TECHNICAL REPORT

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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

Essais de résistance au feu — Éléments de construction —

Partie 3: Commentaires sur les méthodes d'essais et guides pour l'application des résultats des essais de résistance au feu

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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.

ISO/TR 834-3 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

This second edition cancels and replaces the first edition (ISO/TR 834-3:1994), which has been technically revised.

ISO/TR 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*
- Part 3: *Commentary on test method and guide to the application of the outputs from the fire-resistance test*
- 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*

The following parts are under preparation:

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

Fire resistance is a property of a construction and not of a material and the result achieved is to a large extent related to the design of the specimen and the quality of the construction. It is not an “absolute” property of the construction and variations in both the materials and methods of construction will produce differences in the measured performance and changes in the exposure conditions are likely to have an even greater impact on the level of fire resistance the element can provide.

This part of ISO/TR 834 provides guidance to those contemplating testing, the laboratory staff performing the test, the designers of buildings, the specifiers and the authorities responsible for implementing fire safety legislation, to enable them to have a greater understanding of the role of the fire resistance test and the correct application of its outputs.

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

1 Scope

This part of ISO/TR 834 provides background and guidance on the use and limitations of the fire resistance test method and the application of the data obtained. It is designed to be of assistance to code officials, fire safety engineers, designers of buildings and other persons responsible for the safety of persons in and around buildings.

This part of ISO/TR 834 identifies where the procedure can be improved by reference to ISO/TR 22898.

2 Normative references

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

ISO 834-1:1999, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO/TR 834-2, *Fire-resistance tests — Elements of building construction — Part 2: Guide on measuring uniformity of furnace exposure on test samples*

ISO 3009, *Fire-resistance tests — Elements of building construction — Glazed elements*

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

ISO/TR 22898, *Review of outputs for fire containment tests for buildings in the context of fire safety engineering*

3 Standard test procedure

The primary purpose of a fire resistance test, e.g. ISO 834-1, is to characterize the thermal response of elements of construction when exposed to a fully developed fire within enclosures formed by, or within buildings. The output of the test permits the construction tested by this method to be given a classification of performance within a time based classification system (see Clause 5). The test provides data that may be of use to a fire safety engineer, albeit the test only reproduces one, of many, potential fire scenarios.

Practical considerations dictate that it is necessary to make a number of simplifications in any standard test procedure that is designed to replicate a real life event, in order to provide for its use under controlled conditions in any laboratory with the expectation of achieving reproducible and repeatable results.

The fire resistance test is designed to apply to a particular fire scenario within the built environment, but with an understanding of its limitations and objectives it may be applied to other constructions.

Some of the features which lead to a degree of variability are outside of the scope of the test procedure, particularly where material and constructional differences become critical. Other factors which have been identified in this part of ISO 834 are within the capacity of the user to accommodate. If appropriate attention is paid to these factors, the reproducibility and repeatability of the test procedure can be improved, possibly to an acceptable level.

3.1 Heating regimes

The standard furnace temperature curve described in ISO 834-1:1999, 6.1.1 is substantially unchanged from the time-temperature curve that has been employed to control the fire test exposure environment for the past 80 or so years. It was apparently related in some respects to temperatures experienced in some actual fires in buildings using referenced events, such as the observed time of fusion of materials of known melting points.

The essential purpose of the standard temperature curve is to provide a standard test environment which is representative of one possible fully developed fire exposure condition, within which the performance of various representative forms of building construction may be compared. It is, however, important to recognize that this standard fire exposure condition does not necessarily represent an actual fire exposure situation. The test does, nevertheless, grade the performance of separating and structural elements of building construction on a common basis. It should also be noted that the fire resistance rating accorded to a construction only relates to the test duration and not to the duration of a real fire.

The relationship between the heating conditions, in terms of time-temperature prevailing in real fire conditions and those prevailing in the standard fire resistance test is discussed in Clause 8. A series of cooling curves is also discussed. Proposals have been made to simplify the equations to improve their ability to be computer processed.

The comparison of the areas of the curves represented by the average recorded furnace temperature versus time and the above standard curve, in order to establish the deviation present, d_e, as specified in ISO 834-1:1999, 6.1.2, may be achieved by using a planimeter over plotted values or by calculation employing either Simpson's rule or the trapezoidal rule.

While the heating regime described in ISO 834-1:1999, 6.1.1, is the fire exposure condition which is the subject of this part of ISO/TR 834, it is recognized that it is not appropriate for the representation of the exposure conditions such as may be experienced from, for example, fires involving hydrocarbon fuels.

While the temperature conditions given in ISO 834-1:1999, 6.1.1 are seen to be the same as those used in previous editions of this standard, the method of measuring, and hence controlling the temperature within the furnace has changed significantly in the latest version of the standard.

This change in the measuring instrument has come about as a result of a harmonising process between the European and International test procedures, as a result of implementing the Vienna Agreement. As part of the pan-European harmonisation process, the traditional use of bare wire thermocouples (or sheathed thermocouples with a similar time constant) for measuring the gas temperature within the furnace, has been abandoned in favour of the adoption of a "plate thermometer". The theory behind the plate thermometer is that it receives the same thermal dose as the specimen, unaffected by the geometry of the furnace, the number and position of the burners and the nature of the fuel; all factors having been previously identified as causes of reproducibility and repeatability problems. This method of measuring temperature has been adopted in the latest version of ISO 834-1, and all of its parts.

This device has a greater time constant than the "bare wire" thermocouple described in the 1975 version of ISO 834, and as a consequence the gas temperature at any moment of time is likely to be higher than it was previously, particularly during the first 40 minutes. Therefore, while the latest version of ISO 834 follows nominally the same temperature/time relationship the thermal dose will be measurably greater, particularly over the first 20 to 30 minutes, than when the previous 'bare wire' thermocouples were used. Care should be taken when comparing the results of tests carried out in accordance with the earlier versions of ISO 834 and the present one ISO 834-1:1999, especially for constructions that are temperature sensitive.

Thermocouples do "age" and the current that they generate as a result of the "couple" created between wires of dissimilar resistance at any temperature will differ with time. All temperature measuring devices, but in particular the plate thermometer, should be calibrated on a regular basis or discarded after a short time in use.

3.2 Furnace and equipment design

3.2.1 Factors affecting the thermal dose

The heating conditions prescribed in ISO 834-1:1999, 6.1.1, are not sufficient by themselves to ensure that test furnaces of different design will each present the same fire exposure conditions to test specimens and hence provide for consistency in the test results obtained among these furnaces.

The thermocouples employed for controlling the furnace temperature are in dynamic thermal equilibrium with an environment which is influenced by the radiative and convective heat transfer conditions existing in the furnace. The convective heat transfer to an exposed body depends upon its size and shape and is generally higher with a small body than with a large body like a specimen. The convective component will therefore tend to have greater influence upon a bead thermocouple temperature while the heat transfer to a specimen is mainly affected by radiation from the hot furnace walls and the flames. For this reason the “plate” thermometer has replaced the bead thermocouple in ISO 834-1:1999, 5.5.1.1. The plate thermometer is more influenced by the total heat flux received by the specimen than the bead thermocouple.

There is currently no method of calibrating plate thermocouples and so a rigid regime of replacement should be implemented. While the “plate thermometer” is the specified device in ISO 834, the introduction of a “directional flame thermometer” measuring device is being considered, which may be introduced into subsequent editions of ISO 834.

Both gas radiation and surface to surface radiation are present in a furnace. The former depends on the temperature and absorption properties of the furnace gas as well as being significantly influenced by the visible component of the burner flame.

The surface to surface radiation depends on the temperature of the furnace walls and their absorption and emission properties as well as the size and configuration of the test furnace. The wall temperature depends, in turn, on its thermal properties.

The convection heat transfer to a body depends on the local difference between the gas and the body surface temperature as well as the gas velocity.

The radiation from the gases corresponds to their temperature, and the radiation received by the specimen is the sum of that from the gases and the furnace walls. The latter is less at the beginning and increases as the walls become hotter.

From the foregoing discussion, it is apparent that despite the use of the new plate thermometer, the ultimate solution in respect of achieving consistency among testing organizations utilizing the requirements of this part of ISO 834 will only be realized if all users adopt an idealized design of test furnace which is precisely specified as to size, configuration, refractory materials, construction and type of fuel used.

One method of reducing the problems that have been outlined, which can sometimes be applied to existing furnaces is to line the furnace walls with materials of low thermal inertia that readily follow the furnace gas temperatures such as those with the characteristics prescribed in ISO 834-1:1999, 5.2. The difference between the gas and wall temperatures will be reduced and an increased amount of heat supplied by the burners will reach the specimen in the form of radiation from the furnace walls. While this may improve the reproducibility of results the resulting exposure conditions may represent a more severe condition.

The measurement and control of the thermal dose received by a specimen is complex and further information can be obtained from Reference [4].

Where possible existing furnace designs should also be reviewed to position burners and possibly flues so as to avoid turbulence and associated pressure fluctuations which result in uneven heating over the surface of the test specimen.

Further consideration could be given in the design, or in particular in the refurbishment of furnaces, to the use of a “radiation” screen as proposed for use in ISO/TR 22898, as a way of making the thermal dose more even.

3.2.2 Furnace size

Generally the furnace size should accommodate the full sized element, or in some cases a full sized component which is to be installed within, or onto a proven construction. Often the size of an element in use is greater than the furnace and for these situations it is important that there is a recognized method for extrapolating the result achieved on the tested specimen size to that used in practice (see 3.7). There are, however, many components that are able to be tested at full size in furnaces much smaller than 3m x 3m or 3m x 4m, e.g. building hardware for use on fire doors, penetration sealing systems, electrical components, glazed openings, hatches, single leaf personnel doors, all of which can be tested for their contribution to fire resistance in smaller furnaces. The thermal dose must, however, be delivered in a comparable manner to that which it would receive in the larger furnace.

While the design of the thermometer to be employed in measuring and hence controlling the test furnace environment is specified in ISO 834-1:1999, 5.5.1.1, it is also suggested that experimental work be performed on improved instrumentation for use in measuring the thermal dose received by the specimen.

Finally, one of the most effective "tools" for improving the repeatability of the outputs of fire resistance tests is the use of a calibration routine (see 3.12).

3.3 Conditioning of the specimen

3.3.1 Correction for non-standard moisture content in concrete materials

At the time of test, ISO 834-1:1999, 7.4 permits the specimen to exhibit a moisture content consistent with that expected in normal service.

Except in buildings that are continuously air conditioned or are centrally heated, elements of building construction are exposed to atmospheres that, in varying degrees, tend to follow the cycling of temperatures and/or moisture conditions of the free atmosphere. The nature of the materials comprising the element and its dimensions will determine the degree to which the moisture content of an element will fluctuate about a mean condition.

Relating the specimen condition to that obtained in normal service can therefore result in a variation in the moisture content of specimen construction assemblies, particularly those with hygroscopic components having a high capability for moisture absorption such as portland cement, gypsum and wood. However, after conditioning such as prescribed in ISO 834-1:1999, 7.4, from among the common inorganic building materials, only the hydrated portland cement products can hold a sufficient amount of moisture to affect, noticeably, the results of a fire test.

For comparison purposes, it may therefore be desirable to correct for variations in the moisture content of such specimens using, as a standard reference condition, the moisture content that would be established at equilibrium from drying in an ambient atmosphere of 50 % relative humidity at 20°C.

Alternatively, the fire resistance at some other moisture content can be calculated by employing the procedures described in References [5] and [6].

If artificial drying techniques are employed to achieve the moisture content appropriate to the standard reference condition, it is the responsibility of the laboratory conducting the test to avoid procedures which will significantly alter the properties of the specimen component materials.

3.3.2 Determination of moisture condition of hygroscopic materials in terms of relative humidity

A recommended method for determining the relative humidity within a hardened concrete specimen using electric sensing elements is described in Reference [7]. A similar procedure with electric sensing elements can be used to determine the relative humidity within the fire test specimens made with other materials.

With wood constructions, the moisture meter based on the electrical resistance method can be used, when appropriate, as an alternative to the relative humidity method to indicate when wood has attained the proper moisture content. Electrical methods are described in References [8] and [9].

3.3.3 Curing of non-hygroscopic constructions

Increasingly fire resistance tests are being carried out on materials that rely on a chemical process to be completed before the material reaches its optimum material properties. This period is know as the ‘curing’ period. Before testing such materials it is important that they have achieved this optimum condition, and so there should be adequate “curing” time, which in the case of new materials may need regular monitoring of “parallel” products and associated mechanical tests.

3.4 Fuel input and heat contribution

At the present time the measurement of the fuel input is not among the data required during the performance of a fire test although this parameter is often measured by testing laboratories and users of this part of ISO 834 are encouraged to obtain this information, which will be of assistance in its further development.

When recording the fuel input rate to the burners, the following guidance on experimental procedures may be helpful.

Record the integrated (cumulative) flow of fuel to the furnace burners every 10 min (or more frequently if desired). The total fuel supplied during the entire test period is also to be determined. A continuous recording flowmeter has advantages over periodic reading on an instantaneous or totalizing flowmeter. Select a measuring and recording system to provide flowrate readings accurate to within ± 5 %. Report the type of fuel, its higher (gross) heating value and the cumulative fuel flow (corrected to standard conditions of 15°C and 100 kPa) as a fraction of time.

Where measurements of fuel input have been made, they typically indicate that there is a heat contribution to the test furnace environment during the latter stages of tests performed on test assemblies incorporating combustible components. This information is not usually taken into account by national codes, which sometimes regulate the use of combustible materials based upon the occupancy classification and on the height and volume of buildings in which this type of construction is employed.

It should also be noted that fuel input measurements may be considerably different when testing water-cooled steel structures or massive sections by this method.

3.5 Pressure measurement techniques

When installing the tubing used in pressure sensing devices, the sensing tube and the reference tube must always be considered as a pair and their path (together) traced from the level to which the measurement relates, all the way to the measuring instrument. As far as the reference tube is concerned, it may be physically absent, in places, but it must be regarded as implicitly existing (the air in a room between two particular levels, representing the reference tube in this case).

Where the reference and the sensing tubes are at the same level, they may be at different temperatures.

Where the reference and the sensing tubes curve from one level to another, they must, (at every level) be at the same temperature. They may be hot at the top and cool at the bottom but the temperature at each level must be the same (see also Reference [10]).

Care should be taken with the positioning of sensing tubes within the furnace so as to avoid them being subjected to dynamic effects due to the velocity and turbulence of furnace gases (see also reference [11]).

3.6 Post heating procedures

ISO 834-1 contains no requirements for, or reference to, post heating procedures. In Europe there is an impact test designed for a specific class of fire wall, but it is not meant to be a universally applied post-heating procedure. Similarly, it has been the practice in some countries to maintain the test load, or a factored test load, for a period, usually 24 h, subsequent to the fire test. The objective of this procedure has been to obtain a general assurance concerning the residual strength of the building construction represented by the test specimen, after a fire.

As this information is difficult to relate to a fire (or post fire) situation, it has been concluded that such requirements are outside the scope of the ISO 834-1.

While maintaining a load, or a factored load, for some period after the end of the test will give some general assurance as to the residual strength of the construction, during and after cooling, it does not quantify the strength in measurable terms. The method of loading specimens, especially horizontal ones, e.g. floors, is often not sophisticated enough to carry out load/deflection tests over a limited range of load applications in an easy and repeatable manner. However, if such information was able to be generated at the end of the heating period, and again at various times during the cooling period, all the way down to ambient temperature, this would provide meaningful information to the structural and fire engineering community. Assuming that all other data had been adequately obtained the load deflection test at ambient temperature, after cooling, could be taken to collapse.

Some countries follow the practice of additionally assessing the performance of separating elements by subjecting them to some form of impact test immediately following the fire test. This is intended to simulate the effect of failing debris or of hose stream attacks upon a fire separation, where that separation is required to maintain its effectiveness during or after the attack on the fire. Such impact tests may be applied after the complete fire test duration or after only a portion (e.g. half) of the rating period; and is often considered as a measure of stability apart from any assumptions with respect to simulated attacks with hose streams by fire-fighters.

It should be noted that both of the foregoing practices will, in most cases, discourage the possibility of continuing a fire test beyond the required fire endurance period. With the increasing need to provide data for extrapolation and other calculation purposes, testing organizations should be encouraged to continue the fire exposure period for as long as the limiting criteria may be safely exceeded.

3.7 Specimen design

ISO 834-1 has prescribed a general philosophy that fire resistance tests should be carried out on full-size specimens. It recognizes that for most elements of construction this is not possible because of the limitations imposed by the size of the equipment available (see 3.2.2). In those cases where the use of a full-size specimen is not possible, an attempt has been made to accommodate this shortcoming by specifying standardized minimum dimensions for a specimen representative of the size needed for a room of 3 m height and 3 m by 4 m in area.

Because this specimen size is invariably smaller than the in-use size it is recommended in ISO 834 that for those elements which are to be used at widths greater than that which can be accommodated by the furnace, they should be tested with a free edge or edges, so that the specimen does not derive artificially high level of support, especially against distortion, that do not exist in reality. Such artificial levels could reduce the stress on boards and board fixings (see 3.11 which deals with the influences of restraint on loadbearing capacity). In the case of walls and partitions that are to be used at widths greater than 3.0 m for the element to be tested with one edge free, even though this has not been normal in the equivalent National fire resistance test standard, gasket of material that has a good resistance to high temperatures may be considered suitable to form a seal between the element and the testing surround on the “free edge”. Resilient materials are often used for this purpose because they provide an enhanced seal when under compression. Materials used as gaskets have included high density mineral rock fibre (MRF) semi-rigid boards and, where permitted by national regulation, ceramic fibre.

However, both the use of a free edge, and the choice of materials used for sealing the free edge, must be subject to a detailed analysis before incorporating in a test construction. Many constructions that may appear to be used in long runs, i.e. office partitions, are frequently supported on one side by cross-partitions forming modular offices, even though the other side forms a long corridor lining. It may be inappropriate to test such systems with a completely unrestrained edge.

Metal faced sandwich panel constructions generally rely on interlocking joints for their stability. A free edge, especially one with a thick compressible gasket may allow the facings to expand freely and cause the panel joints to disengage. As a consequence the use of a free edge which permits expansion when testing metal faced sandwich panels should only be adopted after it has been shown that it will not result in a premature and unrealistic mode of failure. In practice, unlimited lateral expansion will normally be prevented by the structural frame of the building.

Therefore while a specimen with one edge fixed and one edge free is the method recommended in the standard for vertical separating elements, as it is thought to represent a generally demanding situation, other edge conditions may be used in the test as long as the selection is justified in the report of the test, as part of the

