BS EN 60695-9-1:2013

BSI Standards Publication

Fire hazard testing

Part 9–1: Surface spread of flame — General guidance

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National foreword

This British Standard is the UK implementation of EN 60695-9-1:2013. It is identical to IEC 60695-9-1:2013. It supersedes BS EN 60695-9-1:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/89, Fire hazard testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Essais relatifs aux risques du feu -
Partie 9-1: Propagation des flammes en surface -
Lignes directrices générales
(CEI 60695-9-1:2013)

Prüfungen zur Beurteilung der Brandgefahr -
Teil 9-1: Flammenausbreitung auf Oberflächen -
Allgemeiner Leitfaden
(IEC 60695-9-1:2013)

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Foreword

The text of document 89/1159/FDIS, future edition 3 of IEC 60695-9-1, prepared by IEC/TC 89 "Fire hazard testing" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60695-9-1:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-03-03
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-06-03

This document supersedes EN 60695-9-1:2005.

EN 60695-9-1:2013 includes the following significant technical changes with respect to EN 60695-9-1:2005:

a) an expanded scope;

b) updated references;

c) updated terms and definitions.

This European Standard is to be used in conjunction with EN 60695-9-2.

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Endorsement notice

The text of the International Standard IEC 60695-9-1:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60332 series	NOTE	Harmonised in EN 60332 series.
IEC 61197	NOTE	Harmonised as EN 61197.
ISO 2719	NOTE	Harmonised as EN ISO 2719.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60695-4	-	Fire hazard testing - Part 4: Terminology concerning fire tests for electrotechnical products	EN 60695-4	-
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 2592	-	Determination of flash and fire points - Cleveland open cup method	EN ISO 2592	-
ISO 13943	2008	Fire safety - Vocabulary	EN ISO 13943	2010

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INTRODUCTION

Fires are responsible for creating hazards to life and property as a result of the generation of heat (thermal hazard), and also toxic effluent, corrosive effluent and smoke (non-thermal hazard). Fire hazard increases with the burning area leading in some cases to flashover and a fully developed fire. This is a typical fire scenario in buildings.

The surface spread of flame beyond the area of ignition occurs as a result of the creation of a pyrolysis front on the surface of the material, ahead of the flame front, arising from the heating by the flame and external heat sources. The pyrolysis front is the boundary between pyrolysed material and unpyrolysed material on the surface of the material. Combustible vapours are generated within the region of pyrolysed material, which mix with air and ignite, creating the flame front.

The surface spread of flame rate is the distance travelled by the flame front divided by the time required to travel that distance. The surface spread of flame rate depends on the heat supplied externally and/or by the flame of the burning material ahead of the burning zone and on the ease of ignition. The ease of ignition is a function of the minimum ignition temperature, thickness, density, specific heat, and thermal conductivity of the material. The heat supplied by the flame depends on the heat release rate, specimen orientation, air flow rate and air flow direction relative to the surface spread of flame direction. In general, materials show one of the following types of surface spread of flame behaviour:

a) non-propagation: there is no flame propagation beyond the area of ignition;
b) decelerating propagation: flame propagation stops before reaching the end of the surface of the material; and
c) propagation: flame propagates beyond the area of ignition and eventually affects the entire surface of the material.

Properties of the materials that are used to describe the surface spread of flame behaviour are associated with surface preheating and pyrolysis, generation of vapours, mixing of the vapours with air, ignition, combustion of the mixture and generation of heat and combustion products. Flame retardants and surface treatments are used to modify the surface spread of flame behaviour. Factors that need to be considered for the assessment of the surface spread of flame behaviour of materials are:

1) the fire scenario (including such parameters as surface orientation, ventilation and the nature of the ignition source);
2) measurement techniques (see 5.5); and
3) the use and interpretation of results obtained (see 6).

FIRE HAZARD TESTING –

Part 9-1: Surface spread of flame –
General guidance

1 Scope

This part of IEC 60695provides guidance for the assessment of surface spread of flame for electrotechnical products and the materials from which they are formed. It provides:

- an explanation of the principles of flame spread for both liquids and solids,
- guidance for the selection of test methods,
- guidance on the use and interpretation of test results, and
- informative references

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, 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.

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

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 13943:2008, *Fire safety – Vocabulary*

ISO 2592, *Determination of flash and fire points – Cleveland open cup method*

3 Terms and definitions

For the purposes of this document, terms and definitions given in IEC 60695-4 and in ISO 13943:2008, some of which are reproduced below for the user’s convenience, apply.

3.1
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 13943:2008, 4.46]

3.2
damaged area
total of those surface areas that have been affected permanently by **fire** (3.6) under specified conditions

Note 1 to entry: Users of this term should specify the types of damage to be considered. This can include, for example, loss of material, deformation, softening, melting behaviour, char formation, **combustion** (3.1), **pyrolysis** (3.25) or chemical attack.

Note 2 to entry: The typical units are square metres (m^2).

[SOURCE: ISO 13943:2008, 4.59]

3.3
damaged length
maximum extent in a specified direction of the **damaged area** (3.2)

[SOURCE: ISO 13943:2008, 4.60]

3.4
extent of combustion
⟨electrotechnical⟩ maximum length of a test specimen that has been destroyed by **combustion** (3.1) or **pyrolysis** (3.25), under specified test conditions, excluding any region damaged only by deformation

[SOURCE: ISO 13943:2008, 4.91]

3.5
fire
⟨general⟩ process of **combustion** (3.1) 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, **fire** (3.6) and **fire** (3.7), relate to specific types of self-supporting combustion with different meanings and two of them are designated using two different terms in both French and German.

[SOURCE: ISO 13943:2008, 4.96]

3.6
fire
⟨controlled⟩ self-supporting **combustion** (3.1) that has been deliberately arranged to provide useful effects and is limited in its extent in time and space

[SOURCE: ISO 13943:2008, 4.97]

3.7
fire
⟨uncontrolled⟩ self-supporting **combustion** (3.1) that has not been deliberately arranged to provide useful effects and is not limited in its extent in time and space

[SOURCE: ISO 13943:2008, 4.98]

3.8
fire hazard
physical object or condition with a potential for an undesirable consequence from **fire** (3.7)

[SOURCE: ISO 13943:2008, 4.112]

3.9
fire point
minimum temperature at which a material ignites and continues to burn for a specified time after a standardized small **flame** (3.11) has been applied to its surface under specified conditions

Note 1 to entry: In some countries, the term “fire point” has an additional meaning: a location where fire-fighting equipment is sited, which may also comprise a fire-alarm call point and fire instruction notices.

Note 2 to entry: The typical units are degrees Celsius (°C).

[SOURCE: ISO 13943:2008, 4.119]

3.10
fire scenario
qualitative description of the course of a **fire** (3.7) with respect to time, identifying key events that characterise the studied fire and differentiate it from other possible fires

Note 1 to entry: It typically defines the **ignition** (3.21) and fire growth processes, the **fully developed fire** (3.18) stage, the fire decay stage, and the environment and systems that impact on the course of the fire.

[SOURCE: ISO 13943:2008, 4.129]

3.11
flame, noun
zone in which there is rapid, self-sustaining, sub-sonic propagation of **combustion** (3.1) in a gaseous medium, usually with emission of light

[SOURCE: ISO 13943:2008, 4.133, modified – added "zone in which there is".]

3.12
flame front
boundary of flaming **combustion** (3.1) at the surface of a material or propagating through a gaseous mixture

[SOURCE: ISO 13943:2008, 4.136]

3.13
flame retardant, noun
substance added, or a treatment applied, to a material in order to suppress or delay the appearance of a **flame** (3.11) and/or reduce the **flame-spread rate** (3.15)

Note 1 to entry: The use of (a) flame retardant(s) does not necessarily suppress **fire** (3.5) or terminate **combustion** (3.1).

[SOURCE: ISO 13943:2008, 4.139]

3.14
flame spread
propagation of a **flame front** (3.12)

[SOURCE: ISO 13943:2008, 4.142]

3.15
flame-spread rate
surface spread of flame 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

[SOURCE: ISO 13943:2008, 4.143]

3.16
flashover
⟨stage of fire⟩ transition to a state of total surface involvement in a **fire** (3.7) of combustible materials within an enclosure

[SOURCE: ISO 13943:2008, 4.156]

3.17
flash point
minimum temperature to which it is necessary to heat a material or a product for the vapours emitted to ignite momentarily in the presence of **flame** (3.11) under specified conditions

[SOURCE: ISO 13943:2008, 4.154]

3.18
fully developed fire
state of total involvement of combustible materials in a **fire** (3.5)

[SOURCE: ISO 13943:2008, 4.164]

3.19
heat flux
amount of thermal energy emitted, transmitted or received per unit area and per unit time

Note 1 to entry: The typical units are watts per square metre ($W \cdot m^{-2}$)..

[SOURCE: ISO 13943:2008, 4.173]

3.20
heat release rate
DEPRECATED: burning rate
DEPRECATED: rate of burning
rate of thermal energy production generated by **combustion** (3.1)

Note 1 to entry: The typical units are watts (W).

[SOURCE: ISO 13943:2008, 4.177]

3.21
ignition
DEPRECATED: sustained ignition
⟨general⟩ initiation of **combustion** (3.1)

[SOURCE: ISO 13943:2008, 4.187]

3.22
ignition
DEPRECATED: sustained ignition
⟨flaming combustion⟩ initiation of sustained **flame** (3.11)

[SOURCE: ISO 13943:2008, 4.188]

3.23
ignition source
source of energy that initiates **combustion** (3.1)

[SOURCE: ISO 13943:2008, 4.189]

3.24
minimum ignition temperature
ignition point
minimum temperature at which sustained **combustion** (3.1) can be initiated under specified test conditions

Note 1 to entry: The minimum ignition temperature implies the application of a thermal stress for an infinite length of time.

Note 2 to entry: The typical units are degrees Celsius (°C).

[SOURCE: ISO 13943:2008, 4.231]

3.25
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** (3.5) before flaming **combustion** (3.1) has begun.

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

[SOURCE: ISO 13943:2008, 4.266]

3.26
pyrolysis front
boundary between the region of **pyrolysis** (3.25) and the region of unaffected material at the surface of the material

[SOURCE: ISO 13943:2008, 4.267]

3.27
surface spread of flame
flame spread (3.14) away from the source of **ignition** (3.22) across the surface of a liquid or a solid

[SOURCE: ISO 13943:2008, 4.317]

3.28
thermal inertia
product of thermal conductivity, density and specific heat capacity

EXAMPLES The thermal inertia of steel is $2{,}3 \times 10^8$ $J^2 \cdot s^{-1} \cdot m^{-4} \cdot K^{-2}$. The thermal inertia of polystyrene foam is $1{,}4 \times 10^3$ $J^2 \cdot s^{-1} \cdot m^{-4} \cdot K^{-2}$.

Note 1 to entry: When a material is exposed to a **heat flux** (3.19), the rate of increase of surface temperature depends strongly on the value of the thermal inertia of the material. The surface temperature of a material with a low thermal inertia rises relatively quickly when it is heated, and vice versa.

Note 2 to entry: The typical units are joules squared per second per metre to the fourth power per kelvin squared ($J^2 \cdot s^{-1} \cdot m^{-4} \cdot K^{-2}$).

[SOURCE: ISO 13943:2008, 4.326]

4 Principles of flame spread

4.1 Liquids

The surface spread of flame over a liquid surface is governed by the flash and fire points of the liquid. The flash point is the minimum temperature to which the liquid must be heated for the vapours emitted to ignite momentarily in the presence of a flame under specified test conditions. In this case, the flash point is measured according to ISO 2592 (Cleveland open cup).

NOTE Defining the test method is important because the flame spread is described over an open liquid surface, for which ISO 2592 is applicable. The alternative method of measuring the flash point, described in ISO 2719 (Pensky – Martens closed cup) which is cited in IEC standards for insulating liquids, measures the flash point in a confined space and is intended to detect minor amounts of volatile material. The flash point measured in this way is significantly lower than that measured by ISO 2592.

The fire point is the temperature at which the liquid will not only ignite but will continue to burn.

The surface spread of flame rate is determined by gas phase parameters, when the temperature of the liquid is greater than that of its flash point, and by liquid phase parameters, when the liquid is at a temperature lower than that of its flash point. Gas phase parameters include air flow, flame and thermal radiation effects. Liquid phase parameters include convective fluid motion, surface tension, and liquid viscosity.

4.2 Solids

The surface spread of flame over a solid surface is always associated with air flow, caused by external factors (wind and ventilation) and by air flows induced by the flame itself. Air flowing in the opposite direction to that of the surface spread of flame (opposed flow) reduces the surface spread of flame rate and air flow in the same direction as the surface spread of flame (wind-aided) enhances the surface spread of flame rate.

For vertical test specimens with ignition at the bottom, the flame moves towards the top and is defined as the upward surface spread of flame. For vertical test specimens with ignition at the top, the flame moves towards the bottom, and this behaviour is defined as the downward surface spread of flame. For horizontal test specimens, the flame moves sideways away from the area of ignition, and this behaviour is defined as the lateral surface spread of flame.

After ignition of the test specimen, flame propagation will occur if the flame transfers sufficient heat flux, mostly as thermal radiation, ahead of the pyrolysis front so as to continue pyrolysis and ignition at a sufficient rate.

The magnitude of the heat flux transferred ahead of the pyrolysis front depends on the heat release rate of the test specimen, whereas the resistance to ignition is a function of the minimum ignition temperature of the test specimen and the rate of heating of the surface.

The rate of heating of the surface is, in turn, a function of a number of properties of the test specimen:

a) thickness;
b) thermal conductivity, (k);

c) density, (ρ);

d) specific heat capacity, (c).

In a thick test specimen, material below the surface is able to conduct heat away thus reducing the rate of surface heating and increasing the resistance to ignition. In a thin test specimen this effect is much reduced and so ignition resistance is lower.

The product, $k\rho c$, is known as 'thermal inertia'. If the thermal inertia is high, for example as in the case of a solid metal, the rate of surface heating will be relatively low and it will therefore take a relatively long time for the ignition temperature to be reached. If the thermal inertia is low, for example as in the case of some foamed plastics or low density combustible materials, the rate of surface heating will be relatively high and it will therefore take a relatively short time for the ignition temperature to be reached.

Further detailed guidance concerning flame spread on solids is given in ISO/TS 5658-1.

5 Consideration for the selection of test methods

5.1 Fire scenario

The test method(s) selected should be relevant to the fire scenario of concern. Important parameters to be considered include:

a) the geometry of the test specimen, including the presence of edges, corners or joints;

b) the surface orientation;

c) the direction of flame propagation;

d) the rate and direction of air flow;

e) the nature and position of the ignition source;

f) the magnitude and position of any external heat flux;

g) whether the flammable material is a solid or a liquid.

5.2 Ignition sources

The ignition source used in a laboratory test should be relevant to the fire scenario of concern. In the case of the fire hazard of electrotechnical equipment, two types of ignition source are of concern:

a) from unusual localized, internal sources of excessive heat within electrotechnical equipment and systems;

b) from sources of flame or excessive heat which are external to electrotechnical equipment and systems.

5.3 Types of test specimen

The test specimen may be a manufactured product, a component of a product, a simulated product (representative of a portion of a manufactured product), a basic material (solid or liquid), or a composite of materials.

Variations in the shape, size and arrangement of the test specimen should be limited.

Some test specimens may exhibit anisotropy, for example extruded or moulded thermoplastic materials. Where the intended usage and installation practice is such that bi-directional spread of fire presents a fire safety hazard, for instance computer housings, such test specimens should be tested in both 'x' and 'y' directions.

NOTE This recommendation does not apply to products typically installed in long, thin configurations, e.g. cables and conduits.

5.4 Test procedure and apparatus

The test procedure should preferably be designed so that the results can be used for hazard analysis. However, this may not be necessary in the case of simple tests intended only for quality control or regulatory purposes.

The test apparatus should be able to test the actual electrotechnical product, a simulated product, a material or a composite, as described in 5.3.

The test apparatus should be able to impose a heat flux from an external heat source or from a flame, in an approximately uniform fashion to the test specimen in the region where ignition is intended to occur.

The test apparatus with imposed heat flux should be able to ignite the vapour-air mixture emanating from the test specimen. An electrical spark ignitor or a premixed gas-air flame has been found to be suitable.

Tests for surface spread of flame under well-ventilated conditions should be performed using an air flow rate which is relevant to the fire scenario of concern.

5.5 Measurement techniques

5.5.1 Direct measurement

The position of the flame front is observed visually. It may be recorded as a function of time or simply to check some pass/fail distance criterion.

5.5.2 Indirect measurement

Two methods are employed to indirectly assess the rate or amount of flame spread.

One method is to note whether an indicator material has been burned or damaged. Examples are a paper flag, cotton waste or cotton thread. These indicator materials are positioned at defined points on or near the test specimen.

The other method is to note the position and/or amount of charred or damaged surface. Measurements may be made as a function of time or simply to record some pass/fail distance or area criterion.

It should be noted that direct and indirect methods will not normally give equivalent results.

Limited correlations have been established between results for the rate and extent of surface spread of flame using these two techniques.

6 Use and interpretation of results

Surface spread of flame depends on the pyrolysis, ignition, and combustion behaviour of a material. As the heat release rate from a material increases, the surface flame spread over the surface of a material increases and so does the generation of combustion products. Thus, for a specific fire, the following all increase together: the surface spread of flame, the heat release rate, the evolution of combustion products, the fire hazard, and the difficulty in fighting the fire.

By determining the surface spread of flame rate (and associated heat release rate and generation rates of combustion products), the relative hazard expected in fires of electrotechnical products is assessed. The assessment is based on the principle that the slower the surface spread of flame, the lower the expected hazard. It is always desirable that the surface spread of flame be non-propagating or decelerating.

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