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**Fire hazard testing –
Part 9-2: Surface spread of flame – Summary and relevance of test methods**

**Essais relatifs aux risques du feu –
Partie 9-2: Propagation des flammes en surface – Résumé et pertinence
des méthodes d'essai**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIRE HAZARD TESTING –

**Part 9-2: Surface spread of flame –
Summary and relevance of test methods**

FOREWORD

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International Standard IEC 60695-9-2 has been prepared by IEC technical committee 89: Fire hazard testing.

It has the status of a basic safety publication in accordance with IEC Guide 104.

This second edition cancels and replaces the first edition of IEC 60695-9-2 published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Updated introduction
- b) Updated normative references
- c) Updated terms and definitions
- d) New Subclauses 4.1 and 4.2

e) Reference to *fire* stages as defined in ISO 19706 (Table 1)

f) New sub-division of tests into the following subclauses:

4.3 *Small-scale fire tests*

4.4 *Medium and intermediate-scale fire tests*

4.5 *Intermediate and large-scale fire tests* for cables

4.6 *Real-scale fire tests* for cables

g) Updated text in parts of Clause 4

h) Addition of the following test methods:

IEC TS 60695-11-21

IEC 60684-2:2011, Clause 26

ISO 3582

ISO 9772

ISO 9773

ISO 12992

ISO 21367

i) New Clause 5 and Table 4 giving an overview of test methods

j) Deletion of all the Annexes

k) Updated bibliography

The text of this International Standard is based on the following documents:

Draft	Report on voting
89/1469/CDV	89/1505/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 60695 series, published under the general title *Fire hazard testing*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60695-1.

In this standard, the following print types are used:

terms referred to in Clause 3: in italic type.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

In the design of an electrotechnical product, the risk of *fire* and the potential hazards associated with *fire* need to be considered. In this respect the objective of component, circuit and equipment design, as well as the choice of materials, is to reduce the risk of *fire* to a tolerable level even in the event of reasonably foreseeable (mis)use, malfunction or failure.

IEC 60695-1-10, IEC 60695-1-11 [1]¹, and IEC 60695-1-12 [2] provide guidance on how this is to be accomplished.

Fires involving electrotechnical products can also be initiated from external non-electrical sources. Considerations of this nature are dealt with in an overall *fire hazard* assessment.

The aim of the IEC 60695 series of standards is to save lives and property by reducing the number of *fires* or reducing the consequences of the *fire*. This can be accomplished by:

- trying to prevent *ignition* caused by an electrically energised component part and, in the event of *ignition*, to confine any resulting *fire* within the bounds of the enclosure of the electrotechnical product;
- trying to minimise *flame spread* beyond the product's enclosure and to minimise the harmful effects of *fire* effluents including heat, smoke, and toxic or corrosive combustion products.

Fire hazard increases as the burning area increases, leading in some cases to *flashover* and a *fully developed fire*. This is a typical *fire scenario* in buildings. It is therefore useful to measure the rate and extent of the *surface spread of flame*.

This part of IEC 60695-9 describes *surface spread of flame* test methods in common use to assess electrotechnical products or materials used in electrotechnical products. It forms part of the IEC 60695-9 series which gives guidance to product committees wishing to incorporate test methods for *surface spread of flame* in product standards.

¹ Numbers in square brackets refer to the bibliography.

FIRE HAZARD TESTING –

Part 9-2: Surface spread of flame – Summary and relevance of test methods

1 Scope

This part of IEC 60695-9 presents a summary of published test methods that are used to determine the *surface spread of flame* of electrotechnical products or materials from which they are formed.

It represents the current state of the art of the test methods and, where available, includes special observations on their relevance and use.

The list of test methods is not to be considered exhaustive, and test methods that were not developed by the IEC are not to be considered as endorsed by the IEC unless this is specifically stated.

This summary cannot be used in place of published standards which are the only valid reference documents.

This basic safety publication is intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication will not apply unless specifically referred to or included in the relevant publications.

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.

IEC 60695-1-10, *Fire hazard testing – Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-4:2012, *Fire hazard testing – Part 4: Terminology concerning fire tests for electrotechnical products*

IEC 60695-9-1, *Fire hazard testing – Part 9-1: Surface spread of flame – General guidance*

IEC GUIDE 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

ISO 13943:2017, *Fire Safety – Vocabulary*

ISO 19706:2011, *Guidelines for assessing the fire threat to people*.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60695-4:2012 and ISO 13943:2017 (some of which are reproduced below) and the following apply.

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

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

3.1

burned length

maximum extent in a specified direction of the burned area

Note 1 to entry: The typical unit is m.

Note 2 to entry: Compare with the term *damaged length* (3.5).

[SOURCE: ISO 13943: 2017, definition 3.37]

3.2

char length

length of charred area

Note 1 to entry: Compare with the terms *burned length* (3.1) and *damaged length* (3.5).

Note 2 to entry: In some standards, *char length* is defined by a specific test method.

[SOURCE: ISO 13943: 2017, definition 3.49]

3.3

combustible, noun

item capable of combustion (3.4)

[SOURCE: ISO 13943: 2017, definition 3.53]

3.4

combustion

exothermic reaction of a substance with an oxidizing agent

Note 1 to entry: Combustion generally emits *fire effluent* accompanied by *flames* (3.11) and/or glowing.

[SOURCE: ISO 13943: 2017, definition 3.55]

3.5

damaged length

maximum extent in a specified direction of the damaged area

Note 1 to entry: Compare with the terms *char length* (3.2) and *burned length* (3.1)

[SOURCE: ISO 13943: 2017, definition 3.73]

3.6

fire

(general) process of *combustion* (3.4) characterized by the emission of heat and *fire effluent* and usually accompanied by smoke, *flame* (3.11), glowing or a combination thereof

Note 1 to entry: In the English language the term “*fire*” is used to designate three concepts, two of which relate to specific types of self-supporting combustion with different meanings. Of these three, two of them are designated using two different terms in both French and German.

[SOURCE: ISO 13943: 2017, definition 3.114]

3.7

fire

⟨controlled⟩ self-supporting *combustion* (3.4) that has been deliberately arranged to provide useful effects and is limited in its extent in time and space

[SOURCE: ISO 13943: 2017, definition 3.115]

3.8

fire

⟨uncontrolled⟩ self-supporting *combustion* (3.4) that has not been deliberately arranged to provide useful effects and is not limited in its extent in time and space

[SOURCE: ISO 13943: 2017, definition 3.116]

3.9

fire hazard

potential for harm associated with *fire* (3.8)

Note 1 to entry: Alternatively, *fire hazard* can be a physical object or condition with a potential for an undesirable consequence from *fire*.

[SOURCE: ISO 13943: 2017, definition 3.131]

3.10

fire scenario

qualitative description of the course of a *fire* (3.8) with respect to time, identifying key events that characterize the studied *fire* and differentiate it from other possible *fires*

Note 1 to entry: It typically defines the *ignition* (3.18) and *fire* growth processes, the *fully developed fire* (3.16) stage, the *fire* decay stage, and the environment and systems that impact on the course of the *fire*.

Note 2 to entry: Unlike deterministic *fire* analysis, where *fire scenarios* are individually selected and used as design *fire scenarios*, in *fire* risk assessment, *fire scenarios* are used as representative *fire scenarios* within *fire scenario* clusters.

[SOURCE: ISO 13943: 2017, definition 3.152, modified – Note 1 removed as not relevant]

3.11

flame, noun

zone in which there is rapid, self-sustaining, sub-sonic propagation of *combustion* (3.4) in a gaseous medium, usually with emission of light

[SOURCE: ISO 13943: 2017, definition 3.159 – modified by the addition of “zone in which there is”]

3.12

flame front

boundary of flaming combustion at the surface of a material or propagating through a gaseous mixture

[SOURCE: ISO 13943: 2017, definition 3.162]

3.13

flame spread

propagation of a *flame front* (3.12)

[SOURCE: ISO 13943: 2017, definition 3.168]

3.14

flame-spread rate

DEPRECATED: burning rate

DEPRECATED: rate of burning

distance travelled by a *flame front* (3.12) during its propagation, divided by the time of travel, under specified conditions

Note 1 to entry: The typical unit is m.s^{-1} .

[SOURCE: ISO 13943: 2017, definition 3.169]

3.15

flashover

⟨stage of *fire*⟩ transition to a state of total surface involvement in a *fire* (3.8) of combustible materials within an enclosure

[SOURCE: ISO 13943: 2017, definition 3.184]

3.16

fully developed fire

state of total involvement of combustible materials in a *fire* (3.6)

[SOURCE: ISO 13943: 2017, definition 3.192]

3.17

heat release rate

DEPRECATED: burning rate

DEPRECATED: rate of burning

rate of thermal energy production generated by *combustion* (3.4)

Note 1 to entry: The typical unit is W.

[SOURCE: ISO 13943: 2017, definition 3.206]

3.18

ignition

DEPRECATED: sustained ignition

⟨general⟩ initiation of *combustion* (3.4)

[SOURCE: ISO 13943: 2017, definition 3.217]

3.19

ignition source

source of energy that initiates *combustion* (3.4)

[SOURCE: ISO 13943: 2017, definition 3.219]

3.20

intermediate-scale fire test

fire test performed on a test specimen of medium dimensions

Note 1 to entry: A *fire* test performed on a test specimen for which the maximum dimension is between 1 m and 3 m is usually called an *intermediate-scale fire test*.

Note 2 to entry: The dimensions in Note 1 to entry usually refer to reaction-to-*fire* testing and not to *fire* resistance testing.

Note 3 to entry: ISO 29903 considers medium dimensions to be those with a maximum dimension between 1 m and 3 m.

[SOURCE: ISO 13943: 2017, definition 3.233]

3.21

large-scale fire test

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

Note 1 to entry: A *fire* test performed on a test specimen of which the maximum dimension is greater than 3 m is usually called a *large-scale fire test*.

[SOURCE: ISO 13943: 2017, definition 3.239]

3.22

medium-scale fire test

fire test performed on a test specimen of small-medium size dimensions

Note 1 to entry: A *fire* test performed on a test specimen of which the maximum dimension is between 0,5 m and 1,0 m is often called a *medium-scale fire test*.

Note 2 to entry: The dimensions referenced in Note 1 to entry usually refer to reaction-to-*fire* testing and not to *fire* resistance testing, where a maximum dimension of 1 m corresponds to a small-scale test.

[SOURCE: ISO 13943: 2017, definition 3.269]

3.23

pyrolysis

chemical decomposition of a substance by the action of heat

Note 1 to entry: *Pyrolysis* is often used to refer to a stage of *fire* (3.6) before flaming combustion has begun.

Note 2 to entry: In *fire* science, no assumption is made about the presence or absence of oxygen.

[SOURCE: ISO 13943: 2017, definition 3.316]

3.24

real-scale fire test

fire test that simulates a given application, taking into account the real scale, the real way the item is installed and used, and the environment

Note 1 to entry: Such a *fire* test normally assumes that the products will be used in accordance with the conditions laid down by the specifier and/or in accordance with normal practice.

[SOURCE: ISO 13943: 2017, definition 3.325]

3.25

riser cable

cable that runs vertically between floors in a building

Note 1 to entry: This is a term used predominantly in North America

3.26

small-scale fire test

fire test performed on a test specimen of small dimensions

Note 1 to entry: There is no clear upper limit for the dimensions of the test specimen in a *small-scale fire test*. In some instances, a *fire* test performed on a test specimen with a maximum dimension of less than 1 m is called a *small-scale fire test*. However, a *fire* test performed on a test specimen of which the maximum dimension is between 0,5 m and 1,0 m is often called a *medium-scale fire test*.

[SOURCE: ISO 13943: 2017, definition 3.346]

3.27

surface spread of flame

flame spread (3.13) away from the source of *ignition* (3.18) across the surface of a liquid or a solid

[SOURCE: ISO 13943: 2017, definition 3.378]

4 Summary of published test methods

4.1 General

This summary does not replace published standards, which are the only valid reference documents.

In cases where *fire* tests are not yet specified, and need to be developed or altered for the special purpose of an IEC technical committee, this shall be done in liaison with the relevant IEC technical committee, as mandated by IEC Guide 104. The test method(s) selected shall be relevant to the *fire scenario* of concern. Guidance on the selection and relevance of *fire* tests for electrotechnical products is given in IEC 60695-1-10.

General guidance on *surface spread of flame* tests for electrotechnical products is given in IEC 60695-9-1.

4.2 The physical fire model

Flame spread is not an inherent property of a material or product, but is critically dependent on the conditions under which that material or product is burnt. The various factors that affect *flame spread* are discussed in IEC 60695-9-1.

It is important to show that the test conditions defined in a standardised test method (the physical *fire* model) are relevant to, and replicate the desired stage of a real *fire*. ISO has published a general classification of *fire* stages in ISO 19706:2011, shown in Table 1.

Table 1 – Characteristics of *fire* stages (ISO 19706:2011)

Fire stage	Heat flux to fuel surface kW/m ²	Max. temperature °C		Oxygen volume %		Fuel/air equivalence ratio (plume)	$\frac{[\text{CO}]}{[\text{CO}_2]}$ v/v	$\frac{100 \times [\text{CO}_2]}{([\text{CO}_2] + [\text{CO}])}$ % efficiency
		Fuel surface	Upper layer	Entrained	Exhausted			
1. Non-flaming								
a. self-sustaining (smouldering)	n.a.	450 to 800	25 to 85 ^d	20	20	—	0,1 to 1	50 to 90
b. oxidative <i>pyrolysis</i> from externally applied radiation	—	300 to 600 ^a	^b	20	20	< 1	^c	^c
c. anaerobic <i>pyrolysis</i> from externally applied radiation	—	100 to 500	^b	0	0	>> 1	^c	^c
2. Well-ventilated flaming ^d	0 to 60	350 to 650	50 to 500	≈ 20	≈ 20	< 1	< 0,05 ^e	> 95
3. Under-ventilated flaming ^f								
a. small, localized <i>fire</i> , generally in a poorly ventilated compartment	0 to 30	300 to 600 ^a	50 to 500	15 to 20	5 to 10	> 1	0,2 to 0,4	70 to 80
b. post- <i>flashover fire</i>	50 to 150	350 to 650 ^g	> 600	< 15	< 5	> 1 ^h	0,1 to 0,4 ⁱ	70 to 90
a The upper limit is lower than for well-ventilated flaming combustion of a given <i>combustible</i>. b The temperature in the upper layer of the <i>fire</i> room is most likely determined by the source of the externally applied radiation and room geometry. c There are few data; but for <i>pyrolysis</i>, this ratio is expected to vary widely depending on the material chemistry and the local ventilation and thermal conditions. d The <i>fire</i>'s oxygen consumption is small compared to that in the room or the inflow, the <i>flame</i> tip is below the hot gas upper layer or the upper layer is not yet significantly vitiated to increase the CO yield significantly, the <i>flames</i> are not truncated by contact with another object, and the burning rate is controlled by the availability of fuel. e The ratio may be up to an order of magnitude higher for materials that are <i>fire</i>-resistant. There is no significant increase in this ratio for equivalence ratios up to ≈ 0,75. Between ≈ 0,75 and 1, some increase in this ratio may occur. f The <i>fire</i>'s oxygen demand is limited by the ventilation opening(s); the <i>flames</i> extend into the upper layer. g Assumed to be similar to well-ventilated flaming. h The plume equivalence ratio has not been measured; the use of a global equivalence ratio is inappropriate. i Instances of lower ratios have been measured. Generally, these result from secondary combustion outside the room vent.								

4.3 Small-scale fire tests

4.3.1 Horizontal and vertical 50 W and 500 W flame tests – IEC 60695-11-10 and IEC 60695-11-20

4.3.1.1 Purpose and principle

IEC 60695-11-10 [3] is a test using a 50 W flame. IEC 60695-11-20 [4] is a test using a 500 W flame. These tests refer to solid electrical insulating materials and are intended to serve as a preliminary indication of their behaviour when exposed to an *ignition source*. The results make it possible to check the constancy of the characteristics of a material and provide an indication of the progress in the development of the flame retardancy of insulating materials. The results also provide a relative comparison and classification of insulating materials.

4.3.1.2 Test specimen

The relatively small test specimen is 125 mm long, 13 mm wide, and up to 13 mm thick.

4.3.1.3 Test method

These tests involve the application of an *ignition source* to a horizontal or vertical test specimen and the evaluation of the linear burning rate (HB classification) and the vertical spread of flame (V classification).

4.3.1.4 Repeatability and reproducibility

Data are available in IEC 60695-11-10:2013, Annexes A and B, and IEC 60695-11-20:2015, Annex A.

4.3.1.5 Relevance of test data

These test methods are used to evaluate materials. The test methods provide classifications that may be used for quality assurance, the preselection of component materials of products, or to verify the required minimum flammability classification of materials used in end products. The tests are not valid for determining the *fire* behaviour and *fire hazard* of complete items of equipment, since the dimensions of the insulating systems and the design and heat transfer to adjacent metallic parts, greatly influence the flammability of the electrical insulating materials being used.

4.3.2 Fire hazard testing – Part 11-21: Test flames – 500 W vertical flame test method for tubular polymeric materials – IEC TS 60695-11-21 [5]

4.3.2.1 Purpose and principle

This document describes a small-scale laboratory pass/fail procedure which is based on the comparative burning characteristics of tubular polymeric materials. A flame is applied to test specimens held in a vertical position, supported by a wire or mandrel. Upon removal of the test flame, the extinguishing times and the burning characteristics are determined.

4.3.2.2 Test specimen

Test specimens are at least 450 mm long samples of tubular polymeric material.

4.3.2.3 Test method

A burner conforming to IEC 60695-11-3 [6], Method A, is used. This provides a pre-mixed methane flame of nominal power 500 W.

The test specimen is secured by a wire or mandrel with its longitudinal axis vertical. An indicator flag is attached to the test specimen with its lower edge (250 ± 2) mm above the

point at which the blue inner cone of the test *flame* touches the test specimen. A flat horizontal layer of cotton is placed below the test specimen.

The *flame* is applied for $(15 \pm 0,5)$ s to the side of the test specimen at a point near its lower edge. It is then removed for $(15 \pm 0,5)$ s. The flaming time, t , is noted. This operation is repeated until the test specimen has been subjected to five applications of the test *flame*. Where flaming of the test specimen persists longer than 15 s after the previous application of the test *flame*, the test *flame* is not reapplied until flaming of the test specimen has ceased of its own accord. The test *flame* is reapplied as soon as flaming of the test specimen has ceased.

The test specimen is considered to have passed the test if three criteria apply to all three test specimens. These are:

- a) the test specimen does not *flame* longer than 60 s following any of five 15 s applications of the test *flame*;
- b) flaming material from the test specimen does not ignite the cotton pad; and
- c) the indicator flag is not more than 25 % damaged, during, between, or after the five applications of the test *flame*.

4.3.2.4 Repeatability and reproducibility

No data are given.

4.3.2.5 Relevance of test data

This test method can be used to compare the burning characteristics of tubular polymeric materials. It can be used to compare the relative performance of materials, to aid in material selection, for quality control purposes and for quality assurance.

It is not to be used to compare the burning characteristics of any wire or cable products or any cable management systems.

4.3.3 Flexible insulating sleeving – Part 2: Methods of test, Clause 26: Flame propagation tests – IEC 60684-2:2011 [7], Clause 26

4.3.3.1 Purpose and principle

These are three small-scale laboratory procedures of different severities for determining the burning characteristics of flexible insulating sleeving. Methods A and B are vertical burning tests. Method C tests a sample at 20° from the vertical.

NOTE IEC 60684-3 [8] indicates which tests should be applied to a particular type or grade of sleeving.

4.3.3.2 Method A

4.3.3.2.1 Test specimen

Test specimens are at least 450 mm long. Heat-shrinkable sleeving is recovered before testing. The bore of the sleeving is not more than 10 mm.

NOTE For heat-shrinkable sleeving, this dimension is the specified recovered bore.

4.3.3.2.2 Test method

Tests are carried out in accordance with IEC TS 60695-11-21:2005 except that the source of heat is as defined in 26.3 of IEC 60684:2011.

4.3.3.3 Method B

4.3.3.3.1 Test specimen

Test specimens are approximately 660 mm long (recovered in the case of heat-shrinkable sleeving) and are supported on piano wire 900 mm in length. The sleeving is closed at the top end to prevent a chimney effect.

4.3.3.3.2 Test method

Tests are carried out in accordance with IEC TS 60695-11-21:2005 except that the source of heat is as defined in 26.3 of IEC 60684-2:2011.

4.3.3.4 Method C

4.3.3.4.1 Test specimen

Test specimens are approximately 560 mm long (recovered in the case of heat-shrinkable sleeving) and are supported on piano wire 800 mm in length. The sleeving is closed at the top end to prevent a chimney effect.

4.3.3.4.2 Test method

The source of heat is as defined in 26.3 of IEC 60684-2:2011. An indicator flag is attached to the test specimen with its lower edge (250 ± 2) mm away from the point at which the blue inner cone of the test *flame* touches the test specimen. There is no cotton layer.

The test specimen is supported so as to be 20° from the vertical and the *flame* is applied at 45° to the test specimen. The *flame* is applied for 15 s to the side of the test specimen at a point near its lower edge. After-*flame* time is noted as well as the length of burned specimen.

4.3.3.5 Repeatability and reproducibility

No data are given.

4.3.3.6 Relevance of test data

These test methods are used in order to determine if products meet specifications given in IEC 60684-3. It can also be used for quality control purposes and for quality assurance.

4.3.4 Vertical burning test for cables – IEC 60332-1 [9]

4.3.4.1 Purpose and principle

This test method specifies a method of testing a single vertical wire or cable or optical cable under *fire* conditions. IEC 60332-1-1 defines the apparatus. IEC 60332-1-2 defines the procedure. The *char length* of a vertical test specimen, exposed to a 1 kW pre-mixed *flame* in a suitable chamber, is measured. The standard includes, in an informative annex, recommended requirements for compliance for use where these are not given in the cable product standard. IEC 60332-1-3 is a procedure for determination of flaming droplets/particles.

The method specified is not suitable for the testing of small single insulated conductors or cables of less than $0,5 \text{ mm}^2$ total cross-section, because the conductor melts before the test is completed, or for the testing of small optical fibre cables because the cable is broken before the test is completed – see 4.1.3.

NOTE The corresponding EN standards are EN 60332-1-1, EN 60332-1-2 and EN 60332-1-3.

4.3.4.2 Test specimen

The test specimen consists of a piece of finished wire or cable 600 mm $\pm$ 25 mm long.

4.3.4.3 Test method

The test specimen is held in a vertical position by means of two support arms within a three-sided metallic screen. A calibrated burner is used to ignite the test specimen. Its *flame* is continuously applied for a period of time which is related to the overall diameter of the test specimen. The *damaged length* of the test specimen is then noted.

4.3.4.4 Repeatability and reproducibility

No data are known to be available.

4.3.4.5 Relevance of test data

This method is used to determine the extent of vertical burning of a single finished wire or cable by measuring the *char length*.

The use of insulated wire or cable, which retards *flame* propagation and complies with the requirements of this standard, cannot be assumed by itself to prevent propagation of *fire* under all conditions of installation. Two examples of such conditions are:

- a) vertical runs of bunched or bundled cables
- b) potential *ignition sources* that would impose a more intense thermal environment than that provided by the test method.

It is recommended that wherever the risk of propagation is high, special installation precautions should be taken.

4.3.5 Vertical burning test for cables – IEC 60332-2 [10]

4.3.5.1 Purpose and principle

This test method specifies a method of testing a small insulated wire under *fire* conditions when the method specified in vertical burning test IEC 60332-1 is not suitable – see 4.1.2.1. IEC 60332-2-1 defines the apparatus. IEC 60332-2-2 defines the procedure. The *char length* of a vertical test specimen, exposed to a diffusion *flame* of length 125 mm $\pm$ 25 mm in a draught-free chamber, is measured. The standard includes, in an informative annex, recommended requirements for compliance for use where these are not given in the cable product standard.

NOTE The corresponding EN standards are EN 60332-2-1 and EN 60332-2-2.

4.3.5.2 Test specimen

The test specimen consists of a piece of finished copper wire or cable or optical cable, 600 mm $\pm$ 25 mm long.

4.3.5.3 Test method

The test specimen is held in a vertical position by means of two support arms within a three-sided metallic screen. A load of 5 N for each mm² of conductor area is attached to the lower part of the test specimen. A calibrated burner is used to ignite the test specimen. Its *flame* is continuously applied for a maximum period of 20 s. The *damaged length* of the test specimen is then noted.

4.3.5.4 Repeatability and reproducibility

No data are known to be available.

4.3.5.5 Relevance of test data

This method is used to determine the extent of burning by measuring the *char length*.

Since the use of insulated wire or cable or optical cable, which retards *flame* propagation and complies with the requirements of this document, is not sufficient by itself to prevent propagation of *fire* under all conditions of installation, it is recommended that wherever the risk of propagation is high, for example in long vertical runs of bunched cables, special installation precautions should also be taken. It cannot be assumed that, because the cable test specimen complies with the performance required in this standard, bunched cables will behave in a similar manner.

4.3.6 Flexible cellular polymeric materials – Laboratory assessment of horizontal burning characteristics of small specimens subjected to a small *flame* – ISO 3582 [11]

4.3.6.1 Purpose and principle

This is a small-scale laboratory screening procedure for comparing the relative horizontal burning characteristics of small test specimens of flexible cellular polymeric material exposed to a low energy source of heat.

4.3.6.2 Test specimen

Test specimens are (150 ± 1) mm long by (50 ± 1) mm wide. The thickness is not less than 5 mm and not more than 13 mm. Ten test specimens are evaluated.

4.3.6.3 Test method

A laboratory burner fitted with a wing top is used. Its internal diameter is $(9,5 \pm 0,5)$ mm. A gaseous hydrocarbon fuel is used, e.g. propane. The *flame* is defined by its size and its temperature. The burner and gas pressure are adjusted to give a blue *flame* with a temperature of $(1\,000 \pm 100)$ °C (13 ± 1) mm above the wing top. The visible portion of the *flame* is specified as (38 ± 1) mm high with an inner cone (6 ± 1) mm high.

The test specimen is laid flat on a supporting wire grid and the *flame* is applied to one end for 60 s. A *flame-spread rate* is calculated, if possible, from the time that *flame* reaches a mark 25 mm from the far end of the test specimen. If *flame* does not reach the mark, a burning rate is calculated by dividing the extent of burning by the time taken for the *flame* to go out.

For certain materials that exhibit burning only along the upper surface of the test specimen, the mass loss is measured and reported, if required.

4.3.6.4 Repeatability and reproducibility

No data are provided.

4.3.6.5 Relevance of test data

This method is only intended for the purpose of assessing quickly and simply the horizontal burning characteristics of small test pieces. The burning behaviour is assessed without reference to the environmental conditions under which the material, or products made from it, may be used. As a consequence, it is not possible to establish a correlation between the results of this test and the performance of such materials or products under actual service conditions.

The test is not relevant for test specimens that distort away from and out of reach of the *flame* without *ignition*.

The *ignition source* is not well defined. The burner is not fully specified. Different fuels may be used. Assessment of *flame* size is subjective. No flow rates for fuels are specified.

4.3.7 Horizontal burning rate for road vehicle materials – ISO 3795 [12].

4.3.7.1 Purpose and principle

This test method determines the horizontal burning rate of materials used in the occupant compartment of road vehicles, after exposure to a small *flame*. It is used to determine if the *flame* extinguishes, and the time required for the *flame* to travel a measured distance.

The standard includes the requirement for compliance.

4.3.7.2 Test specimen

The test specimen size is 356 mm × 100 mm × *d* mm. The thickness *d* corresponds to the thickness of the product to be tested but is not more than 13 mm.

4.3.7.3 Test method

During the test, at least five test specimens are tested horizontally in a special combustion chamber, mounted in a defined test specimen holder. The gas burner is a 9,5 mm Bunsen burner. The *flame* height is 38 mm and the burner top is 19 mm below the bottom edge of the test specimen. The burning rate, *B*, in mm/min, is measured.

A test specimen is held in a U-shaped holder and is exposed to the action of a defined low-energy *flame* for 15 s in a combustion chamber, with the *flame* acting on the free end of the test specimen.

4.3.7.4 Repeatability and reproducibility

No data are known to be available.

4.3.7.5 Relevance of test data

Most automotive manufacturers require this test for interior materials.

4.3.8 Cellular plastics – Determination of horizontal burning characteristics of small specimens subjected to a small *flame* – ISO 9772 [13]

4.3.8.1 Purpose and principle

This is a small-scale laboratory screening procedure for comparing the relative burning characteristics of horizontally oriented, small cellular plastic specimens having a density less than 250 kg.m⁻³, when exposed to a small *flame ignition source*.

4.3.8.2 Test specimen

Test specimens are (150 ± 10) mm long by (50 ± 1) mm wide and are cut from a representative sample of the material (sheets or end products). Materials supplied in thicknesses over 13 mm are cut to (13 ± 1) mm thickness with any skin on one side. Materials supplied in thickness of 13 mm or less are tested at the thickness supplied, without removing any skin. If materials with adhesive applied are to be tested, specimens having adhesive on one side only are used.

4.3.8.3 Test method

A P/PF2 laboratory burner, as specified in ISO TR 10093:2018 [14], and fitted with a burner wing top, is used to provide the *ignition source*. Methane or propane can be used, but methane is preferred. The nominal power of the *flame* is 500 W. The test specimen is laid flat on a wire support gauze with a pad of dry cotton below it in order to detect any drips or debris that ignite it.

Two conditioning regimes are specified.

The *flame* is applied to one end of the test specimen for 60 s and timer 1 is started. Timer 2 is started when the test specimen *flame* reaches 25 mm along the test specimen. Timer 1 is stopped when the *flame* or glowing combustion front reaches 60 mm. Timer 2 is stopped when the *flame* or glowing combustion front reaches 125 mm. A variety of burning rate parameters are then noted and calculated. Average values for five specimens for each conditioning treatment are calculated.

A classification system is described in an informative Annex.

4.3.8.4 Repeatability and reproducibility

Data are given in an informative Annex in ISO 9772. The data were determined from an inter-laboratory trial conducted in 1986 involving seven laboratories, five materials and two replicates each using the average of five data points. The variables analysed were “elapsed time” and *flame-spread rate*.

NOTE “Elapsed time” is the sum of afterflame time and afterglow time for cases where the *flame* or glowing combustion did not pass the 60 mm mark.

4.3.8.5 Relevance of test data

The method is intended for quality assurance and the limited product evaluation of cellular plastic materials under controlled laboratory conditions. The optional classification system is intended for the preselection of cellular plastic material for products, including the determination of the ranges of material parameters that give the same classification.

Tests conducted on a material under the conditions specified can be of considerable value when comparing the horizontal burning characteristics of different materials, controlling manufacturing processes or assessing any changes in formulation or treatment prior to use.

Certain materials might shrink from the applied *flame* without igniting. In this event, the test results are not valid and additional test specimens will be required to obtain 10 valid test results. If this proves impossible due to non-*ignition* of all the specimens, then this test is not suitable for these materials.

4.3.9 Plastics – Determination of burning behaviour of thin flexible vertical specimens in contact with a small-*flame ignition source* – ISO 9773 [15]

4.3.9.1 Purpose and principle

This is a small-scale laboratory screening procedure for comparing the relative burning behaviour of vertically oriented thin and relatively flexible plastic specimens exposed to a low energy level *flame ignition source*. A test specimen having a nearly cylindrical form is supported vertically by one end and the free end is exposed to two successive applications of a specified gas *flame*. The burning behaviour of the specimen is assessed by measuring the afterflame and/or afterglow time.

4.3.9.2 Test specimen

Test specimens are (200 ± 5) mm long by (50 ± 2) mm wide and are a maximum of 0.25 mm thick.

The longitudinal axis of the specimen is wrapped tightly around the longitudinal axis of a 13 mm diameter rod to form a lapped cylinder. Overlapping portions of the specimen are secured with pressure-sensitive adhesive tape. The rod is then be removed. For stiff specimens, the pressure-sensitive tape may be reinforced or replaced by nichrome wire wound around the top 75 mm of the specimen.

4.3.9.3 Test method

A P/PF2 laboratory burner, as specified in ISO TR 10093:2018 [14] is used to provide the *ignition source*. Methane or propane can be used, but methane is preferred. The nominal power of the *flame* is 50 W. The test specimen is clamped vertically within its upper 6 mm so that the upper end of the tube is closed to prevent any chimney effects. The lower end is above a layer of cotton in order to detect any drips or debris that could ignite it.

Two conditioning regimes are specified.

The *flame* is applied to the lower end of the test specimen for 3 s and then a timer is started to measure the afterflame time. As soon as afterflaming ceases the *flame* is applied again for 3 s and the timer is started again to measure the afterflame and afterglow times. The two afterflame times are added to give a total afterflame time. A variety of burning rate parameters are then noted and calculated. Average values for five specimens for each conditioning treatment are calculated.

A classification system is described in an informative Annex.

4.3.9.4 Repeatability and reproducibility

Data are given in ISO 9773. The data were determined from an inter-laboratory trial conducted in 1986 involving six laboratories, four materials and two replicates. Each replicate was determined by averaging the values of five measurements. The variables analysed were “afterflame time after the first *flame* application” and “afterflame time plus afterglow time after the second *flame* application”.

4.3.9.5 Relevance of test data

The classification system is intended for quality control and the preselection of component materials for products. Tests made on a material under the conditions specified can be of considerable value when comparing the relative burning behaviour of different materials, controlling manufacturing processes or assessing any change in burning characteristics prior to, or during, use. The effects on the burning behaviour of additives, deterioration, and possible loss of volatile components are measurable using this method.

4.3.10 Fire propagation apparatus – ISO 12136 [16]

4.3.10.1 Purpose and principle

ISO 12136 provides four test methods for determining and quantifying the flammability characteristics of materials, in relation to their propensity to support *fire* propagation, by means of a *fire* propagation apparatus (FPA). Material flammability characteristics that are quantified in this international standard include time to *ignition*, chemical and convective *heat release rates*, mass loss rate, effective heat of combustion, heat of gasification and smoke yield. These properties can be used for *fire* safety engineering and for *fire* modelling.

The *ignition*, combustion and *pyrolysis* test methods involve the use of horizontal specimens subjected to a controlled, external radiant heat flux, which can be set from 0 kW/m² to

65 kW/m². The *fire* propagation test method involves the use of vertical specimens subjected to *ignition* near the base of the specimen from an external radiant heat flux and a pilot *flame*. The combustion, *pyrolysis* and *fire* propagation test methods can be performed using an inlet air supply that is either normal air or other gaseous mixtures, such as air with added nitrogen, 100 % nitrogen or air enriched with up to 40 % oxygen.

4.3.10.2 Test apparatus

See ISO 12136 [16], ASTM E2058 [17] and NFPA 287 [18].

4.3.10.3 Test specimens

Square test specimens are 102 mm x 102 mm and are mounted in a square holder. Circular test specimens are 96,5 mm in diameter and are mounted in a circular holder. The test specimen thickness is not less than 3 mm and not greater than 25,4 mm. For the vertical *fire* propagation test, the test specimen is 102 mm in width and 305 mm in length and is mounted in a vertical test specimen holder.

4.3.10.4 Test methods and results

The four test methods given in this document are based on measurements of time to observed *ignition*, mass loss rate, *heat release rate* and smoke generation rate. The tests are performed using a laboratory calorimeter known as *fire* propagation apparatus whereby the heat source is isolated from the test specimen. The test methods are intended to produce flammability property measurements that will characterize *fire* behaviour during reference-scale *fire* tests.

4.3.10.5 Repeatability and reproducibility

Some reproducibility data are given in an informative Annex in ISO 12136. Data on *ignition* time and *heat release rate* from two laboratories are reported. No data on *flame spread* are reported.

4.3.10.6 Relevance of test data

The *ignition*, combustion or *fire* propagation test methods, or a combination thereof, have been performed with materials and products containing a wide range of polymer compositions and structures, including electrotechnical products, materials for electrotechnical products and electric cables [19] to [26].

The unique feature of the *fire* propagation test method is that it produces laboratory measurements of the chemical *heat release rate* during upward *fire* propagation and burning (from a material's own *flame* after initiation by an external radiant flux) on a vertical test specimen in normal air, oxygen enriched air, or in oxygen-vitiated air.

These test methods are intended for evaluation of specific flammability characteristics of materials. Materials to be analysed consist of specimens from an end-use product or the various components used in the end-use product. Results from the test methods provide input to *flame spread* and *fire* growth models, risk analysis studies, building and product designs and materials research and development. The test methods are used extensively by FM Global for a variety of insurance industry norms including for clean room and cable applications.

This international standard can be used to measure and describe the response of materials, products, or assemblies to heat and *flame* under controlled conditions, but does not by itself incorporate all factors required for *fire hazard* or *fire* risk assessment of the materials, products or assemblies under actual *fire* conditions.

4.3.11 Plastics – Vertical *flame spread* determination for film and sheet – ISO 12992 [27]

4.3.11.1 Purpose and principle

This is a *small-scale fire test* for the measurement of *flame spread* properties of vertically oriented test specimens of plastics in the form of film or sheet, 3 mm or less in thickness, subject to a small *flame ignition source*.

4.3.11.2 Test specimen

Test specimens are (325 ± 5) mm long by (300 ± 5) mm wide. The thickness is not more than 3 mm. Three test specimens are evaluated unless the material is anisotropic, in which case three test specimens are tested in both directions.

4.3.11.3 Test method

A laboratory burner, as specified in ISO 11925-2 [28], is used with commercial-grade propane. The gas flow is adjusted so that the *flame* is (40 ± 4) mm high when the burner is vertical. The power of the *flame* is approximately 32 W.

The *flame* is applied to the bottom edge of the test specimen for 60 s and a *flame-spread rate* is calculated from the times that *flame* reaches markings 100 mm and 300 mm vertically above the bottom of the test specimen.

4.3.11.4 Repeatability and reproducibility

Data are given in ISO 12992. The data were obtained in an interlaboratory trial conducted in 1993 involving seven laboratories testing eight materials. The variable analysed was *flame-spread rate*.

4.3.11.5 Relevance of test data

The method may be useful for preselection or for quality control purposes. The test is not relevant for test specimens that distort away from and out of reach of the *flame* without *ignition*. Other test methods should be explored for such test specimens.

4.3.12 Vertical burning test for aircraft materials – FAR 25 [29]

4.3.12.1 Purpose and principle

The requirements for electrical system components are given in FAR 25.869 (a). Insulation on electrical wires and electric cable installed in any area of an airplane fuselage shall be self-extinguishing when tested in accordance with a 60° Bunsen burner test described in Part I, (b), (7) in Appendix F of FAR 25 (1965).

The requirements for materials and parts used in the crew and passenger compartments are given in FAR 25.853. Electrical conduit shall be self-extinguishing when tested in accordance with a vertical Bunsen burner test described in Part I, (b), (4) in Appendix F of FAR 25 (1965).

4.3.12.2 Test specimen

The test specimen for the vertical Bunsen burner test is at least 50 mm wide and 30,5 mm long, unless the actual size used in the airplane is smaller. The test specimen thickness is no thicker than the minimum thickness qualified for use in an airplane.

The test specimen for the 60° Bunsen burner test is a length of wire or cable. The gauge is the same as that used in the airplane. The test specimen span between a lower clamp and an upper pulley or rod is 24 inches.

4.3.12.3 Test method

These tests involve applying an *ignition source* to a 60 ° or vertical test specimen. The *flame* time, *burned length*, and flaming time of drippings, if any, are then measured or noted.

Electrical conduits are submitted to a 12 s application of *flame*. Wire and cable are submitted to a 30 s application of *flame*.

4.3.12.4 Repeatability and reproducibility

No data are known to be available.

4.3.12.5 Relevance of test data

These test methods are used for the preselection of materials, quality control and product evaluation in the aviation industry in the USA.

4.4 Medium and *intermediate-scale* fire tests

4.4.1 Lateral *flame spread* on building and transport products – ISO 5658-2 [30]

4.4.1.1 Purpose and principle

This test provides a simple method by which lateral spread of *flame* on a vertical test specimen can be determined for comparative purposes. The test provides data suitable for comparing the performance of essentially flat materials, composites or assemblies, which are used primarily as the exposed surfaces of walls in buildings and transport vehicles, such as ships and trains. Some profiled products (such as pipes) can also be tested under specified mounting and fixing conditions.

NOTE The test was developed from the method of the International Maritime Organization (IMO) published as IMO Resolution A.653 [31].

4.4.1.2 Test specimen

Test specimens are 800 mm long by 155 mm wide. Products of thickness 70 mm or less are tested using their full thickness. For products of thickness greater than 70 mm the unexposed face is cut away to reduce the thickness to 70 mm.

4.4.1.3 Test method

The test method consists of exposing conditioned test specimens to a well-defined field of radiant heat flux and measuring the time to *ignition*, the lateral spread of *flame*, and its final extinguishment. A test specimen is placed in a vertical position adjacent to a gas-fired radiant panel. A pilot *flame* is sited close to the hot end of the test specimen to ignite volatile gases. Following *ignition*, any *flame* front which develops is noted, and a record is made of the progression of the *flame* front horizontally along the length of the test specimen. The results are expressed as the critical heat flux at extinguishment and the average heat for sustained burning.

4.4.1.4 Repeatability and reproducibility

Data obtained in an interlaboratory trial are given in the standard for “heat for sustained burning” (HSB) and for “critical heat flux at extinguishment” (CIE). Between five and eight laboratories reported data.

4.4.1.5 Relevance of test data

The test is applicable to the measurement and description of the properties of materials, products or assemblies in response to radiative heat in the presence of a pilot *flame* under controlled laboratory conditions. The test deals only with a simple representation of a

particular aspect of the potential *fire* situation typified by a radiant heat source and *flame*; it cannot alone provide any direct guidance on behaviour or safety in *fire*. The test is particularly useful for research, development and quality control purposes. Profiled test specimens such as cables and pipes can be tested using this test method.

Note The same test apparatus is used for the procedures described in ASTM E1321 [32] which provides a more scientifically detailed method by which the ignitability and spread of *flame* parameters of materials can be determined. Data derived from this test are suitable for use as input in *fire* safety engineering calculations.

4.4.2 Intermediate-scale fire test of vertical flame spread – ISO 5658-4 [33]

4.4.2.1 Purpose and principle

This part of ISO 5658 specifies an *intermediate-scale fire test* for measuring the vertical spread (upward and downward) of *flame* over a specimen of a product orientated in the vertical position. A measure of lateral spread can also be obtained. It provides data suitable for comparing the performance of materials, composites or assemblies, which are used as the exposed surfaces of walls or other vertically orientated products in construction applications. Some products with profiled surfaces can also be tested with a modified procedure representative of the end-use conditions of the product.

This test method consists of exposing the lower part of a conditioned vertically-oriented test specimen to a single well-defined field of radiant heat flux (maximum 40 kW·m⁻²) and measuring the time to *ignition*, vertical and horizontal spread of *flame* and, where appropriate, observing other *fire* spread effects such as flaming drips or debris and lateral spread. A non-impinging line pilot burner is positioned above the radiated area of the test specimen to ignite volatile gases.

4.4.2.2 Test specimen

Test specimens are representative of the product and are 1 525 mm long by 1 025 mm wide. The specimen is mounted in a holder on a support trolley with the long edge vertical and the short edge horizontal.

4.4.2.3 Test method

The test specimen is marked with reference lines (vertical and horizontal). When the radiant panel has attained thermal equilibrium, the pilot burner is lit and the trolley is moved into the test position. The *ignition* time is recorded together with any other flaming effects. Times of arrival of any sustained *flame* at the reference lines on the test specimen and at the edges of the test specimen are recorded. The test time is a maximum of 30 min. The burned area and the type of damage are recorded.

4.4.2.4 Repeatability and reproducibility

The precision of the method was examined in an interlaboratory trial in 1997. Eleven laboratories from eight countries participated. Sixteen products were tested. Each product was tested with six replicates. The test results were analysed according to ISO 5725 [34]. Data for the time to *ignition* and the area of *flame spread* are given in ISO 5658-4.

4.4.2.5 Relevance of test data

The test 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 developing stage of a *fire*. The test should not be used alone to describe or appraise the *fire hazard* or *fire risk* of materials, products, composites or assemblies under actual *fire* conditions.