TECHNICAL SPECIFICATION

ISO/TS 3814

First edition
2014-03-01

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

Reference number
ISO/TS 3814:2014(E)

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Foreword

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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).

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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.

For modelling purposes, input parameters like heat release rate, smoke production, flame spread, and gross calorific value are often used. However, the implementation of test data in modelling calculations is only possible under the assumption that the tested product will behave similarly in the test and in the calculated fire scenario which cannot be assumed generally. Major purposes of the tests are the ranking and discrimination of products under different fire conditions; most of them were not developed to provide suitable input data for modelling calculations. Using test data for modelling calculations must take this fact into account.

— The recent developments in Fire Safety Engineering (FSE) show that test data of several tests, e.g. Cone calorimeter tests, open calorimetry, room corner test, and Fire Propagation Apparatus tests, can be used successfully to perform FSE calculations, e.g. using data as input data for performance based fire safety concepts. The FSE models are under recent and further development. Their range of applicability has been widened. However, the limits of the models have to be taken into account as well as the applicability of test data as input data for the models.

Using test data as input data for modelling calculations which do not represent similar fire scenarios and conditions could lead to incorrect modelling predictions.

6.2 An estimate of the ignitability of the product being ignited under particular conditions

The probability of a fire occurring is a most important consideration in the fire hazard assessment process, and this can be very difficult to estimate. Currently, much reliance is placed on experience and fire records, including statistics, to determine this probability.

The traditional approach was based on the so-called “fire triangle” which required the three components, viz. heat, fuel, and oxygen, to be available in appropriate quantities for a fire to start and to be sustained. However, even this was not a simple concept to apply since it was found that factors other than just the quantities of the various components needed to be taken into account. For instance, the total quantity of fuel available can not be a critical factor for determining ignitability since the physical form in which the fuel is presented to the ignition source can also have a significant effect. In general, a material in a finely divided form with a relatively large surface area such as thin strips, shavings, etc., will be more easily ignited and permit more rapid flame spread across its surface and consequently be potentially more hazardous than an equivalent quantity of the same material in a solid form. Indeed, when some materials are used in the form of a fine powder, the ignition process can occur explosively under certain conditions.

Other considerations also need to be taken into account during the assessment procedure, such as whether any heat generated is likely to be retained in close proximity to the fire source, e.g. from a fire in a closed compartment.

6.3 Knowledge of the reaction of the product in various fire situations

Fire tests developed by ISO/TC 92 and similar organizations can provide the necessary information on the reactions of products to different fire situations. However, such tests are most useful when a range of ignition sources and heating conditions can be used. Results based only on a restricted range of test conditions should therefore be used with caution. For example, a product can react entirely differently when exposed to a high heat flux than when tested with a relatively low heat flux. The used test methods should reflect the end use conditions of the product as far as possible regarding the mounting and fixing and the possible fire situations the product can face when it is used. Shape of the product, e.g. if the products shape is not flat, can influence the performance of the product and the test conditions; large scale tests might be necessary in these cases.

Although desirable, it is not possible at this time for any one test method to simulate every possible fire scenario. However, every effort should be made to use a thermal exposure in each test which relates to some real fire situation, preferably one that will also give results which can be used for fire modelling calculations.

6.4 Uses of reaction-to-fire tests in reducing fire hazard in different areas

The reaction-to-fire tests developed with ISO/TC92/SC 1 are intended to form a portfolio of tests for use by fire engineers and scientists for the evaluation of the fire performance of a wide range of building materials and products. These tests will be particularly useful for measuring reaction-to-fire phenomena under variable conditions mostly during the pre-flashover phase of a developing fire. It is worth pointing out that some tests e.g. ISO 1182 and ISO 1716 are used for assessing potential post-flashover contributions of materials and products. The gross calorific value data from ISO 1716 in particular can be used to calculate the possible maximum fire load. Test data of ISO 5660-1 and ISO 12136 tests are used as input data for FSE calculations, e.g. the rate of heat release and smoke production. Ultimately, in terms of the use of data from tests developed within SC 1 for fire safety engineering, whether the data are suitable for a particular application or not depends on the assumptions and simplifications that the fire safety engineer is willing to accept.

Table A.1 gives an overview of all reaction-to-fire tests which were developed in SC 1 to act as a glossary of what is available. Details can be found in the test methods and in the supporting documentation in ISO 17252. The first column indicates the test method with the accordant ISO number, the second column gives the title of the document, the test sample size is given in column three. Advantages and disadvantages of the test methods with respect to FSE are briefly discussed in column four. Column five describes the type of test data and the last column gives a brief conclusion, again regarding the use of these test data for FSE.

These test methods are increasingly being used by building control authorities, both nationally and internationally, for the production of fire safety regulations and codes. The European Union has adopted 4 of these tests (ENISO 1182, ENISO 1716, ISO 9239-1, ISO 11925-2) for use in its harmonized test and classification for construction products.

In Europe, for railway vehicles, CEN/EN 45545-2 specifies ISO 5660-1, ISO 5658-2, ISO 11925-2, ISO/TR 9705-2, ISO 5659-2, and ISO 9239-1. For minor and non-listed products, ISO 4589-2 can be used (although this is an ISO/TC 61 method). Note also that for products classified as A1 according to EN 13501-1, no further testing is required. Therefore, this results in further use of ISO 1182 and ISO 1716.

In the maritime area, fire safety is extremely important and IMO (International Maritime Organization) which is responsible for revising the international regulatory framework for fire safety of ships in the International Convention of Safety of Life at Sea (SOLAS) includes in Regulation 5 in Chapter II-2 which specifies application of fire safety in relation to use and spaces where materials are used.

Specific reaction to fire test methods from ISO are detailed in the FTP Code and include ISO 1182, ISO 5659-2, ISO 5658-2, ISO 9705, and ISO 5660-2 among others. Provision for fire safety engineering solutions is also made where alternative designs and arrangements can be allowed if they satisfy functional requirements and meet an equivalent fire safety level.

Countries intending, in the future, to introduce new national testing and classification systems for fire safety of building materials and products should, as a first step, quantify the hazards relating to reaction-to-fire, concerned in their own control system, and then choose the appropriate test, or tests, from the ISO portfolio. Annex A summarizes all the test methods in the portfolio giving a simple assessment of the advantages and disadvantages of the various test methods and a conclusion on the usefulness of the data measured.

Over the years many different techniques have been used and continue to be used to reduce the risks arising from building, compartment, and vehicle fires, these include:

a) reduction of fire incidents by education of occupants and personnel;

b) isolation and control of potential ignition sources, such as heating device and electrical appliances;

c) control of the types and amounts of hazardous materials permitted in specific areas;

d) providing separations between easily ignitable materials;

e) restriction of rapid fire spread by the use of flame retardant materials;

f) mitigation of the effects of a fire by providing adequate early detection, easily accessible escape routes, smoke control, and extinguishing equipment;

g) containment of fires within limited areas by the use of fire resistant structural elements such as floors and walls; and the protection of openings by the use of fire doors, shutters, etc.

Therefore, fire hazard cannot be achieved solely by control of products under fire conditions. While reaction to fire data, as detailed in items b), c), and d), is both useful and necessary, it is still only one aspect of the complex process of fire risk reduction.

7 Future developments and conclusions

The development work already carried out, or nearing completion, within SC 1 has resulted in the availability of a number of test methods forming an ISO portfolio of reaction to fire tests (see Annex A). These methods satisfy the required specification regarding ruggedness and ease of operation of test apparatus and reproducibility of test results. Some tests outputs or results directly describe the basic material flammability parameters governing the fire growth process within a compartment and can be used directly in fire engineering calculations. Other parameters are only implicitly given by the test data. A serious deficiency is the lack of suitable procedures to translate fire test data accurately and unambiguously into actual fire performance specifications.

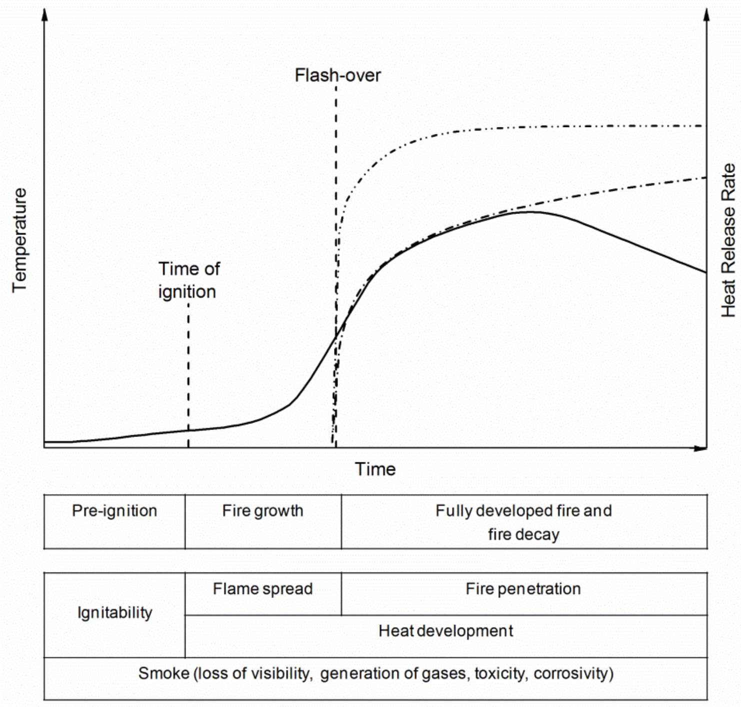
The elementary method of validation, i.e. the linking of test output with the room fire growth process, would employ a statistical correlation analysis, with test output quantities as independent variables, and time to significant fire process events, such as room flashover, as dependent variables. Unfortunately, the number of combinations of independent variables and the number of room fire scenarios which need to be included in such a study would make this approach prohibitively expensive and onerous.

Validation shall therefore be based on a theoretical understanding of the test procedures and of the room fire process. Recent developments in mathematical fire modelling suggest that significant progress is being made towards such an understanding.

Theoretical investigations of some of the methods have indicated procedures which are suitable for the derivation of relevant material flammability parameters. These include minimum exposure levels for ignition, effective values of thermal inertia, and flame spread parameters. For other tests, such as the rate of heat release test, the results are immediately applicable for mathematical modelling. It is important that the scenario the test refers to should be taken into account when using test data in fire modelling calculations. For instance, the measured heat release rate of a single object derived from a standard test cannot be the same as the heat release rate of the same object in a room where other objects present in the room are also burning. A standard test does not generally reflect the interaction between different objects.

Some continuing research has been able to correlate the parameters mentioned above with selected full-scale room fire scenarios e.g. it has been shown that a correlation can exist between ignition data and heat release from ISO 5660-1 and heat release in ISO 9705-1. The number of scenarios needs to be increased in order to enlarge the area of applicability and in order to gain more confidence in the validation studies. There are good reasons to believe that within a few years this research will lead to the production of engineering calculation rules and a rational methodology based on data obtained from some reaction-to-fire tests.

Widespread use of the ISO series of reaction-to-fire tests should make a significant contribution to the reduction of fire hazards by providing a greater understanding to users of the performance of building materials and products under standard fire conditions. With the increasing use of these tests, large databases will become available for a wide range of materials, which should in turn lead to wider international acceptance of fire test data.



Key

———————— development of fire (HRR)

—— . —— . —— ISO 834-1 (T, fire curve)

—— . . —— . . —— hydrocarbon curve (T, Eurocode 1)

Figure 1 — Diagram showing the different phases in the development of several fires within an enclosed space

Annex A
(informative)

Reaction-to-fire tests

A.1 Introduction

The current defined objectives of SC 1 are to develop International Standards for the following.

1) Fire safety engineering (FSE):

   i. Test protocols, measuring techniques, and procedures for securing data of fundamental fire properties.

   ii. Test protocols, measuring techniques, and procedures for input data to FSE models.

   iii. Standards relating to fire scenarios and characteristic fire growth of products.

NOTE It is however true that not all the tests in the portfolio developed in SC 1 and included here can be used exclusively for FSE. The tests which are suitable have been identified earlier in this Technical Specification and also in ISO 17252.

2) Performance codes:

   i. Test protocols for so-called reference scenarios.

   ii. Test protocols, measuring techniques, and procedures for fire calorimetry.

3) Prescriptive codes:

   i. Updating tests already in use.

   ii. Test protocols clearly needed for prescriptive codes.

4) Test validation

   i. Protocols to determine the precision of fire test procedures (e.g. uncertainty).

   ii. Test protocols for validation of fire growth predictions.

5) Instrumentation

   i. Protocols for measurement technologies used in fire test procedures (e.g. heat flux measurement).

In terms of illustrating the extensive range of tests covered by the subcommittee, the schematic in Figure A.1 can be shown to be useful.

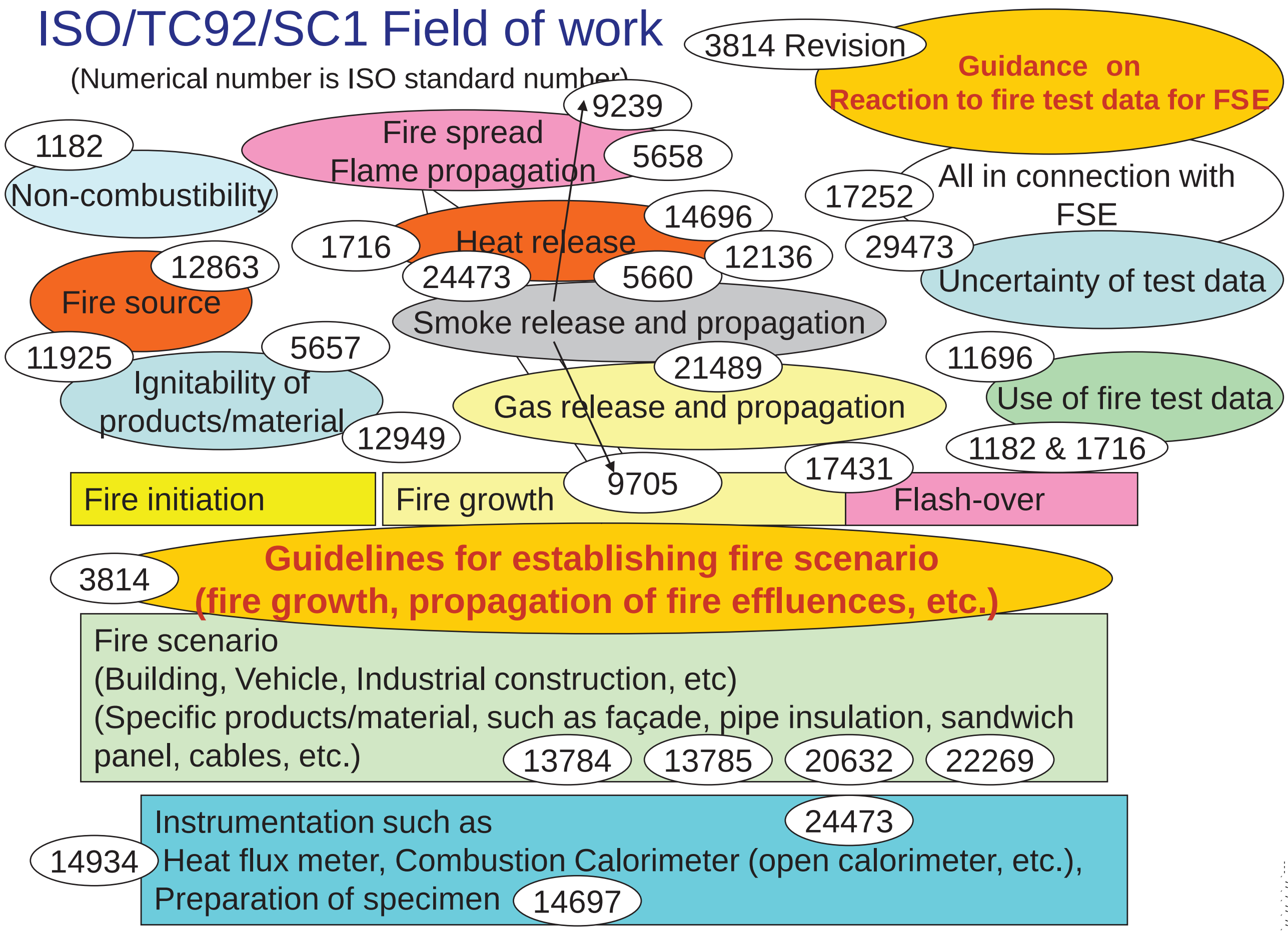


Figure A.1 — Extensive range of tests covered by Subcommittee 1

A.2 Reaction-to-fire test methods covered in SC 1

The intention is that Table A.1 gives an overview of all the test methods as a showcase for SC 1. This then acts as a glossary of what is available. Details can then be found in the test methods and in the supporting documentation in ISO 17252.

Work is on-going to introduce precision (Repeatability and Reproducibility) into the different reaction to fire standards where it is not already present.

Table A.1 — Reaction-to-fire test methods covered in SC 1

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 1182	Reaction to fire tests for building products — Non-combustibility tests	Cylindrical, volume: 76 (+8,-8) cm^3, diameter: 45 (+0, -2) mm Height: 50 (+3,-3) mm	Assessment of the possible contribution of a product in a fully developed fire only by temperature rise in the furnace.	Temperature in the furnace during test, visible flames	Basis of some classification schemes for reaction to fire.
ISO 1716	Reaction to fire tests for building- products Determination of the heat of combustion	Representative specimen, milled	Not applicable to layered materials, sometimes difficult to have a representative specimen.	Gross calorific potential e.g. to calculate max. fire load, consideration should be given for sample preparation for layered samples	Applicable for FSE.
ISO 5657	Reaction to fire tests- Ignitability of building products using a radiant heat source	165 (+0,-5)mm × 165 (+0,-5mm)	Ignitability of flat products, not meaningful for products which intumesce.	Ignition data exposure to selected levels of irradiance range 10–70 kW/m2	Useful but often replaced by the cone calorimeter for ignition data.
ISO/TS 11925-1	Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 1: Guidance on ignitability				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	250 (+0,-1) mm × 90 (+0,-1) mm in end-use thickness (up to 60 mm)	Ignitability assessed with only one flame source.	Ignition with small flame, Y/N decision based on duration of sustained flaming and extent of flame spread to a limit of 15cm	Useful in simple hazard assessment and basis of some minimum classification schemes for reaction to fire.
ISO 11925-3	Reaction to fire tests: Ignitability of building products subjected to direct impingement of flame — Part 3 Multi-flame source test	Various	Ignitability assessed to various flame sources.	Y/N decision based on duration of sustained flaming and extent of flame spread for various flame sources	Useful in fire hazard assessment since range of sources are considered.
ISO/TS 5658-1	Reaction to fire tests — Spread of flame — Part 1: Guidance on flame spread				Guidance document.

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 5658-2	Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building and transport products in vertical orientation	155 mm +0,-5 mm × 800 mm +0,-5 mm	Flame spread of essentially flat products is assessed with radiant panel and an impinging pilot flame. Heat flux gradient from 50kW/m2 down to 1.5kW/m2. Cannot be appropriate for some thermoplastics.	Average heat flux for sustained burning (HSB) Critical heat flux at extinguishment (CFE)	Opposed flow lateral flame spread is measured useful and is for tops of walls in rooms and corridors.
ISO 5658-4	Reaction to fire tests — Spread of flame — Part 4: Intermediate scale test of vertical spread of flame with vertically oriented specimen	1 025 ± 25 mm × 1 525 ± 25 mm	Vertical spread (upward and downward) of flame over a specimen of a product orientated in the vertical position. Heat flux of 40 kW/m^2 near the base of the specimen reducing to zero at the top. Other furnace positions can be used to obtain different heat flux exposures, but these are not standardised. For most testing, test specimens should be substantially flat, Profiled products can be difficult to test.	Time to ignition and area of flame spread. Rate of flame spread	The fire model represents a single burning item attack on the wall of a well-ventilated enclosure, which can be small or large. The specimen is sufficiently large to allow some end-use fixings (e.g. joints, air-gaps) to be incorporated into the test specimen. Used in FSE.
ISO 5660-1	Reaction to fire tests —Heat Release, smoke production and mass loss rate— Part 1: Heat release rate(cone calorimeter method)	100 (+0,-2) mm × 100 (+0,-2) mm, end use thickness up to 50 mm	Different levels of incident radiation are tested (typically 15 to 75 kW/m^2). Heat release rate is measured which is useful to assess the fire hazard of a product, normally horizontal position is tested, vertical orientation is an option, difficulties can occur for dimensionally unstable products during combustion.	Heat release rate, mass loss rate, time to ignition, effective heat of combustion	Applicable for FSE, used in Japan.
ISO 5660-2	Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 2: Smoke production rate (dynamic measurement)	100 (+0,-2) mm × 100 (+0,-2) mm, end use thickness up to 50 mm	Different levels of incident radiation are tested (typically 15 to 75 kW/m^2), normally horizontal position is tested, vertical orientation is an option, difficulties can occur for dimensionally unstable products during combustion.	Smoke production rate, total smoke production (in addition to data measured according to part 1)	Applicable for FSE.
ISO/TS 5660-3	Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 3: Guidance on measurement				Guidance document

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 12136	Reaction to fire tests — Measurement of material properties using a fire propagation apparatus	102 mm × 102 mm × 96,5 mm ± 2 mm in diameter For vertical propagation tests, 102 mm (W) × 305 mm (L)	Ignition, heat release rate and pyrolysis tests are conducted at different levels of incident radiation up to 65 kW/m^2 for horizontal sample. Fire propagation test is also conducted with vertical sample. Does not take into account fixing details, joints and edges finishes, since the specimen is too small to accommodate such fixings. Sample size is small compared with 'end use' application.	Time to ignition, chemical and convective heat release rates, mass loss rate, effective heat of combustion, heat of gasification and smoke yield	Provides input to flame spread and fire growth models, risk analysis studies, building and product designs and materials research and development, applicable for FSE.
ISO 9239-1	Reaction to fire tests for floorings — Part 1: Determination of the burning behaviour using a radiant heat source	1 050 (+5,-5) mm × 230 (+5,-5) mm	No measurement of the heat release rate, can also be used for assessing attic/loft insulation.	Burning length, heat flux and critical heat flux are determined	Used in prescriptive legislation in Europe, Australia and USA.
ISO 9239-2	Reaction to fire tests for floorings — Part 2: Determination of flame spread at a heat flux level of 25 kW m-2		Exposure to higher heat flux than 9239–1	As above	Can be used for hazard assessment for flame spread on inclined surfaces of floor coverings where higher heat fluxes can be expected.
ISO 9705-1	Fire tests — Full scale room test for surface products	Sample to line Room dimension 3,6 m by 2,4 m by 2,4 m (L × W × H)	Different configurations can be assessed – product lining walls and ceiling (standard) or only walls. Burner level is changed after 10 min from 100 to 300 kW in the standard procedure.	Time to ignition, Heat release rate and smoke release rate, total smoke released, as well as combustion gases CO, CO_2 (other potential toxicants if measuring systems included) Flame spread by using a drawn grid on the material surface, total heat flux by total heat flux meters, Flow measurement in door opening, Temperatures inside the room, Surface temperatures, Observations of extent of damage after test	The test method is a full scale test representing a small room scenario. Modelling using cone calorimeter data has shown link to this test performance, applicable for FSE.

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO/× 9705-2	Reaction-to-fire tests — Full-scale room tests for surface products — Part 2: Technical background and guidance				Guidance document
ISO/TR 11696:—	Uses of reaction-to-fire test results — Part 1: Application of test results to predict fire performance of internal linings and other building products				Guidance document
ISO 13784-1	Reaction-to-fire tests for sandwich panel building systems —Part 1: Test methods for small rooms	Room dimensions -3,6 m by 2,4 m by 2,4 m (L × W × H) -internal dimensions Doorway is 0,8 m wide × 2 m high, the test specimen shall be representative of that used in practice, both in construction and materials. All constructional details of joints, fixings etc., shall be reproduced and positioned in the test specimen as in practice	Exposure is 10 min at 100 kW and then 10 min at 300 kW for the standard ignition sequence. HRR range is 0–2 MW. No fire resistance performance is assessed.	Time to ignition, Heat release rate and smoke release rate, total smoke released, as well as combustion gases CO, CO_2 (other potential toxicants if measuring systems included) Flame spread by using a drawn grid on the material surface, total heat flux by total heat flux meters, Flow measurement in door opening, Temperatures inside the room, Surface temperatures, Observations of extent of damage after test	Small room test for industrial insulation and sandwich panels.
ISO 13784-2	Reaction-to-fire tests for sandwich panel building systems — Part 2: Test methods for large rooms	Room dimension 4,8 m by 4,8 m by 4 m (L × W × H) (Internal dimensions) Door 4,8 m by 2,8 m Specimen information as above	Sand box burner -Duration of exposure is 5 min at 100 kW, 5 min at 300 kW and 5 min at 600 kW for the standard ignition sequence.	Visual observations made of performance and assessment of damage at end of test	Scenario test

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 13785-1	Reaction to fire tests for façades — Part 1: Intermediate-scale test	The test specimen consists of sufficient cladding or façade panels together with battens and insulation where appropriate to cover two areas: 1,2 m wide and 2,4 m high, and 0,6 m wide and 2,4 m high. The joints where used in practice and fixings shall be installed in end-use condition into the test specimen. The test specimen shall incorporate a central horizontal joint at mid-height and a central vertical joint. The bottom edge of the specimen shall be closed by the method normally used for the incorporation of window casements.	Applies only to façades and claddings that are not free standing and that are used by adding to an existing external wall. The test method also only applies to vertical elements and does not apply to determination of the structural strength of the façade or cladding.	Ignition by visual observation and heat flux measurement. Flame spread by using a drawn grid on the material surface, total heat flux by total heat flux meters, Surface and gas temperatures Observations made during and after the test and assessment of damage. Behaviour of the façade panel construction and the resulting flame spread on or within the façade construction is studied	
ISO 13785-2	Reaction to fire tests for façades — Part 2: Large scale test		The method applies only to façades and claddings that are non-load-bearing. No attempt is made to determine the structural strength of the façade or cladding.	Ignition by visual observation and heat flux measurement. Flame spread, total heat flux by total heat flux meters, Surface and gas temperatures.	Evaluates the inclusion of combustible components within façades and claddings of buildings which are otherwise of non-combustible construction.

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 14696	Reaction-to-fire—Determination of fire parameters of materials, products and assemblies using an intermediate-scale calorimeter (ICAL)	Specimen size 1 m × 1 m and actual thickness up to 150 mm	Heat fluxes ranging from 0 to 50 kW/m^2. Hot wires are used as the ignition source. Material, product or assembly evaluations can be done .	The ignitability, heat release rates, mass loss rates, and visible smoke development of materials, products and assemblies under well ventilated conditions.	Effective heat of combustion, surface temperature, ignition temperature, temperature gradients in the sample, combustion gas yields, heat of gasification and flame spread. Useful for FSE .
ISO 14934-1	Fire tests — Calibration and use heat flux meters — Part 1: General principles				Calibration standards
ISO 14934-2	Fire tests — Calibration and use heat flux meters — Part 2: Primary calibration methods				Calibration standards
ISO 14934-3	Fire tests — Calibration and use heat flux meters — Part 3: Secondary calibration method				Calibration standards
ISO 14934-4	Fire test — Calibration and use heat flux meters — Part 4:Guidance on the use of heat flux meters in fire tests				Calibration standards
ISO/TR 17252	Fire Tests —Applicability of reaction to fire tests to fire modelling and fire safety engineering				Reference guidance document collating a summary of the reaction to fire tests in more detail than this document.
ISO/TS 17431	Fire tests — Reduced scale model box test	840 mm × 840 mm × 1 680 mm internal dimensions of the test model box for three walls and ceiling	Developing to post-flashover	Heat release rate, smoke and gas generation	Used in Japan, applicable to FSE.

Table A.1 *(continued)*

Test method	Title	Test sample size	Advantages/Disadvantages	Type of data	Conclusion
ISO 20632	Reaction-to-fire tests — Small room test for pipe insulation products or systems	Pipe insulation samples lining parts of walls and ceiling with specified dimensions Room size as for ISO 9705	Reference scenario simulation close to end use construction for pipe insulation. The scenario is valid for fires in a room where pipe insulation products are installed within building applications, e.g. pipe and duct rooms in public buildings, apartment blocks, hospitals and ships. It is not suitable for pipe insulation in concealed spaces, such as a horizontal or a vertical shaft.	As for ISO 9705, time to ignition, HRR, total heat release, smoke production rate and total smoke produced, Visual observations	Can be used in hazard assessment with limitations as described.
ISO/TS 22269	Reaction to fire tests — Fire growth — Full-scale test for stairs and stair coverings				Reference scenario
ISO 24473	Fire tests — Open calorimetry Measurement of the rate of production of heat and combustion products for fires of up to 40 MW	None specified		Time to ignition, and others as for ISO 9705	Guidance on standardised method for assessment, applicable for FSE.

Bibliography

[1] ISO/TR 13387-4, *Fire safety engineering — Part 4: Initiation and development of fire and generation of fire effluents*

[2] ISO/TR 13387-5, *Fire safety engineering — Part 5: Movement of fire effluents*

[3] ISO/TR 13387-6, *Fire safety engineering — Part 6: Structural response and fire spread beyond the enclosure of origin*

[4] ISO/TR 13387-7, *Fire safety engineering — Part 7: Detection, activation and suppression*

[5] ISO/TR 11696 –1, *Uses of reaction to fire test results — Part 1: Application of test results to predict fire performance of internal linings and other building products*

[6] ISO/TR 11696–2, *Uses of reaction to fire test results Part 2 — Fire hazard assessment of construction products*

[7] ISO/TR 13387-8, *Fire safety engineering — Part 8: Life safety — Occupant behaviour, location and condition*

[8] Dowling V.P., & Ramsay G.C. 1997, Building fire scenarios — Some fire incident statistics, In Fire Safety Science, Proceedings of the Fifth International Symposium, Melbourne, International Association for Safety Science, Boston, Massachusetts, pp. 643–654

[9] Kokkala M.A., Thomas P.H., Karlsson B. Rate of heat release and ignitability indices for surface linings. *Fire Mater.* 1993, **17** pp. 209–216

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