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Plastics — Development and use of intermediate-scale fire tests for plastics products —

Part 1:
General guidance

Plastiques — Développement et utilisation des essais au feu à une échelle intermédiaire pour les produits plastiques —

Partie 1: Lignes directrices générales

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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. www.iso.org/directives

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The committee responsible for this document is ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

This second edition cancels and replaces the first edition (ISO 15791-1:2002), which has been technically revised.

ISO 15791 consists of the following parts, under the general title *Plastics — Development and use of intermediate-scale fire tests for plastics products*:

— *Part 1: General guidance*

Guidance on product fire testing for semi-finished and finished products is to form the subject of a future part 2.

Introduction

Products for many applications are made of or contain substantial proportions of plastics. The fire performance of a product depends on the materials from which it is made, the design of the product and its environment.

Industry needs to test products used for different applications for regulatory, quality control, development and pre-selection purposes.

Numerous regulations and regional, state and local codes make reference to combustibility tests and standards, and ranking of products derived from these tests are the most commonly available means of comparing the various combustion characteristics of products. More than one test and possibly intermediate- or full-scale tests may be necessary to qualify products containing plastics for intended or proposed use or representative product end-use conditions.

Plastics — Development and use of intermediate-scale fire tests for plastics products —

Part 1: General guidance

1 Scope

This part of ISO 15791 provides a framework guide for the development and use of intermediate-scale fire tests for products made of or containing plastics.

The guidance identifies typical applications of plastics products and possible fire scenarios that can arise involving products in these applications. The development and use of intermediate-scale tests is described to ensure their relevance to the end use of the product.

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 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.

3.1
fire scenario
qualitative description of the course of a fire with respect to time, identifying key events that characterize the studied fire and differentiate it

[SOURCE: of ISO 13943:2008, definition 4.129, modified.]

3.2
intermediate-scale fire test
fire test performed on a test specimen of medium dimensions

[SOURCE: ISO 13943:2008, definition 4.200, modified — The note has been omitted.]

3.3
large-scale fire test
fire test that cannot be carried out in a typical laboratory chamber, performed on a test specimen of large dimensions

[SOURCE: ISO 13943:2008, definition 4.205, modified — The note has been omitted.]

3.4
product
manufactured article ready for end use

3.5
material
basic single substance or uniformly dispersed mixture

Note 1 to entry: Metal, stone, timber, concrete, mineral fibre and polymers are examples.

[SOURCE: ISO 5659-2:2012, 3.6]

3.6
semi-finished product
manufactured articles ready for assembly for an end use application

3.7
small-scale fire test
fire test performed on a test specimen of small dimensions

[SOURCE: of ISO 13943:2008, definition 4.292, modified — The note has been omitted.]

3.8
test specimen
item subjected to a procedure of assessment or measurement

[SOURCE: ISO 13943:2008, definition 4.321, modified — The note has been omitted.]

4 Types of plastics and typical products

4.1 Generic types

Products containing materials that are either thermoplastics or thermosets are subject to a fire performance assessment. Such plastics can be elastomers, fibres or foams (cellular materials) and can contain additives (including fibre reinforcements).

4.2 Typical applications

Some typical applications for plastics, which present particular problems in small-scale tests for their fire performance assessment and which may require the use of intermediate-scale fire testing, are listed below:

— semi-finished products;

— housings for electrical appliances;

— profiled sheets, e.g. roofing, or panels for containers;

— profiles, e.g. conduits for electric cables, window-frames, extruded sections;

— weatherproof glazing for agricultural buildings;

— foam pipe-sections;

— pipes, e.g. rainwater drainage and discharge pipes;

— furniture, e.g. chairs;

— pipes for air ventilation systems in e.g. ships, trains, aircraft;

— containers for liquids (e.g. oil, kerosene);

— waste containers (for recycling materials or for rubbish).

NOTE This list is not exhaustive.

4.3 Composites

The following special composites should be considered:

— laminates, e.g. melamine-formaldehyde-covered chipboard;

— laminated film and sheet, e.g. weatherproofing membranes;

— moulded foams, e.g. for packaging;

— structural mouldings, e.g. for ships, lorries, coaches, trains;

— composite panels, e.g. rigid foams faced with metal sheets (especially steel or aluminium sheets) or inorganics (especially gypsum or plasterboard) for thermal insulation;

— fibre-reinforced products.

4.4 End-use conditions

Assessment of structural composite panels, thermoplastic glazing and similar plastics products, etc. can only be done by taking into account their end-use conditions and installations. Orientation of test specimens with respect to the ignition source of the fire test should reflect the actual possible heat exposure at the end use condition. For non-planar products, different parts of the specimen will be heated at different flux levels at any given time.

5 Fire scenarios

5.1 General

The fire scenario (see 3.1) should reproduce the conditions in which the hazard exists. Any additional assumptions, such as the environmental conditions, should be defined. The subject of the assessment, i.e. the material, product or system, should be determined by an investigation of the contribution of the subject in the assumed fire scenario and the stage of the fire.

NOTE Annex B gives examples of standardized reference test scenarios.

5.2 Ignition stage

The ignition source used in the test should represent the fire hazard in end use conditions and may result in different fire responses of the materials and product. The ignition source may pose a variety of hazards dependent on the associated environmental conditions and on a number of characteristic fire test responses of materials, products or assemblies, including ease of ignition, flame spread, rate of heat release, smoke generation, toxicity of combustion products and ease of extinction.

5.3 Fire growth stage

In small rooms, the typical primary ignition source is small, e.g. candles, matches and hot electrical wires. The relevant parameters for further assessing the fire hazard are flame spread and rate of heat release. Combustible materials in the vicinity of the first ignited item are heated by convection and irradiance, and the oxygen content in the room air, almost 21 % initially, begins to decrease. After a certain time, flashover may occur, at which stage the room temperature can exceed 500 °C and the irradiance at floor level can typically exceed 25 kW/m^2 (see Figure 1). In such cases, the oxygen content in small rooms is not normally sufficient for complete combustion.

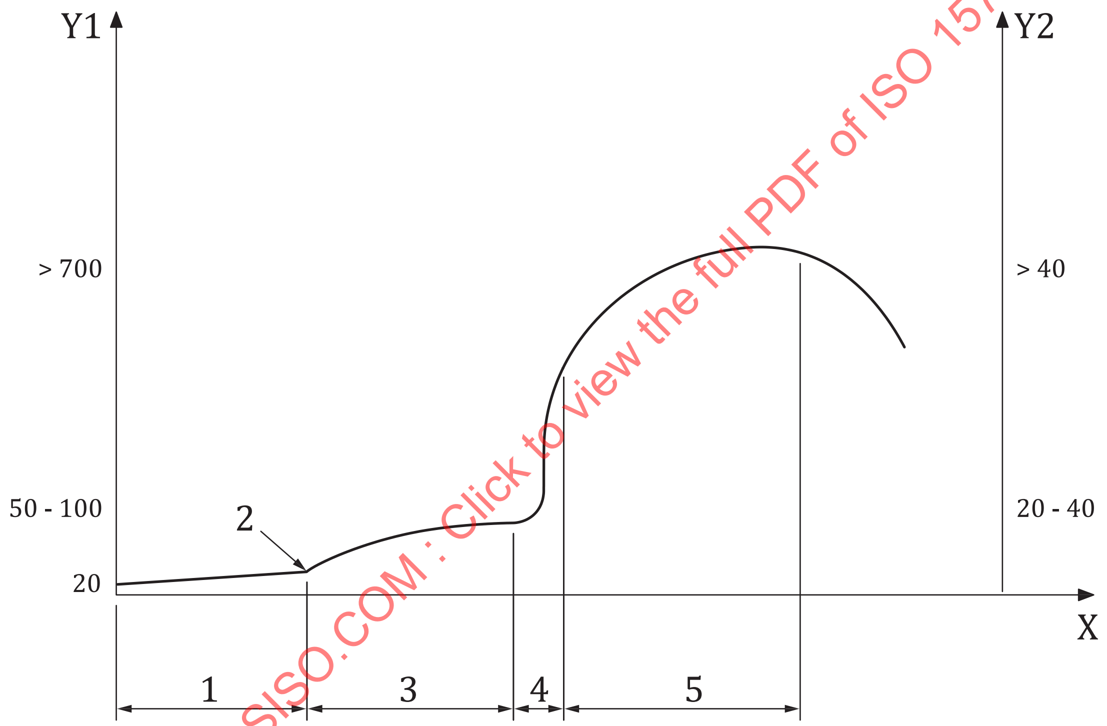
Smouldering fires will not significantly increase room temperatures but may begin to deplete oxygen and cause smoke. Typical ignition sources for smouldering fires can be a cigarette on a mattress or a faulty electric blanket. Smouldering rates can be derived from experiments.

Another scenario is a flaming fire caused by primary ignition sources igniting, for example waste-paper baskets, curtains and mattresses. These sources can lead to secondary ignition of other combustible products.

Small ignition sources cause accelerated development of fire when stored combustible liquids result in flashover. In such cases, the heat release can be expressed as the hydrocarbon curve.[29] Relatively high ventilation is necessary for such development, and the CO_2/CO ratio is about 100. Fires with low ventilation are likely to lead to temperatures in the range 600 °C to 900 °C.

5.4 Large room fire

In large rooms such as theatres, open-plan offices, warehouses, supermarkets and sports halls, fires are freely ventilated for a long time. In contrast to small rooms, there are hardly any interrelated effects and development of fire is directly dependent on the successive combustion of the burning items. The scenario can be compared with fires in the open air for a certain period of time. Flashover causes a rapid decrease in the CO_2/CO ratio.



Key

1 time to ignition

2 T > 100 °C, I > 25 kW/m^2 close to ignited item

3 developing fire

4 flashover

5 fully developed fire

X time

Y1 average temperature T in fire compartment (°C)

Y2 average irradiance I in fire compartment (kW/m^2)

Figure 1 — Typical course of a fire in a room

Evaluation of fire development is linked to the quantification of a design fire as described in ISO/TR 13387-2. It is necessary to define design fires and design fire scenarios because the course of real fires varies depending on the nature of the combustibles, the ignition source, the fire load and the conditions in the fire compartment. It is practically impossible to predict the real fire taking into account all these interactions and real boundary conditions.

There are two distinctly different methods of determining the design fire for a given scenario. One is based on knowledge of the amount, type and distribution of combustible materials in the compartment of fire origin. The other is based on knowledge of the type of occupancy, where very little is known about the details of the fire load.

A design fire may be needed for a wide range of design fire scenarios. These may be internal or external fire scenarios. Examples of typical design fire scenarios include:

— large/medium/small-room fires (corner, ceiling, floor, wall);

— corridor fires;

— roofing fires;

— cavity fires;

— staircase fires;

— fires in/on façades;

— single burning item fires (furniture, cable conduits, pipes).

Design fire specifications should be translated into characteristics of the fuel load environment near the initial fire.

These regimes are used to determine the growth of the initial fire as a function of time.

6 Thermal characteristics of ignition sources

Design fires are usually quantified in terms of the heat release rate of the assumed ignition source as a function of time. Once the heat release rate is known, the flame area and height can be estimated. The heating of a second object can then be predicted. Typical ignition source heat release rates are shown in Table 1.

Table 1 — Heat release rates for typical ignition sources

Source	Heat output kW
Match	0,1
Waste-paper basket	10 to 40
Small chair	10 to 300
Upholstered furniture, large wood crib	> 300

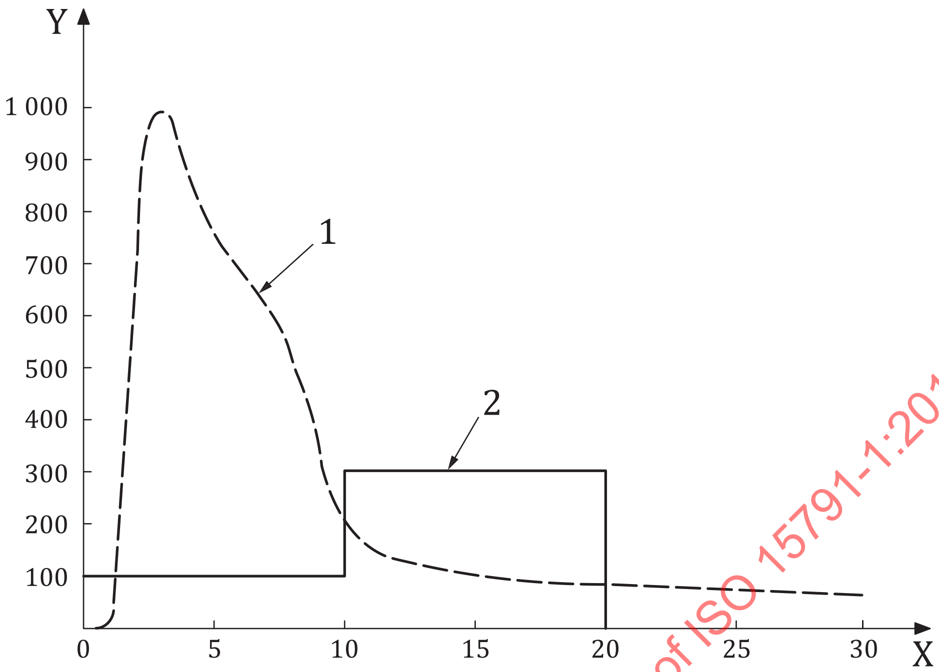
If the net heat flux from the surface of actual ignition sources is known, these ignition sources can be simulated by radiant panels. Typical fluxes are shown in Table 2.

Table 2 — Typical heat fluxes

Source	Heat flux kW/m²
Match flame	18 to 20
Developing fire	20 to 60
Paper bag, wood crib	25 to 50
Oxidative pyrolysis with oxygen concentration of 5 % to 21 %	< 25
Small gas-diffusion flame	30 to 40
Fully developed low-ventilation fire	40 to 70
Premixed-gas burner	50 to 70
Fully developed high-ventilation fire	50 to 150
Premixed-gas blow torch	140 to 150
Peak value for hydrocarbon-fire resistance test	200
Jet fire	350
Theoretical maximum for organic fire	1 500

When gas burners or radiant panels are used as ignition sources, it should be recognized that the thermal shock created by these heating regimes may influence especially the charring and melting behaviour and have an influence on the performance of many plastics products.

Figure 2 shows typical characteristics of a natural source (i.e. a 35 kg wood crib) and a gas burner source as defined in ISO 9705.



Key

1 35 kg wood crib

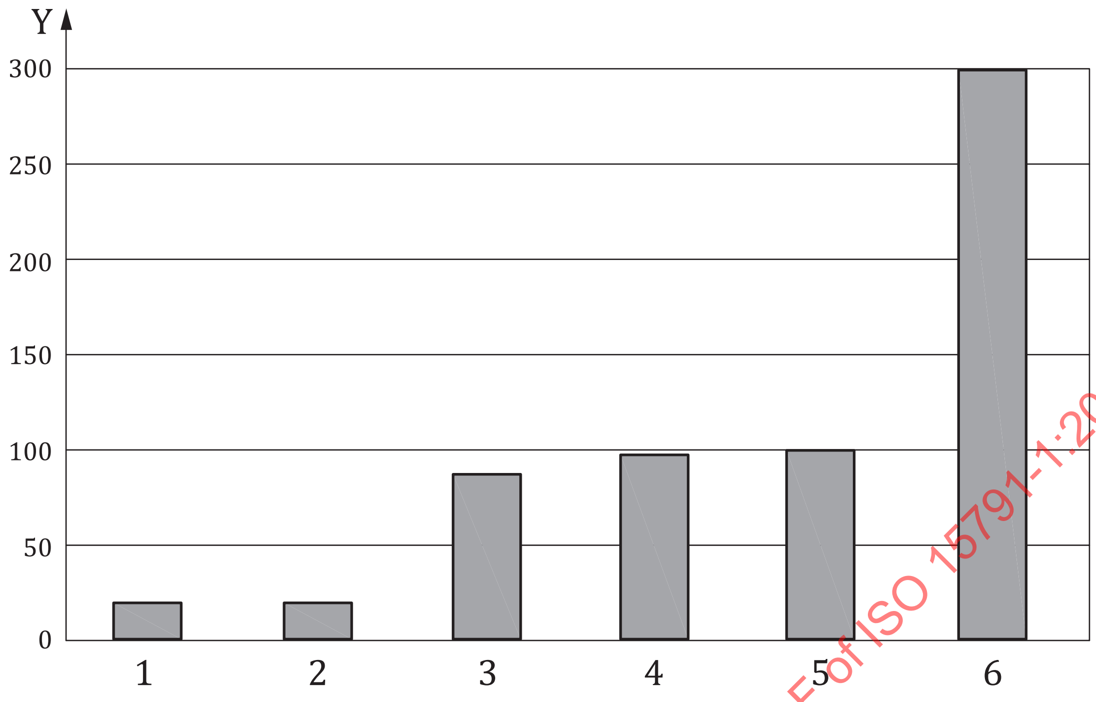
2 propane burner (as specified in ISO 9705)

X time (min)

Y heat release rate (kW)

Figure 2 — Comparison of heat release characteristics of a natural source and a gas burner

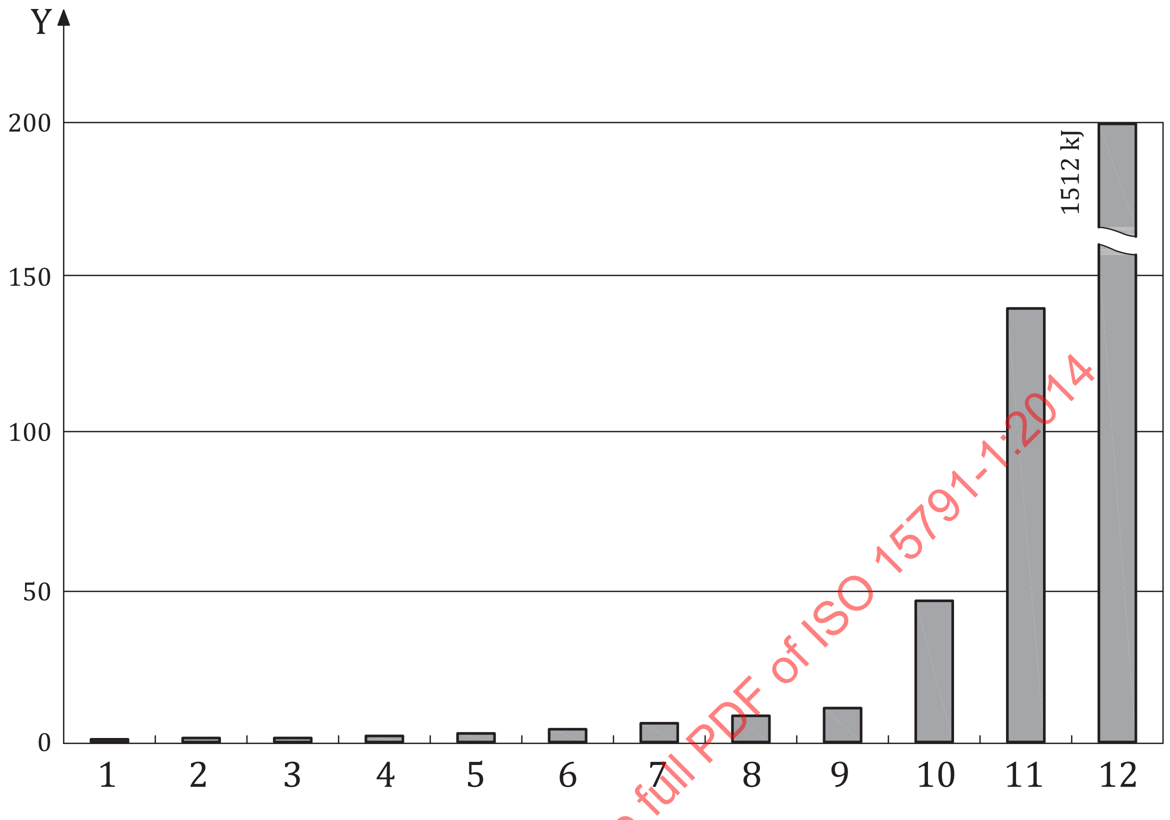
National and international standards (see Figures 3 and 4 and Tables 3 and 4) provide a variety of ignition sources (a range of such ignition sources is described in ISO 10093). These include gas burners with different flame heights up to 250 mm, glowing wires and fuels used for testing and classifying products. Fire statistics indicate that a much higher proportion of fires are caused by ignition sources such as burning paper, which is often used in malicious fires.



Key

1 DIN 4102-7 (B1)
2 DIN VDE 0472 (T804c)
3 ASTM E84
4 FAR 25.853
5 ISO 9705 (first 10 min)
6 ISO 9705 (next 10 min)
Y heat output rate (kW)

Figure 3 — Power of standardized gas burners



Key

1 DIN 4102-1 (B2)
2 UL 94V
3 CSE RF 4 (3,IM)
4 FAR 25.853a
5 BS 5852 (Source 1)
6 CSE RF 4 (2,IM)
7 FAR 25.853b
8 CSE RF 4 (1,IM)
9 BS 5852 (Source 2)
10 BS 5852 (Source 3)
11 DIN 54837
12 ÖN 3800 (B1)
Y energy (kJ)

Figure 4 — Energy of standardized ignition sources

Table 3 — Example of wood and paper ignition source

Standard	Description	Mass g	Power kW	Duration s	Energy kJ
BS 5852	Wood crib 4	8,5	1	200	200
BS 5852	Wood crib 5	17	1,4	200	280
BS 5852	Wood crib 6	60	3	340	1 020
BS 5852	Wood crib 7	126	6	370	2 220
EN 1021	Paper cushion	20	2	120	240
DIN 54341	Paper cushion	100	8	180	1 440
DIN 4102–7	Wood-wool basket	600	23	450	10 350
NT 007	Wood crib	40	3	190	570

Table 4 — Typical characteristics of ignition sources

Application	Standard	Flow rate (gases) or mass (solids)	Power kW	Duration s	Energy kJ
Electrotechnical	VDE 0304/3	—	0,4	180	72
	IEC 60695-11-10	0,11 l/min methane	0,05	20	1,0
	IEC 60695-11-20	0,97 l/min methane	0,5	25	12,5
Transport	FAR 25.853a	0,2 l/min natural gas	0,1	12	1,2
	FAR 25.853b	0,2 l/min natural gas	0,1	60	6,0
	DIN 54837	0,5 l/min propane	0,8	180	144
	DIN 54341	100 g paper	8	180	1 440
	FAR 25.853	0,142 l/min kerosene	99	120	11 880
Furniture	Match	0,1 g	0,1	15	1,5
	DIN 4102–1	0,025 l/min propane	0,04	15	0,6
	CEN/TC 207	20 g paper	2	120	240
	BS 5852, crib 5	17 g wood	1	200	200
	DIN 54341	100 g paper	8	180	1 440
	BS 5852, crib 7	126 g wood	9	370	3 330
Building	ÖN 3800, B1	1,08 l/min propane	2	900	1 800
	DIN 4102–7	600 g wood wool	23	450	10 350
	DIN 4102–1	0,025 l/min propane	0,04	15	0,6
	DIN 4102–1, DIN 4102–15	35 l/min methane	21	600	12 600
	—	1 kg wood[a]	26	600	15 840
	—	5 kg wood[a]	88	900	79 200
	—	10 kg wood[a]	130	1 200	156 000

[a] Heat power (kW), duration of burning and total energy output of wood are dependent on how it is burned (woodpile and stick dimensions, etc.).

7 Design requirements

The main reaction-to-fire parameters used in most global classification systems for hazard-oriented evaluation of materials and products are based on ignitability and fire growth.

Anticipated correlation with real fire performance is a function of the scale of the simulated fire. The purpose of an intermediate-scale fire test is to generate information on the fire growth stage.

The fire scenario influences the generation of heat, smoke, and toxic and corrosive effluents.

Small-scale tests that evaluate these parameters require all the specimens to be exposed to the conditions used in the test. This cannot easily simulate the range of thermal, ventilation and other physical conditions experienced by products during the fire growth phase where fire boundary conditions will be constantly changing. Actual condition of heat input to the specimen and ventilation should be simulated in intermediate-scale tests as far as possible.

Large-scale tests with larger specimens are often required to effectively model the effects of thermal deformation, delamination, fixation failure, substrates, joints, etc., on product performance. Many such tests require extensive combustion product handling facilities in order to cope with the test effluent from the large specimens. The large-scale test is expensive and needs large effort to conduct. In order to evaluate a fire performance of a product it is therefore desirable to develop flexible intermediate-scale tests that can effectively quantify the relevant parameters. These test methods permit the evaluation of semi-finished or finished products in end use conditions with specimens of different sizes. Table A.1 of Annex A describes how these different scale tests can together provide a complete evaluation of product fire performance from material development to product evaluation.

8 Guidance for intermediate scale tests

Most tests focus on the vertical specimen orientation. Few International Standards are available for assessing the reaction to fire of horizontally oriented products (see ISO 9239-1).

Fire hazard assessment should primarily identify the safety objectives to be achieved, and intermediate-scale tests should take into account the following considerations:

a) the specimen should be of such a size that it can be accommodated in a laboratory;

b) the apparatus should not be excessively difficult to house or install and the test should be designed for efficient testing and easy specimen handling;

c) the test should have simple and commonly available instrumentation;

d) the ignition source should be of such a size that it can be accommodated in a laboratory;

e) ventilation conditions should reflect realistic fire conditions as far as possible;

f) the test configuration should allow for one of the following three conditions: open, semi-open or closed;

g) intermediate-scale tests should be capable of being validated by carrying out large-scale tests;

h) where possible, precision data for the test methods should be obtained.

Applications of products should be investigated taking into account the intended use:

1) is the product likely to be the item first ignited?

2) is the product likely to be the second item ignited, i.e. a product ignited by the item first ignited?

3) is the product a potentially significant fuel source even if it is not the first or second ignited item?

4) is the effluent likely to cause a hazard to life and/or the environment?

5) what is the potential way in which the product could contribute to the hazard?

ISO/TS 15791-2 describes specific test methods that can be used for testing semi-finished and finished products.

9 Examples of intermediate-scale tests for plastics products

9.1 IEC 61034-2 — 3 m cube test

IEC/TC 20, *Electric cables*, has developed IEC 61034-2. The equipment comprises a cubic enclosure with inside dimensions of (3 ± 0,03) m. One side has a door, with a glass inspection window. The walls of the enclosure include orifices at ground level to ensure pressure equalization inside the chamber. These orifices can also serve to introduce additional monitoring equipment, e.g. thermocouples to measure temperature changes during the test. Transparent sealed windows on two opposite sides permit the transmission of a light beam from a horizontal photometric system. The standardized ignition source is (1,00 ± 0,01) litres of alcohol with the composition ethanol (90 ± 1) %, methanol (4 ± 1) % and water (6 ± 1) %.

9.2 ISO 5658-4 — Vertical flame spread test

ISO/TC 92/SC 1, *Fire Safety — Fire initiation and growth*, has developed the intermediate-scale test ISO 5658-4. The test is applicable to the measurement and description of vertical surface spread of flame over products or assemblies in response to radiant heat in the presence of a pilot flame (to ignite effluent gases) under controlled laboratory conditions. It is suitable for taking into account end-use conditions such as joints. Other specimen configurations may be installed in the test apparatus for different purposes, and a measure of lateral spread of flame may also be obtained.

The apparatus basically consists of a radiant panel measuring (0,480 ± 0,005) m × (0,280 ± 0,005) m, the heat from which impinges on the flat surface of a test specimen. The heat flux to the specimen varies from 0 to 45 kW m^{-2}. The specimen is (1,525 ± 0,025) m high by (1,025 ± 0,025) m wide by end-use thickness.

9.3 ISO 14696 — Intermediate-scale calorimeter (ICAL) test

Intermediate-scale calorimeter (ICAL) test, ISO 14696, was developed by ISO/TC 92/SC 1 using a hood with opening dimensions of 2,44 m by 2,44 m. The test was developed to give realistic data from 1 m by 1 m specimens. Although the test is limited to the vertical specimen orientation, the instrumentation and exhaust gas collecting system may also be used for other purposes.

9.4 EN 13823 — Single burning item (SBI) test

The development of an intermediate-scale test in Europe, the single burning item (SBI) test, was a key factor in achieving consensus on the Euroclass system for reaction to fire of building products. The SBI test facility basically consists of a test enclosure, a specimen trolley and frame, burners, a hood, a collector and tubing, a propane supply system, a smoke exhaust system and measurement equipment. The test enclosure has a height of (2,4 ± 0,1) m (top of the frame level) and a floor size of (3,0 ± 0,6) m x (3,0 ± 0,6) m.

A test specimen consisting of two vertical wings (one short, one long) forming a right-angled corner is exposed to the flame from a burner placed at the bottom of the corner. Sheet products have dimensions at the short wing of (0,495 ± 0,005) m by (1,5 ± 0,005) m and at the long wing (1,0 ± 0,005) m by (1,5 ± 0,005) m. The apparatus is capable of accommodating test specimens up to 200 mm in thickness. The flame is obtained by combustion of propane gas, injected through a sandbox. The heat output of the burner is (30 ± 2) kW.

After ignition of the burner, the following parameters of the specimen burning process are recorded:

— lateral flame spread;

— heat release;

— smoke production;

— flaming droplets/particles.

9.5 ISO 24473 — Open calorimetry

There have been many fire tests conducted in the last couple of decades in which the test specimen was positioned under a fume hood that was connected to a duct system for measuring heat release rate and smoke production rate. ISO/TC92/SC1, recognizing the need for standardization of such a test method, developed ISO 24473.

ISO 24473 specifies a series of test methods that simulate a real scale fire on a test object or group of objects under well-ventilated conditions. A range of different fire sizes can be studied according to the scale of the equipment available. The method is intended to evaluate the contribution to fire growth provided by an object or group of objects using a specified ignition source. A test performed in accordance with the method specified in this standard provides data for all stages of a fire.

9.6 ISO 21367 — Medium scale fire test for plastics

This standard specifies a test method for plastics for the determination of the heat release rate, ignitability, surface spread of a flame, falling droplets/particles and smoke production using a "medium" scale specimen that simulates the early development stage of the fire. This test method can be used as a screening test for intermediate scale and large scale tests in addition to its use in factory production control, research and product development.

10 Test report

The test report should contain the following information:

a) data on the laboratory and its GLP (good laboratory practice) status;

b) the date of the test, the test atmosphere and details of specimen conditioning;

c) a description of the specimen material;

d) data on the decomposition model and decomposition conditions;

e) the characteristics (heat flux profile) of the ignition source;

f) the thermal profile (temperature and heat flux distribution) within the test enclosure;

g) any visual observations, including burning characteristics;

h) the measured responses of the material or product tested (e.g. time to ignition, flame spread, heat release);

i) the vent pressure/velocity profile (e.g. pressure of smoke vents, flow through vents);

j) details of a smoke analysis as a function of test duration (including the methods of measurement used);

k) the results calculated.

Annex A
(normative)

Different scale fire tests for obtaining information on fire performance of material and product

Table A.1 — Scaling matrix for material and product tests

	Material		Product		System/installed product	
			Semi-finished product	**Finished product**	**Large scale**	**Real scale**
Scale of test	Bench	Small	Intermediate	Intermediate	Large	Real
What is seen	Intrinsic properties of the matter	Intrinsic properties of the matter — Multilayer effect — Charring/intumescent effect	Material fire behaviour — Propagation — Effect of joints	Product fire behaviour — Mounting and fixing (including panels joints)	Global system fire behaviour, including realistic environment System effect (complete mounting, including walls/roof connections)	System fire behaviour
Main characteristics of the scale and degradation model	Thermally — thin degradation Developed for different fire stages, including vitiated conditions Heat, smoke and toxic potencies	— 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 — Scale effect — Only available for well—ventilated fire stages — 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	10–500 g ≈0,01 m^2	500 g–5 kg 0,5–1 m^2	5 kg–50 kg > 1 m^2	> 100 kg > 10 m^2	—
Usages	— fire safety engineering (FSE) input data — Research and development — Monitoring production	— FSE input data — Research and development — Materials homologation	— FSE adjusting — Materials/products homologation	— FSE adjusting — Products homologation	— FSE validation — Contention arbitration — Research	— FSE validation — Research

a Not yet developed.

b An annex to ISO 9705 concerning coupling with ISO 19702 (FTIR) is under consideration.

Table A.1 *(continued)*

	Material		Product		System/installed product	
			Semi-finished product	**Finished product**	**Large scale**	**Real scale**
Scale of test	Bench	Small	Intermediate	Intermediate	Large	Real
Main user	Compound developer	Compound supplier	Product supplier	Product supplier	Prime contractor Regulator	Prime contractor Regulator
Main standards for ignition and flame spread	ISO 4589-2/ ISO 4589-3 ISO 9772 ISO 9773 ISO 12992 ISO/TR 11925-1	ISO 5660-1	ISO 5658-2 ISO 5658-4 ISO 21367	EN 13823	ISO 9705 ISO 13784-1/ ISO 13784-2	ISO 24473
Main standards for heat release	—	ISO 5660-1	ISO 21367	EN 13823	ISO 9705 ISO 13784-1	ISO 24473
Main standards for smoke	—	ISO 5659-2 ISO 5660-2	ISO 21367	EN 13823	ISO 9705	ISO 24473
Main standards for gas analysis	ISO/TS 19700 NF X70–100	—[a]	—[a]	—	—[b]	—

a Not yet developed.

b An annex to ISO 9705 concerning coupling with ISO 19702 (FTIR) is under consideration.