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Standard tests for measuring reaction-to-fire of products and materials — Their development and application

Essais de mesurage de la “réaction au feu” des matériaux de bâtiment — Leur élaboration et leur application

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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 1, *Fire initiation and growth*.

This first edition cancels and replaces ISO/TR 3814:1989, which has been technically revised.

Introduction

A fire can constitute a hazard to both the structure, e.g. building, transport, and to its occupants, because of the heat generated and the production of smoke and gaseous products of combustion. Consequently, early codes and regulations for fire safety were designed to prevent rapid fire development and spread within individual structures and also from one structure to another. These codes have since developed into more complex laws governing public safety. Formerly, a distinction was made between the protection of persons from fire and the protection of property, with more importance being placed upon the latter. However, this distinction becomes somewhat difficult to make when considering modern, large-area, high-rise structures, where protection of the occupants in-place needs to be substituted for rapid evacuation. Restrictions on the use of combustible materials, compartmentalization, early fire detection, and suppression are key factors for in-place protection of occupants and are also important for minimizing property loss.

Real-scale fire tests are the ideal way to quantify the fire hazard of products. However, such tests are impractical in the vast majority of cases. The reaction-to-fire tests developed by ISO/TC 92/SC 1 seek to quantify aspects of the fire hazard that may result from the use of particular products in particular applications in a meaningful, cost-effective, and reproducible way.

This Technical Specification describes the work being carried out by ISO/TC 92/SC 1 on the development of tests and guidance for the “reaction-to-fire” of products and discusses the role and limitation of these tests in reducing fire danger.

Standard tests for measuring reaction-to-fire of products and materials — Their development and application

1 Scope

This Technical Specification describes the relevance of, and how to apply, the fire tests developed by ISO/TC 92/SC 1 so that they can be used effectively to reduce the hazard of fire. Each reaction-to-fire test is related to the different phases of a developing fire in buildings and transport and has to be seen in its relation to the fire scenario and phase of the fire it represents. Some reaction-to-fire tests are proposed to assess the fire hazard in those different phases.

Although this Technical Specification does not address smouldering combustion, this does not mean that smouldering is not important in some fire development situations. However, there are no tests in Subcommittee 1 (SC 1) which currently address this phenomenon.

This Technical Specification is aimed at indicating those ISO tests which produce relevant and useful data for fire safety engineering and those which do not. This Technical Specification is also of use to regulators, people who are performing reaction-to-fire tests including manufacturers and all people who are responsible to create, control, and assess fire safety concepts.

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 5657, *Reaction to fire tests — Ignitability of building products using a radiant heat source*

ISO/TS 5658-1, *Reaction to fire tests — Spread of flame — Part 1: Guidance on flame spread*

ISO 5658-2, *Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building and transport products in vertical configuration*

ISO 5658-4, *Reaction to fire tests — Spread of flame — Part 4: Intermediate-scale test of vertical spread of flame with vertically oriented specimen*

ISO 5660-1, *Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)*

ISO 9239-1, *Reaction to fire tests for floorings — Part 1: Determination of the burning behaviour using a radiant heat source*

ISO 9239-2, *Reaction to fire tests for floorings — Part 2: Determination of flame spread at a heat flux level of 25 kW/m2*

ISO 9705-1, *Reaction to fire tests — Room corner test for wall and ceiling lining products — Part 1: Test method for a small room configuration*

ISO/TR 9705-2, *Reaction-to-fire tests — Full-scale room tests for surface products — Part 2: Technical background and guidance*

ISO/TR 11925-1, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 1: Guidance on ignitability*

ISO 11925-2, *Reaction to fire tests — Ignitability of products subjected to direct impingement of flame — Part 2: Single-flame source test*

ISO 11925-3, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 3: Multi-source test*

ISO 12136, *Reaction to fire tests — Measurement of material properties using a fire propagation apparatus*

ISO/TR 13387-1, *Fire safety engineering — Part 1: Application of fire performance concepts to design objectives*

ISO/TR 13387-2, *Fire safety engineering — Part 2: Design fire scenarios and design fires*

ISO/TR 13387-3, *Fire safety engineering — Part 3: Assessment and verification of mathematical fire models*

ISO 13784-1, *Reaction to fire test for sandwich panel building systems — Part 1: Small room test*

ISO 13784-2, *Reaction-to-fire tests for sandwich panel building systems — Part 2: Test method for large rooms*

ISO 13785-1, *Reaction-to-fire tests for façades — Part 1: Intermediate-scale test*

ISO 13785-2, *Reaction-to-fire tests for façades — Part 2: Large-scale test*

ISO 13943, *Fire safety — Vocabulary*

ISO 14696, *Reaction-to-fire tests — Determination of fire and thermal parameters of materials, products and assemblies using an intermediate-scale calorimeter (ICAL)*

ISO 14934-1, *Fire tests — Calibration and use of heat flux meters — Part 1: General principles*

ISO 14934-2, *Fire tests — Calibration and use of heat flux meters — Part 2: Primary calibration methods*

ISO 14934-3, *Fire tests — Calibration and use of heat flux meters — Part 3: Secondary calibration method*

ISO 14934-4, *Fire tests — Calibration and use of heat flux meters — Part 4: Guidance on the use of heat flux meters in fire tests*

ISO/TS 16732, *Fire Safety Engineering — Guidance on fire risk assessment*

ISO/TR 17252, *Fire tests — Applicability of reaction to fire tests to fire modelling and fire safety engineering*

ISO/TS 17431, *Fire tests — Reduced-scale model box test*

ISO 20632, *Reaction-to-fire tests — Small room test for pipe insulation products or systems*

ISO/TS 22269, *Reaction to fire tests — Fire growth — Full-scale test for stairs and stair coverings*

ISO 24473, *Fire tests — Open calorimetry — Measurement of the rate of production of heat and combustion products for fires of up to 40 MW*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 apply.

NOTE ISO 13943 defines reaction-to-fire as the response of a product (material) in contributing by its own decomposition to a fire to which it is exposed, under specified conditions.

4 Development of reaction to fire tests

Authorities responsible for fire safety in many countries have been concerned over the years about the safe use of materials in the construction environment. A number of national test methods have, therefore, been developed to provide the data necessary to identify the important characteristics of materials and products under fire conditions. These tests, most of which are of laboratory scale, are collectively referred to as “reaction-to-fire” tests and include

— ignitability,

— surface spread of flame,

— smoke development and obscuration,

— rate of heat release,

— non-combustibility, and

— corner, wall, and/or room fire development.

The original “reaction-to-fire” tests were generally developed with particular hazards, or fire situations, in mind. For example, the predecessors of the modern surface spread of flame tests were developed in the 1930s and 1940s using flame or radiative heat exposure to represent a fire burning freely in one corner of a room. Such tests are frequently referred to as “open tests”. Later developments led to tests which included a representation of the room itself, these tests being called “enclosure tests” or “box tests”. In the latter case some, or all of the heat produced by the burning material, is retained in the enclosure and therefore can in turn affect more of the material. Consequently, fire exposures in “enclosure tests” are often more severe (in terms of heat release rate) than in “open tests”.

Some tests are designed to measure more than one fire parameter. The individual results can sometimes be used independently, although the importance attached to each can vary, whereas in others the test results can be combined empirically to produce an index, or a range of indices, of performance. Considerable care should be taken when interpreting the results of such combined tests.

Because the various national reaction-to-fire test methods have been developed in different ways, even though they are intended to measure essentially the same fire characteristics, it has proved very difficult, and in some cases impossible, to obtain any meaningful correlations between the test results obtained when using them. This has created major difficulties, both for the product manufacturers and for regulatory authorities around the world, when comparing the fire performance of products which have been tested using different national test methods. Additional problems have also arisen concerning international acceptance of fire test data, and in some cases these have created barriers to trade.

In attempt to resolve this situation, ISO/TC 92 decided in the late 1960s to develop a series of individual test methods, each of them capable of providing information about certain aspects of the fire performance of a range of building products, including those intended for use as wall and ceiling linings, floors and external cladding. It was intended that as the new international test methods were developed and accepted, countries should incorporate them into their regulations, thereby minimizing the problems caused by the use of individual national tests.

Subcommittee 1 was, therefore, established and instructed to devise a portfolio of reaction-to-fire tests which could be used either individually, or collectively, to provide the required information on the fire performance of building materials and products.

5 Fire development and growth

5.1 General context

Fire statistics show that the majority of fires are started by the ignition of contents as well as building products[8]. Nevertheless, during a fire in a building compartment all combustible items present are capable of contributing to the overall fire hazard, whether they are present as contents, or are used to form part of the building itself. The item first involved in a fire will emit both convective and radiative energy in the form of hot gases and radiative heat. Under unfavourable conditions, this can then cause ignition of other combustibles in the room. If sufficient fuel and oxygen are available, the fire will continue to grow. Building products could therefore become involved at any stage of a developing fire.

Consequently, reaction-to-fire tests have to provide different exposure intensities simulating a variety of fire situations ranging from fire initiation to a fully-developed fire.

The different phases occurring during the development of a fire within a room under different ventilation conditions are shown in Figure 1. Reaction-to-fire properties such as ignitability, spread of flame, smoke production, and heat release produced by fire effluents are primarily related to the phases of a developing fire before "flashover". Different possible fire developments, e.g. ISO 834 fire curve and the hydrocarbon fire curve, are shown to emphasize that fires develop very differently under different conditions. Fire curves such as the ISO 834 fire curve and the hydrocarbon fire curve only take the stage of the fully developed fire into account. To assess the reaction-to-fire of materials, the earlier phases of the fire also need to be considered.

5.2 Fire performance of products

The fire performance of a product is generally highly complex and is not usually solely dependent on the nature or chemical composition of the materials from which it is composed, but is affected by many other factors. These factors can include its shape, surface area, mass, and thermal inertia. Its orientation and position in relation to any potential ignition source and the presence of other products or items are also important. In addition, the environmental and service conditions to which the product has been exposed prior to ignition, the intensity and duration of the thermal exposure, and also the ventilation conditions during exposure can strongly influence the fire performance of a product.

These factors, provided by the product and its environment, shall be taken into consideration when designing fire test methods and when using the results for estimating potential fire hazards. Large scale testing is not always feasible due to the cost of the test, the pollution created, and the amount of product needed for the test. It is therefore desirable to develop small scale tests which can, if possible, be linked to large scale tests. For example, the cone calorimeter (ISO 5660-1) has been shown[9] that it can be linked to the ISO 9705-1 room/corner test. The link in this case allows the prediction of large scale (ISO 9705) performance from cone calorimeter data. However, other links have not been predicted.

Fire risk is a combination of many factors of which fire performance of a building product is only one factor. Other factors include building design, building use, human behaviour, fire and smoke control systems, and active and passive fire protection systems.

On a simple level, it is possible to describe a range of specific fire scenarios and link them to some specific fire tests. Fire tests developed in ISO/TC 92/SC 1 are linked to specific fire scenarios in Table 1:

Table 1 — Relationships between scenarios and reaction to fire tests

Scenario geometry	ISO Test number	Scale of test	Fire type
Open No compartment	ISO 24473	Large	Developing to fully developed
Small room	ISO 9705	Large	Developing to the point of flashover
Small room	ISO 13784-1	Large	Developing
Small room	ISO 20632	Large	Developing
Small room	ISO/TS 17431	Intermediate	Developing and post-flash-over
Small room	ISO 12949	Large	Developing to flash-over
Large room	ISO 13784-2	Large	Developing
Corridor	No test identified -		
Stairway	ISO/TS 22269	Large	Developing
Façade	ISO 13785-2	Large	Developing
Façade	ISO 13785-1	Intermediate	Developing

Table 1 *(continued)*

Scenario geometry	ISO Test number	Scale of test	Fire type
Roof	ISO 12468-1	Large	Developing
No geometry linked	ISO 1182	Small scale	Post-flashover
No geometry linked	ISO 1716	Small scale	Post-flashover
Single surface	ISO 5658-2	Small scale	Developing
No geometry linked	ISO 5660-1 to 4	Small scale	Ignition and developing ≤ 50 kW, 75kW is post flashover
Floor	ISO 9239-2	Small scale	Developing
No geometry linked	ISO 11925-3	Small scale	Ignition
Single surface	ISO 14696	Intermediate	Developing

NOTE All fire tests in Table 1 developed in SC 1 start under a well-ventilated fire condition.

6 Fire hazard assessment

Authorities in charge of fire safety, fire protection engineers, and scientists have been developing and using fire hazard assessment procedures for many years. These procedures, which have formed the basis for the development of fire protection codes and standards, have of necessity been primarily based on experience, since until recently very little effort has been made to refine the state-of-art knowledge to provide a technical basis for them.

In fire safety engineering, ISO 16732-1:2012 has been developed to provide the conceptual basis for fire risk assessment by outlining the principles underlying the quantification and interpretation of fire-related risk. The quantification steps to conduct a fire risk assessment are initially placed in the context of the overall management of fire risk and then explained within the context of fire safety engineering, as discussed in ISO/TR 13387-1, ISO/TR 13387-2, and ISO/TR 13387-3. The use of scenarios and the characterization of probability and consequence related to hazard are then described as steps in fire risk estimation, leading to the quantification of combined fire risk. Guidance is also provided on the use of the information generated, i.e. on the interpretation of fire risk. Finally, there is an examination of uncertainty in the quantification and interpretation of the fire risk estimates obtained following the procedures in this Technical Specification.

These fire risk principles can apply to all fire-related phenomena and all end-use configurations, which mean these principles can be applied to all types of fire scenarios.

Fire hazard assessment procedures usually include an evaluation of the following (see 6.1 to 6.4).

6.1 A determination that a particular product can be potentially hazardous in a fire

The possibility that a particular product will create a hazard in a fire has generally been based on the assumption that combustible materials can contribute actively to a fire, whereas non-combustible materials will not. Consequently, most regulations are based on the concept that combustible materials, as defined by a specified test method, could be considered to be potentially “harmful” and non-combustible materials are, therefore, conversely considered to be “safe”. Whereas, this can be considered to be a reasonable general approach it shall not be assumed to be applicable in all cases, since the presence of non-combustible materials can influence fire performance to some degree, particularly in the context of fire growth and spread in a compartment. For example, when making a hazard assessment of a product intended for use in a particular situation, account has to be taken of the thermal inertia (kpc) of products in surrounding structures and the reflecting properties of those products, organic compounds both inside or outside the products, e.g. binders, adhesives or covering, and the influence of air gaps between non-combustible and combustible products.