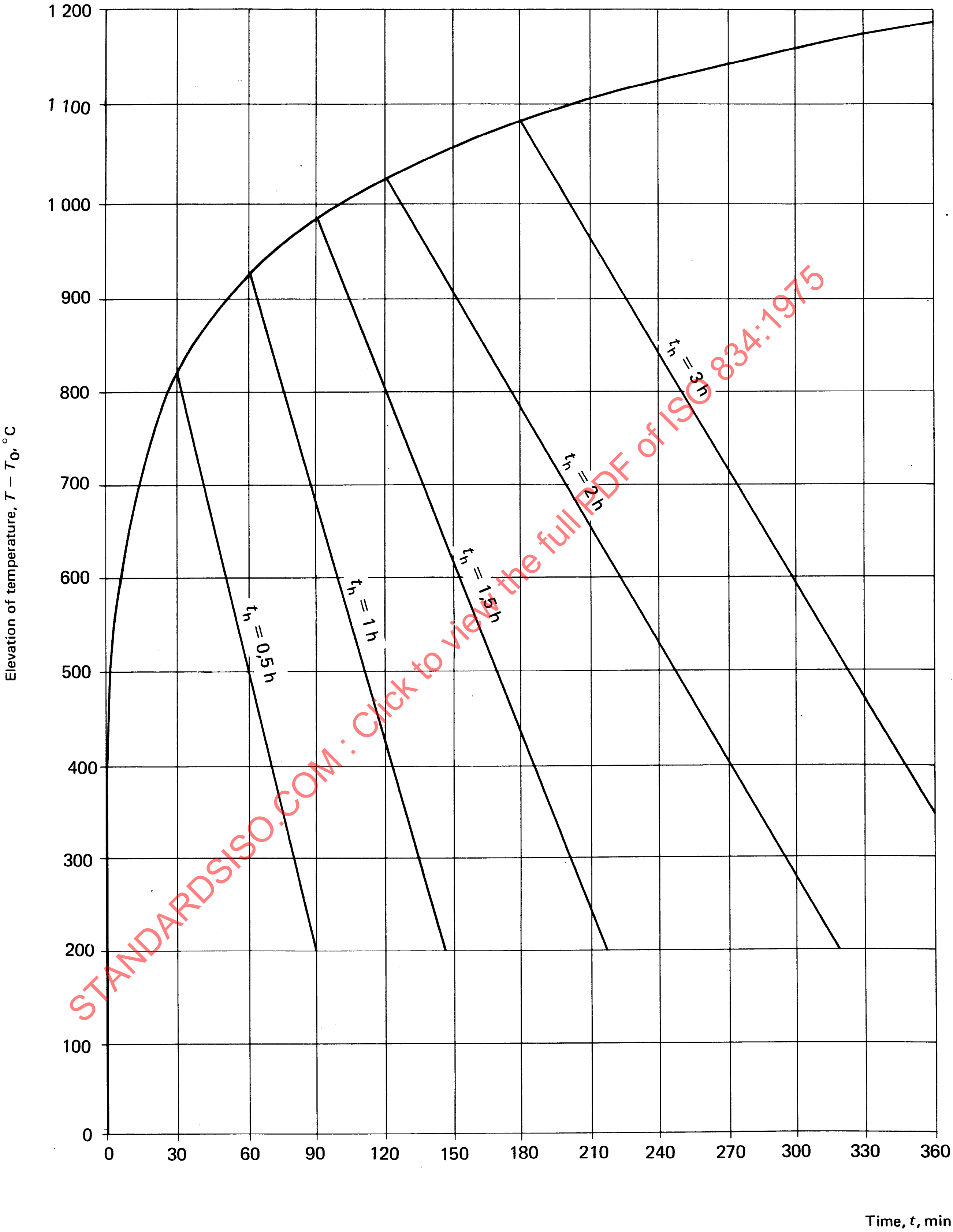

FIGURE 4 — **Cooling conditions**

A.5 PREPARATION OF TEST SPECIMENS

A.5.1 Dimensions

This International Standard specifies that the test specimens shall be full size wherever possible and specifies minimum dimensions for different types of test element to be applied when the use of a full-size test specimen is not possible. The dimensions of a fire-test specimen should be chosen with due regard to standard dimensions, recommended by ISO or stated in corresponding national standards or regulations.

Generally, the development of the testing facilities for fire-resistance tests towards furnaces of larger size is desirable for increasing the possibilities of doing full-scale fire tests for all types of elements of building construction covered by this International Standard. For instance, the minimum dimensions specified for beams and biaxial floors can be seen as a temporary, unsatisfactory solution, forced by the present state of widely varying testing facilities in the different laboratories. An increase of the minimum dimensions for biaxial floors to 4 m X 4 m may be essential. For beams the span can be frequently much larger than the minimum dimension specified in this International Standard.

For simply supported beams, the limitations posed can be met in many cases, without reducing the dimensions of the full-size test specimen, by an arrangement with the supports outside the furnace and with only a limited part of the beam, including the critical sections, within the furnace. Such an arrangement would require additional insulation to be applied on the beam outside the heated section to avoid a detrimental effect of temperature gradients in the axial direction of the beam.

Alternatively, the limitations mentioned can be met by reducing the span length in combination with such arrangements — an increase of the load level, a decrease of the area of the reinforcement for a concrete beam — so that the maximum stresses, decisive for the collapse, will be the same as for the full-size test specimen.

The strong recommendation to use full-size test elements is dictated by the difficulties in reproducing in detail a functionally correct fire behaviour, in model scale, of a load-bearing or separating element of building construction. For ordinary reinforced and prestressed concrete structures, the determination of fire-resistance by model-scale tests is complicated by the considerable influence of, for instance, the interior thermal stresses, the short-time shrinkage and internal creep from heating and the disintegration of the material at certain temperature conditions. For timber structures the problem of determining the fire resistance by a model-scale test is practically insoluble. For steel structures the possibilities of using model-scale tests for a fire-resistance investigation are comparatively favourable, especially for unprotected steel structures.

The previous comments about model-scale tests are related to a classification of a real element of building construction on the basis of the results of a fire-resistance test. Nevertheless, model-scale techniques in many cases can be a very useful instrument in fire-engineering research or a valuable complement to full-scale tests for a fire-engineering classification.

It is essential to emphasize the importance of keeping the functional behaviour unchanged when decreasing the dimensions of a test specimen in a fire-resistance test. This means, for instance, that the ratio between the side lengths should be unchanged when the dimensions of a biaxial floor are reduced.

A.5.2 Construction

This International Standard specifies that the test shall be made on a test specimen which is representative of a complete element in the real structure. This means, for instance, that a partition built up of elements should include representative joints. For a satisfactory determination of the fire resistance of such a partition, sometimes more than one test may be necessary. As an example, in figure 5 are shown two alternative joints for a partition of one-storey high elements, which could give different performances in a test.

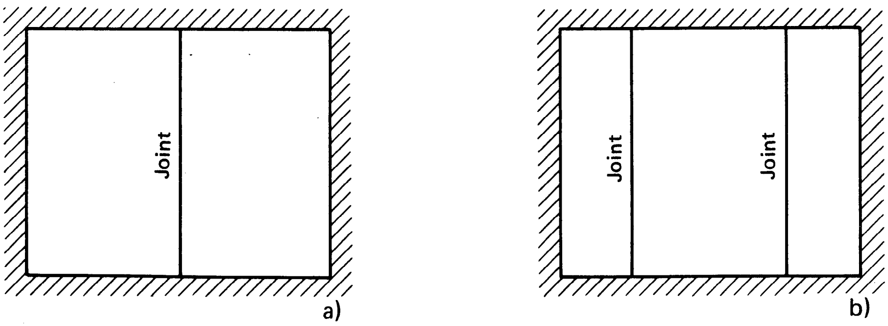

FIGURE 5 — **Alternative arrangements of joints for partitions**