
**Fire tests — Applicability of reaction
to fire tests to fire modelling and fire
safety engineering**

*Essais au feu — Applicabilité des résultats de l'essai de réaction au feu
aux techniques de modélisation et de sécurité contre l'incendie*

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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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

This second edition cancels and replaces the first edition (ISO/TR 17252:2008), which has been technically revised. The main changes compared with the previous edition are as follows:

- The title of Clause 5 was changed;
- Former subclauses 5.1.1 and 5.1.2 have been merged into 5.1;
- New subclause 5.2 has been added: “Quantitative definition of fires and fire scenarios”;
- Clause 6 has been re-written, the title has been changed to “Sources and types of input data for fire safety engineering”, subclauses 6.2 and 6.3 have been added;
- Clause 7 has been re-written, the subclauses have been re-arranged and text has been added;
- Clause 8 has been integrated in Clause 7 and totally changed, the title also has been changed to “Limitations of generalizing product behavior”;
- Annex A has been re-written, tests have been added, description of the tests has been compressed with more focus on FSE.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

There is a current trend towards performance-based approaches in national building regulations. This trend has seen rapid advancement internationally in the development of fire safety engineering. This has been supported by the application of fire modelling over the last 15 years, as marked by the originally published ISO/TR 13387-1 to 8¹⁾, and followed by ISO 23932-1, ISO/TS 16733, ISO 16730, ISO/TS 24679 and ISO/TR 16738. The impact of these documents and activities carried out nationally, have clearly identified that there are inconsistencies between the requirements of fire safety engineering (including the application of fire modelling) and the data reported from standard fire tests and ad hoc experiments.

The document is intended to assist in the development of an internationally consistent approach to support fire safety engineering activities by appropriate fire test methods that, where possible, are also used for the primary function of fire safety regulation of the use of construction products.

It examines the majority of the current reaction to fire test methods in the TC 92/SC 1 portfolio and provides information to support the use of the data that the tests provide for fire safety engineering and fire modelling.

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1) The ISO/TR 13387 series is withdrawn.

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Fire tests — Applicability of reaction to fire tests to fire modelling and fire safety engineering

1 Scope

This document gives guidelines on the applicability of the existing reaction to fire tests to fire safety engineering and fire modelling. It also gives general guidance on the type of data needed for fire safety engineering calculations and for fire modelling.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13943, *Fire safety — Vocabulary*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

design fire

quantitative description of assumed fire characteristics within the design fire scenario

3.2

design fire scenario

specific fire scenario on which an analysis will be conducted

3.3

fire scenario

qualitative description of the course of a fire with time, identifying key events that characterise a particular fire and differentiate it from other possible fires

4 Symbols and abbreviated terms

FSE Fire safety engineering

t_g is the characteristic time from reference ignition to reach heat release rate Q_0 (s)

\dot{Q} is heat release rate (MW)

\dot{Q}_0 is the reference heat release rate, often taken to be 1 MW

5 Fire initiation and growth

5.1 Specification of fires and fire scenarios

5.1.1 Background

Design fire scenarios are at the core of the fire safety engineering methodology described in ISO 23932-1, ISO/TS 16733, ISO 16730-1, ISO 24679-1 and ISO/TR 16738. An additional series of standards: ISO 16734, ISO 16736, ISO 16737 and ISO 16732-1, extend and implement these concepts.

The methodology is based upon analysing particular design fire scenarios and then drawing inferences from the results with regard to the adequacy of the proposed fire safety system to meet the performance criteria that have been defined. Identification of the appropriate scenarios requiring analysis is crucial to the attainment of a building that fulfils the fire safety performance objectives.

The characterisation of a design fire scenario for analysis purposes should involve a description of such things as fire initiation, growth and extinction of fire, together with the likely smoke and fire spread routes under a defined set of conditions. This may include consideration of such conditions as different combinations of outcomes or events of different fire safety subsystems, different internal ventilation conditions and different external environmental conditions. The consequences of each design fire scenario should be considered. For example, it is important to realise that smouldering fires may have the potential to cause a large number of fatalities in certain occupancies such as residential buildings although there is no reaction-to-fire test in the TC 92/SC 1 portfolio which covers smouldering conditions.

Examples of typical design fire scenarios include:

- Room fire (corner, ceiling, wall, floor);
- Fires in corridors and stairwells;
- Single burning item fire (furniture, waste paper basket, fittings);
- Developing fire;
- Cable tray or duct fire;
- Roof fires (underside);
- Cavity fire (wall, floor, facade, plenum);
- Fire in transport vehicles;
- Arson
 - 1) Internal
 - 2) External;
- Fire in neighbouring building;
- Fire in external fuel packages;
- Fire on roof and flying brands from adjacent buildings;
- Fire on facade;
- Subterranean fires;
- Forest fires or wild fires;
- Fire in tunnels and underground facilities.

Following identification of the relevant design fire scenarios, it is necessary to describe the assumed characteristics of the fire on which the design will be based. A combination of fire characteristics is used to define the design fire and usually requires quantification of the following variables with respect to time:

- Heat release rate [HRR (peak, mean, total, etc.)];
- Toxic species production rate;
- Smoke production rate (SPR);
- Fire size (including flame length);
- Time to key events such as flashover;
- Other factors such as temperature, emissivity and location may also be required.

The fire characteristics listed above, are influenced by a number of factors which include:

- type, size and location(s) of ignition source;
- ignitability of fuel;
- distribution and type(s) of fuel (with material related parameters as heat of combustion, combustion efficiency);
- fire load density;
- rate of heat release characteristics;
- geometry of enclosure;
- exposed surface area;
- status of doors and/or windows (open or closed);
- internal ventilation conditions (e.g. building air handling system);
- external environmental conditions (e.g. outside temperature, wind velocity and directions);
- external heat flux.

Additionally, events that happen during the fire can modify the design fire and these are typically accounted for in a fire safety engineering approach to design. For example, the breakage of a window will alter the ventilation conditions and will influence the design fire. The incorporation of active fire protection measures into a design will also impact upon the design fire. It is therefore important that the effects changes in ventilation, of suppression systems, smoke control systems and intervention by the fire service are considered when appropriate.

5.1.2 Design fire types

For design purposes, often an estimate of the heat release rate of the fire or the temperature rise in the room as function of time is used. The design fire curves represent an idealization of a real fire that might occur, and there is a great variety in the way they are mathematically expressed. For example, the design fire curves used for tunnels include different types of fire growth rates, including, linear growth, quadratic growth or exponential etc. Typical fire curves are given for instance in ISO 834-1, Eurocode 1, EN 13501-2 or ISO/TS 3814, where heat release rate, Q , growth in design fires is often characterized in

terms of exponential or power-law rate of time, t , from the reference ignition time. The most commonly used relationship for these models is the t-squared fire given by:

$$Q = Q_0 \left(t / t_g \right)^2 \tag{1}$$

Where time, t , is measured from the reference ignition time, and the growth time t_g is the time from the reference ignition time to reach heat release rate Q_0 .

For design of more realistic fires, the fire growth functions can be combined with a maximum HRR value and a decay function to resemble abatement[33][34]. However, in building fire safety design, usually the growth rate alone, e.g. Formula (1) is considered when growing fires are the unique fire scenario to be dealt with, whereas in other specific applications, such as in tunnel fires, the entire fire curve may be considered. Using different types of growth and decay rates combined with maximum HRR profiles as peak values or plateau periods means that the curve has to be represented mathematically for different time periods. Figure 1 gives examples of different design fire types including the growth phase, a constant phase on a maximum level and a decay phase. Three different curves (1, 2 and 3) are given as heat release rate versus time. All three fires are assumed to have a growth phase following a t-square relation and then a phase of constant maximum heat release rate and then a decay phase. The constant phase of the maximum level can be reduced to 0 s. In this case the design fire may have a triangular shape. Curve 4 shows a steeper increase in the heat release rate in the beginning which can represent circumstances where the fire develops faster than in other design scenarios.

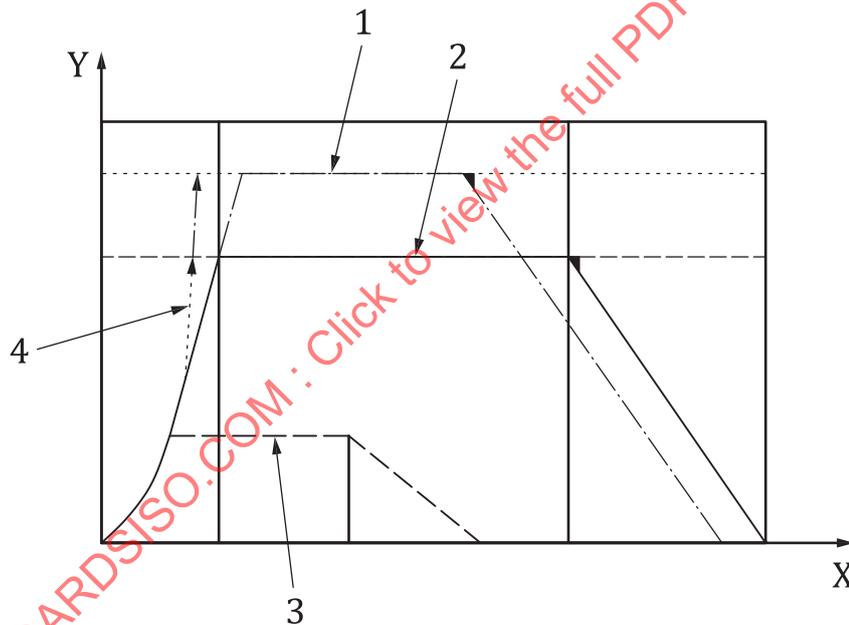


Figure 1 — Examples for different design fire types (curves 1, 2, 3 and 4)

In addition, when the fuel package for a particular design fire scenario is well defined and unlikely to change significantly during the life of the building, the actual burning characteristics of the fuel package can be used as the design fire. In such cases, oxygen consumption calorimetry, for example, ISO 9705-1 is useful for providing quantitative data.

Because of the growing complexity of buildings or other enclosures of interest, and the very different nature of fires associated with such places, it is not always possible or desirable to use a given heat release rate or temperature-time curve. In some cases, the fire spread through the building or enclosure might be important and cannot be predicted easily. In other cases, a fire which already occurred is to be investigated. Moreover, the materials involved in fire (e.g. property, facades, ducts, ceilings etc.) inside a building/enclosure respond differently and in a complex manner to the fire scenarios, in comparison to a mathematical design fire. Therefore, in such cases, it is not always possible nor desirable to use a design fire size as an input to the calculations. In many such cases, it may be preferable to use the

geometry of the building or enclosure, provide material pyrolysis properties, and use the initial fire load as an input for computational fluid dynamics (CFD) model simulations/calculations. CFD models are field models which solve the balances of mass, momentum and energy either in sub volumes or on a numerical grid of the computational domain. CFD models on fire usually include additional models for radiation, turbulence, chemical reactions as well as material pyrolysis to solve the balances. The set of equations can only be solved numerically through various software platforms. Such CFD fire modelling codes require material properties to model the pyrolysis of the materials which are involved in the fire. For CFD applications, different pyrolysis models can be used and combined with CFD models to predict the material pyrolysis behaviour, some of which have been applied recently in similar applications[33][34][35][36].

In some cases, it is now possible to predict the fire growth behaviour using calculation and modelling methods. For such approaches, the validation and verification of the approach will be an important consideration and will be dependent upon the quality and reliability of the input data, whether it is generated from test methods or material data. This is described in more detail in section “sources of data for input into design”.

As a result of the calculations the fire development with its consequences regarding the production and spread of smoke and toxic gases might be used to assess the hazard of different situations which is not further discussed here.

5.2 Sensitivity analysis in the design process

The design fire characteristics will have a major impact upon many aspects of the design since they form the inputs into many of the deterministic quantitative design calculations carried out during a fire safety engineering analysis. A sensitivity analysis can be defined as the calculation of changes in outputs for variations in an input parameter of interest. It may be possible to deal with the uncertainties associated with the deterministic design by taking a conservative approach. However, the judgement of conservatism is very subjective. A worst-case design fire in terms of maximum size or growth rate will typically also be the worst case for determination of the:

- Effect of smoke control systems on the fire scenario;
- Effect of suppression systems on fire growth;
- Time to structural failure;
- Time and extent of fire spread within and from enclosure;
- Fire service extinguishing capacity.

However, the same design fire may represent a best-case scenario for:

- Time of activation of alarm system;
- Time of activation of smoke control systems;
- Time of activation of smoke and fire barriers;
- Time of activation of suppression systems.

It is therefore recommended that a sensitivity study be carried out on the consequences of the choice of design fire on the different parts of the quantitative assessment.

The objective of a sensitivity study is to establish the impact on the output parameter(s) caused by variation in the input parameter(s). It is not intended to check the accuracy of the results.

If a single assumption is shown to be critical to the design and potentially the level of safety, consideration should be given to providing a degree of redundancy in the design or to carrying out a further, perhaps probabilistic study related to that assumption.

5.3 Limits of applicability

Application of empirically-based calculation methods and other types of approach to fire safety engineered design, e.g. zone or CFD models, are generally assumed to be adequate provided that the approaches are used within their stated limits of applicability. However, these limits are not always stated and therefore it is incumbent upon the user to determine what these are for each method applied. If an approach is used outside of its limits of applicability, it is important that it is assessed from a theoretical basis and/or by comparison with experimental data. In such cases, it is usual to include some suitable safety factors in the analysis.

6 Sources and type of data for input into design

6.1 Type of data for input into design

In performance-based fire safety engineering, calculation methods are used that need data for the fire performance of various materials or components[1][2][3]. The performance data can be obtained from several ISO international standards test methods, currently in use. In these tests, relatively simple measurements are made to estimate various aspects of the relative fire performance of the materials at each stage of a fire and thereby better understand hazards that might be associated with use of that material should a fire occur.

There are a limited number of ISO international standards test methods that specify apparatus capable of providing quantitative data for the fire parameters of materials and products which can be utilized in the predictive models for the assessment of fire hazards. Some of these standards and their outputs are presented in Table 2, below. Depending on the complexity of a model, the set of required input parameters will vary. However, the fire parameters as used in ISO 16730-1 and presented in Table 1 may be measured in ISO 5658-2, ISO 5657 (q''_{cr} , T_{ig} , $T_{s,min}$, $k\rho c$, Φ), ISO 5660-1 and ISO 12136 (q''_{cr} , T_{ig} , $k\rho c$, ΔH_{eff} , ΔH_g , E/A).

Table 1 — Fire parameters obtained in ISO international standards test methods

ISO international standard number ^a	q''_{cr}	T_{ig}	TRP $(k\rho c)^{1/2} \Delta T_{ig}$	HRR	ΔH_{eff}	QPCS/ QPCI	χ	RHR	E/A	\dot{m}	
	(kW/m ²)	(K)	(kW·s ^{1/2} /m ²)	(kW)	(kJ/g)	(MJ/kg)		(kW/m ²)	(MJ/m ²)	(kg/s)	(kJ/g)
12136	X	X	X	X	X		X	X	X	X	X
5660-1	X	X	X	X	X		X	X	X	X	
5658-2	X	X									
14696	X	X		X	X		X	X	X	X	X
5657	X	X	X								
1716						X					
9239-1	X										
9705-1		X		X							
24473		X		X	X					X	

^a ISO 12136 Fire Propagation Apparatus, ISO 5660-1 Cone Calorimeter test, ISO 5658-2 Spread of flame test, ISO 14696 ICAL test, ISO 5657 Ignitability test, ISO 1716 Bomb Calorimeter test, ISO 9239-1 Flooring Radiant Panel test, ISO 9705-1 Room corner test, ISO 24473 Open Calorimetry test.

NOTE Critical heat flux measured in ISO 9239-1 is not appropriate for modelling purposes.

6.2 Complexity of the modelling approach with regard to input data

One relatively simple approach to simulate a fire is to define the heat release of the fire (often varying over time) as presented earlier in the document. One example of this approach is the t²-curve,

[Formula \(1\)](#). This approach represents an educated guess of the fire (fire size and development) which might occur in a building, transport vehicle or tunnel. The influence of the given fire on the structure or with respect to tenability criteria is then investigated.

In this document, we intend to identify ISO international standards fire test outputs that can be used in fire safety engineering calculations to predict the performance of materials in a realistic fire scenario. For example, there are several models developed by various researchers in order to predict the performance of materials in an ISO 9705-1 room corner scenario using as input the fire performance data derived from several ISO international standards test methods. Most widely used fire safety engineering models[4][9][11][13][18][19] are based on utilizing data from small-scale fire tests to predict heat release rate (HRR) and flashover in the ISO 9705-1 room corner test (US versions are ASTM E2257 and NFPA 265). In these models, the predicted output of the room corner test is the time to flashover, defined as the time taken for the fire to reach a size of 1 000 kW (HRR). Other engineering models[6][7][10][12][13][14][15][16][17][19] have been used in attempts to predict flame spread behaviour based on fire performance data measured using various ISO international standards test methods. These data include ignition temperature, ignition time, critical heat flux for ignition, thermal inertia, heat release and mass loss rates, effective heat of combustion and gasification, total energy per unit area, etc. It should be pointed out that using such measurements as input data for these modelling calculations is expected to provide tools to predict flame spread behaviour of products only for conditions similar to those used in the test. Such scaling laws and models might not work for other fire scenarios and conditions. ISO/TR 17252 provides guidelines for limits for applicability.

The following are some examples of predictive models for the fire behaviour of interior finish materials of buildings:

- a) Karlsson Magnusson model[6];
- b) Wickstrom-Goransson model[7];
- c) Quintiere Room/Corner fire growth model[19];
- d) Qian and Saito fire growth model[12];
- e) Dillon-Quintiere Room/Corner fire model[13][17];
- f) Hughes Associates/Navy Corner fire model[14];
- g) WPI Room/Corner fire model[15];
- h) Beyler et. al Room/Corner fire model[16];
- i) Quintiere-Lian Room/Corner fire model[19].

In these models, ISO 9705-1 room/corner test results were explicitly compared to model predictions. The fire behaviour of materials in a room/corner test was predicted, using as input, information on a set of fire parameters of materials as measured using smaller-scale test methods. These include ISO 5660-1 cone calorimeter, ISO 12136 fire propagation apparatus, ISO 5657, ISO 5658-2, etc. such as those listed in [Table 1](#), taken from Ref. [13]. In [Table 1](#), \dot{q}_{cr}'' is the critical heat flux below which piloted ignition cannot occur, T_{ig} is the ignition temperature, $T_{s,min}$ is the surface temperature of the material at which lateral flame spread ceases, $k\rho c$ is the thermal inertia of the material, ϕ is the flame spread parameter, ΔH_{eff} is the effective heat of combustion, ΔH_g is the heat of gasification and E/A is the available energy per unit area (AEP), i.e. the total heat release per unit area. For the most part, fire parameters were determined at room temperature. The specific tests used to determine each parameter are discussed in more detail in a later section.

Development of pyrolysis models coupled with computational fluid dynamics (CFD) is increasing. Behavioural models for materials use input data coming from small scale, many from tests like ISO 5660-1 cone calorimeter or ISO 12136 fire propagation apparatus. The produced data are intrinsic properties of the material or generalised behaviour at the material surface.

It is therefore needed to integrate product parameters to estimate real-scale behaviour of real end-use applications. Data obtained at small-scale do not give any information on the effect of mounting conditions or thick systems. Therefore, the pyrolysis model has to be validated by modelling intermediate-scale test and comparing calculation with test results before being used in larger scales. This validation can be performed following ISO 16730-1. This procedure is called “scaling studies for modelling”. It has been shown^[1] that this step is essential for complex materials, especially composites and sandwich panels.

Several (numerical) modelling tools exist which allow to combine the modelling of the solid phase and the gas phase. For a wide range of combustible materials, the solid phase undergoes pyrolysis when exposed to heat. Melting, charring or deformation can also be involved in the process. During pyrolysis, combustible gases are emitted to the gas phase. Often this process is described with an Arrhenius equation which also can be modified to take phenomena like consumption of the material into account. The combustion of the combustible pyrolysis gases occurs in the gas phase. A variation of models for combustion in the gas phase as Eddy Dissipation, Mixture Fraction or kinetic models exist which might be applied to different fire scenarios. The following picture shows the different levels of the modelling process and the input parameters which need to be identified for realistic modelling. Modelling of a certain test scenario can be used to validate the model before it is applied to bigger geometries.

Due to the complexity of CFD modelling itself and the variety of application fields, applicability of modelling is a necessity, especially for modelling with any new application. Either data from full-scale tests or model-scale tests related to the same phenomenon can be used for testing the model, based on which the general uncertainty of CFD modelling can be obtained for the specific scenario^[33].

[Figure 2](#) shows the complexity of a coupled pyrolysis and field model in different scales. The complexity increases from material scale to product scale to room scale.

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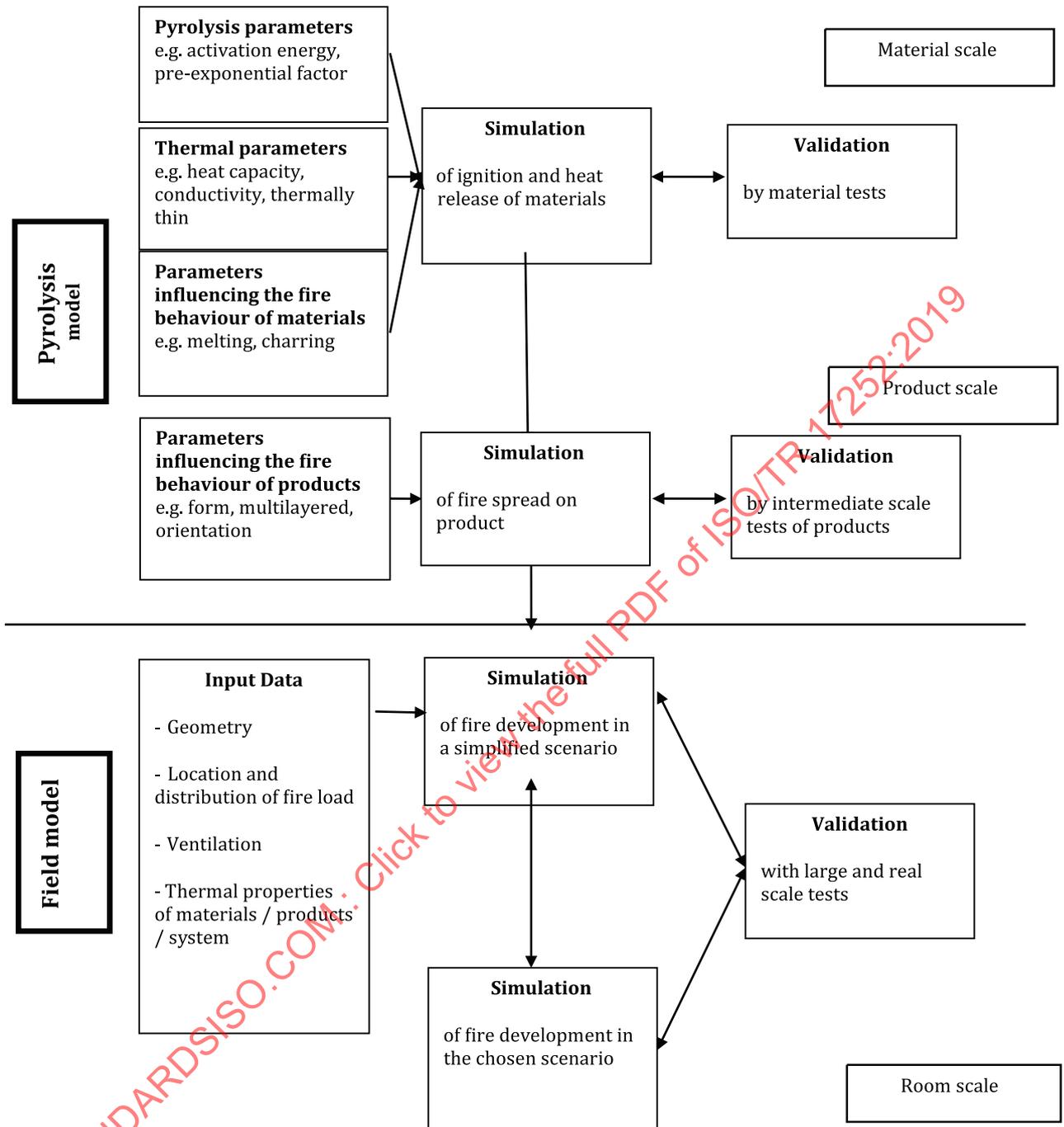


Figure 2 — Complexity of simulation approaches in different scales

6.3 Using ISO/TC 92/SC 1 derived reaction-to-fire tests parameters in models for FSE

The following table provides an overview of reaction-to-fire tests which are used for modelling purposes. The scale of the tests is given as well as the size of the material or product which is normally tested. Observations of the test, main characteristics of the scale and degradation model and usages of the tests are also given. The table provides a connection between fire scenarios and data which can be derived from reaction-to-fire tests for FSE.

Table 2 — Link between test methods and use of data for FSE

	Material	Product	Large scale	Real scale
Scale of test	Small	Intermediate	Large	Real
Observations	Properties of materials regarding different fire scenarios, e.g. size of ignition source, ventilation conditions, including for instance — Multilayer effect — Charring/intumescent effect	Product fire behaviour including for instance — Propagation — Effect of joints	Global system fire behaviour, including realistic environment System effect (complete mounting, including walls/roof connections)	Actual system fire behaviour
Main characteristics of the scale and degradation model	— Thermally-thick degradation — Scale effect — Developed for different fire stages, including vitiated conditions — Heat, smoke and toxic release in conventional situation	— Thermally-thick degradation — Scale effect — Only available for well-ventilated fire stage — Heat and smoke release in conventional situation	— Thermally-thick degradation — System effect — Effect of Flash-over — Heat, smoke and toxic release in realistic situation	Real conditions — No scale effect
Common quantity tested	10 g–500 g ≈0,01 m ²	500 g–5 kg 0,5 m ² –1 m ²	>100 kg >10 m ²	—
Usages	— FSE input data, e.g. HRR — Research and development	— FSE adjusting — Materials/products certification	— FSE validation — Contention arbitration — Research	— FSE validation — Research
Main reaction-to-fire test standards	ISO 5660-1 ISO 1716 ISO 12136 ISO 5657	ISO 5658-2 ISO 5658-4 ISO 9239-1 ISO 9705-1 hood ISO 13785-1	ISO 9705-1 ISO 13784-1/2 ISO 13785-2	ISO 24473 ISO 9705-1 hood
NOTE ISO 5660-1, Cone Calorimeter test, ISO 1716, Bomb Calorimeter test, ISO 12136, Fire Propagation Apparatus, ISO 5657, Ignitability test, ISO 5658-2, Spread of flame test (lateral), ISO 5658-4, Spread of flame test (vertical), ISO 9239-1, Flooring Radiant Panel test, ISO 9705-1, Room corner test, ISO 13784-1/2 Sandwich Panel test, ISO 13785-1,-2 Façade test, ISO 24473 Open calorimetry test				

Annex A gives a detailed overview over the ISO/TC 92/SC 1 reaction-to-fire test portfolio, the derived data of the tests and their applicability for FSE.

7 Application of test results and limits of applicability

7.1 Limiting factors affecting experimental quantification of fire growth

Fire tests do not typically simulate all aspects of a real fire. Typically, they have been designed to assess product or material characteristics in a well-defined methodology to enable direct comparison of fire performance parameters. The fire performance parameters that are measured are considered to be relevant to particular fire hazards and as such, should be useable within modelling methods to predict larger scale and/or real scale fire growth.

A reference scenario is representative of the application of products in buildings on an experimental scale. It is representative of a specific hazard scenario and is to be fully defined in terms of the physical geometry of the space, the properties of the boundaries, the locations of openings and the fire source. Products can be performance tested within an appropriate reference scenario and in some cases, this type of test is the only means of producing reliable performance data. Examples of reference scenarios include, a room corner test, a façade test, a horizontal duct test, a stairwell test and a roof test.

7.2 Repeatability and reproducibility

Information associated with the repeatability and reproducibility of test data is determined through inter-laboratory trials in accordance with the ISO 5725 series. However, it should be noted that the repeatability and reproducibility data relate only to the specific version of the test method and protocols that were used in the trial. If the test method is subsequently updated, then the repeatability and reproducibility data may only be considered to be, at best, indicative of performance. Therefore, in cases where the repeatability and reproducibility are important parameters in relation to the specific application of the test data, effort should be made in establishing the relevance to the particular version of the test method used to generate the test data.

The test method in ISO 29473:2010 gives guidance on the evaluation and expression of uncertainty of fire test method measurements. Application of ISO 29473:2010 is limited to tests that provide quantitative results in engineering units. This includes, for example, methods for measuring the heat release rate of burning specimens based on oxygen consumption calorimetry, as in ISO 5660-1. ISO 29473:2010 does not apply to tests that provide results in the form of indices or binary results (e.g. pass/fail).

7.3 Heat flux measurements

Many of the reaction to fire test methods use heat flux meters to calibrate and/or set the incident radiant heat flux to the surface of the test specimens prior to test, whilst some test methods use them to measure incident heat flux at some points during test. The methodology for calibrating these gauges is provided in ISO 14934-1 to 3, whilst guidance on their use in fire testing applications is provided in ISO 14934-4, where typical levels of heat flux in real scale fire tests are discussed for helping the readers to choose the proper range of heat flux meters used in the fire tests. Furthermore, in ISO 14934-4, typical reaction to fire test are classified by following three major purposes of using heat flux meters for the fire tests:

- a) adjusting heating strength from furnace/heater to the location of specimen prior to fire test;
- b) measuring incident heat flux at some points in the specimen surface during fire test;
- c) measuring incident heat flux at some points distant from the specimen during fire test.

It is important to understand that whilst these standards provide for traceability of the calibrations to a primary calibration standard, the accuracy and relevance of the measurements should be carefully considered, especially if the values are to be used as input data for mathematical modelling and/or as part of a fire safety engineering design. In particular, consideration should be given to characterisation of the radiative and convective contributions to the heat transfer.

7.4 Ignition

Ignition of a solid material or product is generally the point at which the flow of volatiles from the surface is sufficient to enable a flame to persist. This is the start point for any of the fire test methods that have been developed in ISO/TC 92/SC 1. Some of the test methods can be used to attempt to quantify the ignition characteristics of the material or product, whilst others simply ensure that the incident heat flux is sufficient to cause ignition for many materials or products. Whichever case is relevant, it is important that the externally applied heat flux and the external conditions are well characterised (e.g. ventilation conditions). This is certainly believed to be the case for the smaller scale test methods such as the cone calorimeter, however, the ignition sources are far less well characterised in relation to the large-scale test methods such as the ISO 9705-1 test.

7.5 Flame spread

Flame spread can be divided into two categories:

- Opposed flow or counter-current flame spread;
- Wind-aided or concurrent flame spread.

The speed of wind aided flame spread is normally significantly higher than the speed of opposed flow flame spread. The test set up regarding the flow should be taken into account when using the data for FSE.

Flame spread is significantly dependent on the geometry of the material or product and this is not covered by the small-scale test methods.

The flame spread also governed by the heat flux to the material or product, i.e. whether the material or product is exposed to a heat flux partially (from a single burning item) or totally (in a developing stage of fire in a compartment).

Flame spread in a compartment fire can be observed during room fire test of ISO 9705-1.

A detailed guidance on flame spread is given in ISO/TS 5658-1.

7.6 Heat release rate

Data from the cone calorimeter may be used to predict the heat release rate from lining products. However, selection of the incident radiant heat flux levels appropriate to a specific scenario will require consideration. In addition, for scenarios or orientations for which the conditions are vitiated, e.g. ceiling fires, the heat release rates resulting from the cone calorimeter tests will tend to be overestimated. However, the resulting smoke production rates will tend to be under estimated. Below concentrations of 15 % oxygen, the smoke yield tends to increase significantly.

Results from large-scale experimental fire test data may be used as a direct source of heat release data for fire models provided that the limitations of the tests are considered. Much information is available on burning rates for single items under free-burning or well-ventilated conditions in large enclosures. However, consideration should be given to inclusion or not of the effects of:

- Radiative feedback from the hot smoke layer or from an enclosure surfaces;
- Limited supply of oxygen due to ventilation conditions or the flames becoming immersed in the layer of combustion products;
- Interaction between objects, in particular, their orientation and storage configuration.

7.7 Smoke production rate

As a large-scale fire develops and becomes more complex, the correlation between optical density of smoke in the small-scale and large-scale tests tend to break down. This is because the ventilation conditions and heat transfer can have a major impact on the smoke production.

It should be noted that none of the ISO/TC 92/SC 1 fire test methods provide any quantification of the irritancy of smoke.

7.8 Differences between testing conditions and real fire scenarios

There can be significant differences between testing conditions and real fire scenarios. Some of the most obvious differences are listed below, however, it should be realised that this list is not exhaustive.

— Thermal attack

The thermal attack in terms of the imposed heat flux to the specimen surface in a test is reasonably well characterised. As already mentioned, the thermal attack is better defined in some of the test methods than in others and the significant challenge rests with the fire safety engineer to determine how relevant the test results and conditions are in relation to the problem that must be solved. Ignition time and temperature can vary significantly with the type and size of the ignition source which is important if test results are used for FSE.

— Conditioning

Fire test specimens are generally “conditioned” prior to the test. This means that the specimens are kept in a constant environment of temperature and humidity for the period of time required to produce constant mass. That is, the moisture content and any other properties that may vary depending upon the humidity and temperature have stabilised. These conditions are unlikely to reproduce realistic conditions, but do seek to maintain a constant basis from which to compare the fire performance of different products.

— Ageing effects

Typically, specimens for fire tests are delivered from the manufacturers production line to the test laboratory. It is unusual, but not impossible, for any account to be taken of factors such as washing, durability, UV light stability, humidity, leaching of additives, wear and weathering. Clearly these factors may have some influence upon the performance of materials and products during their lifetime, but the importance of any influence will depend upon type of product. For assessments of existing older buildings for example these differences can be significant.

— Mounting and fixing

The performance of a product within a test is dependent upon the mounting and fixing arrangements used in the test and their relationship to the realistic applications of the products. Factors that should be considered when carrying out tests include types of substrate, presence or not of an air gap directly behind the product, the location and type of joints, edge details and fixing details. The trend in reaction-to-fire testing goes to end-use conditions regarding the mounting and fixing. However, it is not possible to cover all end use conditions in a test, especially in bench scale tests.

— Heat flux measurements at the specimen surface

When a heat flux meter is installed into a specimen, holes are drilled in the specimen to accommodate the body of the heat flux meter. When the surface of a heat flux meter is on the same level as the surface of the specimen, both convective and irradiative heat transfer to the cooled absorber are measured. It should be noted that the heat flux meter measures heat transfer to the cooled surface of the absorber and is dependent on its temperature. When the surface of heat flux meter protrudes from the surface of the specimen, in particular when orientated vertically, the convective heat is altered. If the heat flux meter recesses from the surface of the specimen, the edge and side wall of the hole of the specimen limits the field of view to the heat source. When compared with real fire scenarios, it is essential to understand the detailed conditions of how heat flux meters are installed at the specimen surface in fire tests. More details can be found in ISO 14934-4.

7.9 Limitations of generalizing product behaviour

There are some product family behaviours that are important to recognise and that will provide a significant challenge to some types of mathematical modelling approaches. These behaviours include melting, shrinking, slumping, dripping, spalling, charring, delaminating and intumescenting. It may be the case that some of these types of behaviours can only be accommodated through empirical models in the short term, but it is clearly for the fire safety engineer to judge the relevance of these behaviours within the context of the design. In general, the effects of softening and melting are most apparent in tests where the specimen is in vertical orientation. As a result of movement of the specimen from its test position, the data produced is of limited validity. The collapse of a thermoplastic foamed product or the expansion of an intumescent product in any test orientation changes the position of the product surface in relation to the heat source and this needs to be considered in any use of the data.

Additionally, test materials are sometimes assumed to be identical, when they are potentially quite different. This concern pertains to comparisons of test data at different scales and comparisons among different studies using the same apparatus. It affects the validation of the computational models used to simulate fire hazard and risk. Polymers within a generic group are frequently modified or compounded to meet many different requirements, one of which is fire performance. Commercial products that contain multiple polymeric materials have an added degree of diversity and concern.

The information that is central to defining similarity in the material or product to be tested in multiple laboratories and at different scales includes: chemical composition (atom percentages, prevalence of functional groups; nature and level of additives, etc.), thermal properties (including density, thermal conductivity, and heat capacity), and documentation of the aging and conditioning of the specimens. A series of standards developed by ISO/TC 61, *Plastics*, provides guidance about the identification of plastics and standardized designations of materials, e.g. ISO 11469. However, this system is intended to help identify plastic products for subsequent decisions concerning handling, waste recovery, or disposal and is not necessarily sufficient to characterize fire performance.

Annex A (informative)

Review of fire test standards

Cone Calorimeter test	ISO 5660, <i>Reaction-to-fire test — Heat release, smoke production and mass loss rate —</i> <i>Part 1: Heat release (cone calorimeter method)</i> <i>Part 2: Smoke production rate (dynamic measurement)</i>
Application Other related standards	The test method is used to assess the contribution that the product under test can make to the rate of evolution of heat during its involvement in fire. ISO 5660-3, <i>Reaction-to-fire test — Heat release, smoke production and mass loss rate — Part 3: Guidance on heat and smoke release rate</i> ISO 17554, <i>Fire Tests — Reaction to Fire — Mass loss measurement</i> ISO 13927, <i>Plastics- Simple heat release method based on a conical radiator and using a thermopile</i> ISO 11907, Part 4 (being developed by ISO/TC 61) ASTM E 1354, <i>Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter</i>
Description Duration of exposure	External electrical radiant cone shaped heater. Temperature of the heater is pre-set before the test and kept constant throughout the test. Used in either the horizontal (normative) or vertical (alternative) orientation with repetitive igniter spark plug (gap 3 mm). Tests can be carried out in the range of 10 kW/m ² to 75 kW/m ² . For 30 minutes plus 2 minutes of additional data correction, or until specimen burns out totally, or until oxygen concentration keeps within 100 ppm for 10 minutes.
Type of Data Methods of reporting results Advantages	Time to ignition, Heat release rate, Total heat released, Smoke production, O ₂ (CO and CO ₂ optional), Mass loss, Rise in temperature in exhaust duct, exhaust gas vol. rate. Computer generated report containing essential info as required by the standard. Engineering data including ignition time, heat and smoke generation gathered from small samples under different heat flux conditions. Data generated has been used extensively in fire models.

Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Reproducibility and repeatability	See Annex C (ISO 5660-1:2015) where precision in terms of r (repeatability) and R (reproducibility) are described for : t_{ig} , \dot{q}_{Amax} , \dot{q}_{A180} , Q_{Atot} and $\Delta h_{c,eff}$ with results. For materials which intumesce or deform different r and R have been calculated.
Inaccuracies in measurement	Does not take into account fixing details, joints and edges finishes, since the specimen is too small to accommodate such fixings.
Limitation/validity of results	Sample size is small compared with 'end use' application. Limited validity if specimen melts to cause overflow out of the trays, if spalling occurs; or if the specimen swells (dimensionally unstable) and touches the spark igniter or heater base plate.
Conclusion	Useful for gathering material and product data as input data for fire safety engineering.

Model box test	ISO/TS 17431, <i>Fire tests — Reduced-scale model box test</i>
Application	This test method is especially suitable for products with which a full-scale room test (ISO 9705-1) has to be terminated before the full involvement of the room with fire because of the occurrence of flashover or any other safety reasons.
Other related standards	ISO 9705-1, <i>Fire tests — Full-scale room test for surface products</i>
Description	This test method is an intermediate-scale test that simulates a fire that under well ventilated conditions starts in a corner of a small room (box) with a single doorway and can develop until the room is fully involved in the fire.
Box (inside) dimension	1,68 m by 0,84 m by 0,84 m (L × B × H)
Door opening dimension	0,3 m by 0,76 m (B × H)
Heat source	Sand box burner (17 cm by 17 cm) of 40 kW
Duration of exposure	15 minutes
Specimen installation	Combination of a ceiling, two side walls and an end wall, will be inserted into the combustion chamber (made of non-combustible material) through the front opening, and then covered by front wall with doorway, which is not a part of specimen.

Type of Data	Heat release rate, Total heat released, Smoke production, O ₂ (CO and CO ₂ optional), Mass loss, Rise in temperature in exhaust duct, exhaust gas vol. rate.
Advantages	Total heat flux measured by total heat flux meters at the centre of the floor, Temperatures inside the room and door opening, Surface temperatures, Flow measurement in door opening, radiation through opening, etc. Details in end-use construction can be incorporated to the mounting of specimens, such as fixing details, joints and edges finishes. Good correlation on occurrence of flashover was found between this test method and ISO 9705-1. Furthermore, this test method can be continued even flashover happens and after.
Conclusion	Useful for gathering material and product data as input data for fire safety engineering, pertaining to the details of end-use construction.

Non-combustibility test	ISO 1182, <i>Reaction to fire tests for building products — Non-combustibility test</i>
Application	The test method is used for selection of construction products which, whilst not completely inert, produce only a very limited amount of heat and flame when exposed to temperatures of approximately 750 °C.
Other related standards	
Description	The test apparatus consists of a furnace comprising essentially a refractory tube surrounded by a heating coil and enclosed in an insulated surround. A cone-shaped airflow stabilizer is attached to the base of the furnace and a draught shield to its top. The furnace is stabilized at 750 °C before test, whereafter the corresponding power input is kept constant throughout the test. A small cylindrical shaped specimen is placed in the centre of the furnace.
Duration of exposure	The test is carried out until final temperature equilibrium has been reached in the furnace, or 60 min.
Type of Data	Maximum temperature rise in the furnace
Methods of reporting results	Test report containing the essential information as required by the standard.
Advantages	
Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Reproducibility and repeatability	
Inaccuracies in measurement	
Limitation/validity of results	
Conclusion	Useful for use in certification system for prescriptive building regulations.

Bomb calorimeter test	ISO 1716, <i>Reaction to fire tests for building products — Determination of the heat of combustion</i>
Application Other related standards	The test method is used to assess the potential fire load (expressed in MJ/kg or MJ/m ²) of the product.
Description Duration of exposure	A powdered specimen of specified mass is burned under standardized conditions, at constant volume, in an atmosphere of oxygen, in a bomb calorimeter. The heat of combustion determined under these conditions, is calculated on basis of the observed temperature rise, taking into account heat losses and the latent heat of vaporization of water. The test determines an absolute value of a product and does not take into account any inherent variability of the product. Until complete combustion of the specimen has taken place. This normally happens within a short period (a few minutes) after the electric circuit, to cause combustion, is closed.
Type of Data Methods of reporting results Advantages	Gross heat of combustion expressed in MJ/kg or MJ/m ² , Net heat of combustion. Computer generated report containing essential info. as required by the standard. Gross heat of combustion is the maximum of heat which can be released by the product and is independent of the end use of the product.
Precision of Data Reproducibility and repeatability Inaccuracies in measurement Limitation/validity of results	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> . Limited validity if incomplete combustion of the specimen occurs.
Conclusion	Useful for gathering material and product data as input data for fire safety engineering regarding the absolute maximum heat release, e.g. for estimations of maximum fire load.

Ignitability test	ISO 5657, <i>Reaction to fire tests — Ignitability of building products using a radiant heat source</i>
Application Other related standards	<p>The test method is applicable to essentially flat building products. This ignitability test is designed to assess the possibility of secondary ignition by radiative heat transfer in the presence of means for piloted ignition. Specimens of the product are mounted horizontally and exposed to thermal radiation on their upper surface; the selected levels of constant irradiance are within the range 10 kW/m² to 70 kW/m².</p> <p>The standard is part the original portfolio of reaction-to-fire tests developed by ISO/TC 92, which could be used either individually, or collectively, to provide the required information on the fire performance of building materials and products. See ISO/TS 3814, <i>Standard tests for measuring reaction-to-fire of products and materials — Their development and application</i>.</p> <p>ISO/TR 11925-1, <i>Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 1: Guidance on ignitability</i></p>
Description Duration of exposure	<p>The radiator is in the shape of a truncated cone with an upper diameter of 66 mm ± 1 mm and a lower diameter of 200 mm ± 3 mm. The cone consists of a heating element of nominal rating 3 kW. Height of cone is 75 mm.</p> <p>The specimen is mounted on a pressure plate which keeps the specimen in the vicinity of the cone heater during the test, which results in a partially closed system (i.e. limited ventilation).</p> <p>The pilot flame which is applied to the area just above the centre of the specimen surface is not present continuously but is positioned on a dipping mechanism such that is only present for 1 second in every 4.</p> <p>At each irradiance level the exposure duration is a maximum of 15 minutes.</p>
Type of Data Methods of reporting results Advantages	<p>Time to sustained surface ignition</p> <p>Results reported in the form of computer-generated reports containing essential information as required by the standard. This report will contain a full description of the product tested, including details of any surface treatment.</p> <p>Ignitability of essentially flat products.</p> <p>It might be an easy and fast test to carry out if you only want to determine the time to ignition.</p>

Precision of Data	See ISO 5657:1997, Annex D.
Reproducibility and repeatability	Time to sustained surface ignition 4 s - 50 s ...4-51... % of mean 9 - 37 8 s - 75 s 6-75 % of mean 18 - 54
Inaccuracies in measurement	Results on shiny surfaces should be treated with caution. Similarly, for materials that intumesce considerably.
Limitation/validity of results	The present test does not consider the ability to ignite by flame contact alone, without impressed radiation.
Conclusion	Useful but often replaced by the cone calorimeter for ignition data. The test is not widely used.

Spread of flame test (lateral spread)	ISO 5668-2, <i>Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building and transport products in vertical configuration</i>
Application	The method is applicable to the measurement and description of the properties of materials, products and assemblies in response to radiative heat in the presence of a pilot flame under controlled laboratory conditions.
Other related standards	ISO/TS 5658-1, <i>Reaction to fire tests — Spread of flame — Part 1: Guidance on flame spread</i> ISO 5658-4, <i>Reaction to fire tests — Spread of flame — Part 4: Intermediate-scale spread of flame with vertically oriented specimens</i>
Description	Radiant panel is mounted vertically at an angle of 15° to the specimen surface. Area of irradiance is 0,020 m ² . Heat flux decreases from 50 kW/m ² at hot end of specimen to 1,5 kW/m ² at cool end.
Duration of exposure	Radiant panel and pilot burner are applied for whole test (i.e. 30 minutes, or 10 minutes if specimen fails to ignite during this initial period).
Type of Data	Average heat for sustained burning (HSB) Critical heat flux for extinguishment (CIE)
Methods of reporting results Advantages	Results are tabulated in computer-generated reports. Procedures are available for calculation flame spread indexes for lateral flame spread.
Precision of Data	See ISO 29473 <i>Fire tests — Uncertainty of Measurements in fire tests.</i>
Reproducibility and repeatability	HSB 22 - 76 % CIE 33 - 105 % HSB 9 - 43 % CIE 9 - 95 %
Inaccuracies in measurement Limitation/validity of results	
Conclusion	Useful for flame spread modelling

Spread of flame test (vertical spread)	ISO 5658-4, <i>Reaction to fire tests — Spread of flame — Part 4: Intermediate-scale test of vertical spread of flame with vertically oriented specimen</i>
Application	This method is applicable to the measurement and description of the properties of materials, products, composites or assemblies in response to radiative heat in the presence of non-impinging pilot flames under controlled laboratory conditions. The heat source may be considered to represent a single burning item such as a wastepaper bin or an upholstered chair within an enclosure, and this scenario would generally be considered to apply during the early stage of a fire (see ISO/TR 11696-1 and ISO/TR 11696-2).
Other related standards	ISO/TR 5658-1, <i>Reaction to fire tests — Spread of flame — Part 1: Guidance on flame spread</i> ISO 5658-2, <i>Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building products in vertical configuration.</i> ASTM E 1321, <i>Standard Test Method for Determining Material Ignition and Flame Spread Properties</i>
Description	Radiant panel is mounted vertically at an angle of 35 degree to the specimen surface. Heat flux decreases from 40 kW/m ² at hottest part of exposure area to 5 kW/m ² at cooler parts of the exposed area. Total area exposed is approx. 0,4 m ² .
Duration of exposure	Radiant panel and pilot burner are applied for whole test (i.e. 30 mins, or 20 mins if specimen fails to ignite during this initial period).
Type of Data	Time to ignition, temperature and smoke optional
Methods of reporting results	Results are tabulated in computer-generated reports. Derivations may be made to obtain average flame spread rates (vertical and lateral).
Advantages	Procedures are available for calculation flame spread indexes for flame spread.
Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests.</i>
Reproducibility and repeatability	Time to ignition 28 % – 133 % (average 59 %) Area of flame spread 0 % – 61 % (average 31 %) Time to ignition 12 % – 46 % (average 26 %) Area of flame spread 0 % – 36 % (average 17 %)
Inaccuracies in measurement Limitation/validity of results	There is only one test condition in the standard, i.e. 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, although linear products such as pipes may be evaluated. Profiled products are difficult to test. Effluent analysis (i.e. heat release, smoke, toxic gases) is not standardised.
Conclusion	One of few apparatuses that allows measurement of flame spread rates.

Flooring Radiant Panel test	ISO 9239-1, <i>Reaction to fire tests for floorings — Part 1: Determination of the burning behaviour using a radiant heat source</i>
Application Other related standards	The method is applicable to all types of flooring under end-use conditions. ISO 9239-2, <i>Reaction to fire tests for floorings — Part 2 : Determination of the burning behaviour using a radiant heat source at a heat flux level of 25 kW/m²</i>
Description Duration of exposure	Radiant heat panel is placed over test specimen with its longer dimension at 30° to horizontal plane. Pilot burner to ignite combustible gases is used. Radiant panel is applied for whole test (i.e. 30 mins or longer period if specified by sponsor of test). During first 2 mins, pilot burner is not applied. It is then applied to specimen for 10 mins before withdrawal and extinguishing.
Type of Data Methods of reporting results Advantages	Time to ignition, flame spread, temperature in duct, critical heat flux (CHF), smoke (light attenuation of smoke and integral of the product of light attenuation) Results are tabulated in computer-generated reports. Widely used method in building and transport testing methods. Correlation with a room-corridor full-scale scenario is available.
Precision of Data Reproducibility and repeatability Inaccuracies in measurement Limitation/validity of results	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> . CHF (or HF-30) 5 % - 47 % CHF (or HF-30) 2 % - 21 %
Conclusion	Useful for determining a critical heat flux for fire spread in a wind-opposed room-corridor scenario. Usually, not applicable to FSE.

Room corner test	ISO 9705-1, <i>Fire tests — Full-scale room test for surface products</i>
Application	Test method simulates a fire that under well ventilated conditions starts in a corner of a small room with a single open doorway. The method is intended to evaluate the contribution to fire growth provided by a surface product using a specified ignition source.
Other related standards	ISO TR 9705-2, <i>Guidance document of full scale room tests</i> ASTM E 2257, <i>Standard Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies</i>
Description Duration of exposure	Standard ignition source is a sandbox burner of 17 cm by 17 cm. Other ignition sources possible. 10 minutes 100 kW and 10 minutes 300 kW for the standard ignition sequence. Other alternatives possible

Type of Data	Time to ignition, heat release, total heat released, smoke, CO, CO ₂ , O ₂ , temperatures, time to flashover
Methods of reporting results	Descriptive information, numerical results (scalar and vector data), graphical results, photographs, visual observation.
Advantages	Engineering data including ignition time, heat and smoke generation gathered from small room
Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Reproducibility and repeatability	Available in ISO/TR 9705-2.
Inaccuracies in measurement	
Limitation/validity of results	
Conclusion	Useful for gathering material and product data as input data for fire safety engineering, e.g. data for design fires

Small flame test	ISO 11925-2, <i>Reaction to Fire tests — Ignitability of building products subjected to direct impingement of flame — Part 2: Single-flame source test</i>
Application	The test method is used to assess the ignitability of a product under test and relates to the accidental ignition of a small flame in fire.
Other related standards	
Description	A method for determining the ignitability of building products by direct small flame impingement under zero impressed irradiance using specimens tested in a vertical orientation.
Duration of exposure	For 15 s flame application and then removed, total test duration is 20 s. For 30 s flame application and then removed, total test duration is 60 s.
Type of Data	Vertical flame spread
Methods of reporting results	Results reported in the form of report containing essential information as required by the standard.
Advantages	Widely used globally.
Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Reproducibility and repeatability	
Inaccuracies in measurement	
Limitation/validity of results	Valid to small flame ignition only. No time to ignition is measured in the test only time to 150 mm. Indication of ease of flame spread on ignition by small flame.
Conclusion	Useful for limiting vertical flame spread of building products for prescriptive building regulations.

Sandwich panel test (small room)	ISO 13784-1, <i>Reaction to fire tests for sandwich panel building systems — Part 1: Small room test</i>
<p>Application</p> <p>Other related standards</p>	<p>This part of ISO 3784 specifies a method of test for determining the reaction to fire behaviour of sandwich panel building systems and the resulting flame spread on or within the sandwich panel building construction, when exposed to heat from a simulated internal fire with flames impinging directly on the internal corner of the sandwich panel building construction.</p> <p>ISO 9705-1:2016, <i>Reaction to fire tests — Room corner test for wall and ceiling lining products — Part 1: Test method for a small room configuration</i></p> <p>ISO 13784-2:2002, <i>Reaction to fire tests for sandwich panel building systems — Part 2: Test method for large rooms</i></p> <p>ISO 13943:2017, <i>Fire safety — Vocabulary</i>.</p> <p>IEC 60584-2:1982 + A1: 1989, <i>Thermocouples — Part 2: Tolerances</i></p>
<p>Description</p> <p>Duration of exposure</p>	<p>The test method described is applicable to both free-standing self-supporting and frame-supported sandwich panel systems. This part of ISO 13784 is not intended to apply to sandwich panel products which are glued, nailed, bonded, or similarly supported by an underlying wall or ceiling construction. For products used as internal linings, the ISO 9705-1 test method should be used.</p> <p>This part of ISO 13784 provides for small room testing of sandwich panel building systems. For large-room testing of sandwich panel building systems, ISO 13784-2 should be used.</p> <p>Duration of exposure is 10 minutes at 100 kW and then 10 minutes at 300 kW for the standard ignition sequence.</p>
<p>Type of Data</p> <p>Methods of reporting results</p> <p>Advantages</p>	<p>Time to ignition, Heat release rate, Total heat released, Smoke production, O₂, CO and CO₂, Rise in temperature in exhaust duct</p> <p>Descriptive information, numerical results (scalar and vector data), graphical results, photographs, visual observation.</p> <p>Engineering data including ignition time, heat and smoke generation gathered from small room for sandwich panels.</p>
<p>Precision of Data</p> <p>Reproducibility and repeatability</p> <p>Inaccuracies in measurement</p> <p>Limitation/validity of results</p>	<p>See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i>.</p>
Conclusion	<p>Useful for gathering material and product data as input data for fire safety engineering, e.g. data for design fires.</p>

Sandwich panel test (large room)	ISO 13784-2, <i>Reaction to fire tests for sandwich panel building systems — Part 2: Large room test</i>
Application Other related standards	<p>This part of ISO 3784 specifies a method of test for determining the reaction to fire behaviour of sandwich panel building systems and the resulting flame spread on or within the sandwich panel building construction, when exposed to heat from a simulated internal fire with flames impinging directly on the internal corner of the sandwich panel building construction.</p> <p>ISO 9705-1:2016, <i>Reaction to fire tests — Room corner test for wall and ceiling lining products — Part 1: Test method for a small room configuration</i></p> <p>ISO TR 9705-2:2001, <i>Reaction to fire tests — Full scale room tests for surface products — Part 2: Technical background and guidance</i></p> <p>ISO 13784-1:2014, <i>Reaction to fire test for sandwich panel building systems — Part 1: Small room test</i></p> <p>ISO 13943:2017, <i>Fire safety — Vocabulary</i></p> <p>IEC 60584-2:1982 + A1: 1989, <i>Thermocouples — Part 2: Tolerances</i></p>
Description Duration of exposure	<p>The test method described is applicable to both free-standing self-supporting and frame-supported sandwich panel systems.</p> <p>This part of ISO 13784 provides for large room testing of sandwich panel building systems. For small-room testing of sandwich panel building systems, ISO 13784-1 should be used.</p> <p>The test method described is only applicable to sandwich panel wall and ceiling or roof constructions.</p> <p>Duration of exposure is 5 minutes at 100 kW, 5 minutes at 300 kW and 5 minutes at 600 kW for the standard ignition sequence.</p>
Type of Data Methods of reporting results Advantages	<p>Time to ignition, temperatures in room and on surfaces, flame spread</p> <p>Descriptive information, numerical results (scalar and vector data), graphical results, photographs, visual observation.</p> <p>Applicable to large sandwich panel rooms.</p>
Precision of Data Reproducibility and repeatability Inaccuracies in measurement Limitation/validity of results	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Conclusion	Useful for gathering material and product data as input data for fire safety engineering, e.g. data for design fires

Facade test (intermediate scale test)	ISO 13785-1, <i>Reaction to fire tests for façades — Part 1: Intermediate-scale test</i>
Application	This International Standard specifies a screening method for determining the reaction to fire of materials and constructions of façade or claddings when exposed to heat from a simulated external fire with flames impinging directly upon a façade. It is the intention that Part 1 can be used by producers to reduce the burden of testing in part 2 by eliminating those systems which fail in part 1.
Other related standards	ISO 13943:2017, <i>Fire safety — Vocabulary</i> ISO 554:1976, <i>Standard atmospheres for conditioning and/or testing — Specifications</i> ISO/TS 3814, <i>Standard tests for measuring reaction-to-fire of products and materials — Their development and application</i> ISO 9705-1:2016, <i>Reaction to fire tests — Room corner test for wall and ceiling lining products — Part 1: Test method for a small room configuration</i> ISO 13785-2:2002, <i>Reaction to fire tests for façades — Part 2: Large scale test</i> IEC 60584-2:1982 + A1: 1989, <i>Thermocouples — Part 2: Tolerances</i>
Description	The behaviour of the façade panel construction and the resulting flame spread on or within the façade construction is studied. The test method 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 only applies to vertical elements and does not apply to determination of the structural strength of the façade or cladding.
Duration of exposure	Duration of exposure is 30 minutes at 100 kW.
Type of Data	Time to ignition, flame spread, total heat flux, surface and gas temperatures
Methods of reporting results	Descriptive information, numerical results (scalar and vector data), graphical results, photographs, visual observation.
Advantages	Screening method
Precision of Data	See ISO 29473, <i>Fire tests — Uncertainty of Measurements in fire tests</i> .
Reproducibility and repeatability Inaccuracies in measurement Limitation/validity of results	
Conclusion	Screening test for flame spread on external walls.