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Fire hazard testing –
Part 6-1: Smoke obscuration – General guidance

Essais relatifs aux risques du feu –
Partie 6-1: Obscurcissement dû à la fumée – Recommandations générales

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INTERNATIONAL
ELECTROTECHNICAL
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FIRE HAZARD TESTING –

Part 6-1: Smoke obscuration –
General guidance

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60695-6-1 has been prepared by IEC technical committee 89: Fire hazard testing.

This third edition cancels and replaces the second edition of IEC 60695-6-1 published in 2005 and Amendment 1:2010. It constitutes a technical revision.

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

– References to IEC TS 60695-6-30 (withdrawn in 2016) have been removed.
– References to IEC TS 60695-6-31 (withdrawn in 2016) have been removed.
– References to ISO 5659-2 have been inserted.
– The scope contains some additional text.
– Terms and definitions have been updated.

– Subclause 3.2 has been updated.
– Subclause 7.1 has been updated.

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

Draft	Report on voting
89/1472/CDV	89/1504/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.

It has the status of a basic safety publication in accordance with IEC Guide 104 and ISO/IEC Guide 51.

This International Standard is to be used in conjunction with IEC 60695-6-2.

In this standard, the following print types are used:

- *italic font: terms defined in Clause 3.*

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.

IEC 60695-6 consists of the following parts:

Part 6-1: Smoke obscuration – General guidance

Part 6-2: Smoke obscuration – Summary and relevance of test methods

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.

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, and IEC 60695-1-12 [1][1] 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 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.

One of the contributing hazards is the release of *smoke*, which may cause loss of vision and/or disorientation which could impede escape from the building or fire fighting.

Smoke particles reduce the *visibility* due to light absorption and scattering. Consequently, people may experience difficulties in finding exit signs, doors and windows. *Visibility* is often determined as the distance at which an object is no longer visible. It depends on many factors, but close relationships have been established between *visibility* and the measurements of the *extinction coefficient of smoke* – see Annex A.

The production of *smoke* and its optical properties can be measured as well as other fire properties, such as heat release, flame spread, and the production of toxic gas and corrosive effluent. This document serves as a guidance document and focuses on obscuration of light by *smoke*.

1 Numbers in square brackets refer to the bibliography.

FIRE HAZARD TESTING –

Part 6-1: Smoke obscuration – General guidance

1 Scope

This part of IEC 60695 gives guidance on:

a) the optical measurement of *obscuration of smoke*;
b) general aspects of optical *smoke* test methods;
c) consideration of test methods;
d) expression of *smoke* test data;
e) the relevance of optical *smoke* data to hazard assessment.

This basic safety publication focusing on safety guidance is primarily intended for use by technical committees in the preparation of safety publications 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.

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 60695-1-11, *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*

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

IEC 60695-6-2, *Fire hazard testing – Part 6-2: Smoke obscuration – Summary and relevance of test methods*

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*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
extinction area of smoke
product of the volume occupied by *smoke* (3.1.10) and the *extinction coefficient* (3.1.2) of the smoke

Note 1 to entry: The extinction area of smoke is a measure of the amount of smoke. The typical unit is m^2.

[SOURCE: ISO 13943:2017, 3.110]

3.1.2
extinction coefficient
natural logarithm of the ratio of incident light intensity to transmitted light intensity, per unit light path length

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

[SOURCE: ISO 13943:2017, 3.111]

3.1.3
mass optical density of smoke
optical density of smoke (3.1.6) multiplied by a factor which is the volume of the test chamber divided by the product of the mass lost from the test specimen and the light path length

Note 1 to entry: The typical unit is $m^2 \cdot g^{-1}$.

Note 2 to entry: Optical density of smoke = $V/(\Delta m\ L)$, where V is test chamber volume, Δm is test specimen mass loss and L is light path length.

[SOURCE: ISO 13943:2017, 3.265]

3.1.4
obscuration of smoke
reduction in the intensity of light due to its passage through *smoke* (3.1.10)

Note 1 to entry: Compare with the terms *extinction area of smoke* (3.1.1), *extinction coefficient* (3.1.2), *opacity of smoke* (3.1.5), *optical density of smoke* (3.1.6), *smoke obscuration* (3.1.11), *specific extinction area of smoke* (3.1.13) and *specific optical density of smoke* (3.1.14).

Note 2 to entry: In practice, obscuration of smoke is usually measured as the transmittance which is normally expressed as a percentage.

Note 3 to entry: The obscuration of smoke causes a reduction in *visibility* (3.1.6).

[SOURCE: ISO 13943:2017, 3.286]

3.1.5
opacity of smoke
ratio of incident light intensity to transmitted light intensity through *smoke* (3.1.10), under specified conditions

Note 1 to entry: Also, *obscuration of smoke* (3.1.4), *smoke obscuration* (3.1.11).

Note 2 to entry: The opacity of smoke is the reciprocal of transmittance.

Note 3 to entry: The opacity of smoke is dimensionless.

[SOURCE: ISO 13943:2017, 3.287]

3.1.6
optical density of smoke
measure of the attenuation of a light beam passing through *smoke* (3.1.10) expressed as the logarithm to the base 10 of the *opacity of smoke* (3.1.5)

Note 1 to entry: Compare with the term *specific optical density of smoke* (3.1.14).

Note 2 to entry: The optical density of smoke is dimensionless.

[SOURCE: ISO 13943:2017, 3.288]

3.1.7
physical fire model
laboratory process, including the apparatus, the environment and the fire test procedure intended to represent a certain phase of a fire

[SOURCE: ISO 13943:2017, 3.298]

3.1.8
SMOGRA
smoke growth rate parameter that is a function of the rate of smoke production and the time of smoke production

Note 1 to entry: Further details are given in 6.2.4.

3.1.9
SMOGRA index
maximum value of *SMOGRA* (3.1.8) during a defined test period

Note 1 to entry: Further details are given in 6.2.4.

3.1.10
smoke
visible part of a fire effluent

[SOURCE: ISO 13943:2017, 3.347]

3.1.11
smoke obscuration
reduction of light transmission by *smoke* (3.1.10), as measured by light attenuation

Note 1 to entry: Compare with the terms *extinction area of smoke* (3.1.1), *extinction coefficient* (3.1.2), *obscuration of smoke* (3.1.4), *opacity of smoke* (3.1.5), *optical density of smoke* (3.1.6), *specific extinction area of smoke* (3.1.13) and *specific optical density of smoke* (3.1.14).

[SOURCE: ISO 13943:2017, 3.349]

3.1.12
smoke production rate
amount of *smoke* (3.1.10) produced per unit time in a fire or fire test

Note 1 to entry: The smoke production rate is calculated as the product of the volumetric flow rate of *smoke* (3.1.10) and the *extinction coefficient* (3.1.2) of the smoke at the point of measurement.

Note 2 to entry: The typical unit is $m^2 \cdot s^{-1}$.

[SOURCE: ISO 13943:2017, 3.351]

3.1.13
specific extinction area of smoke
extinction area of smoke (3.1.1) produced by a test specimen in a given time period divided by the mass lost from the test specimen in the same time period

Note 1 to entry: The typical unit is $m^2 \cdot g^{-1}$.

[SOURCE: ISO 13943:2017, 3.358]

3.1.14
specific optical density of smoke
optical density of smoke (3.1.6) multiplied by a geometric factor

Note 1 to entry: The geometric factor is $V/(A \cdot L)$, where V is the volume of the test chamber, A is the area of the exposed surface of the test specimen, and L is the light path length.

Note 2 to entry: The use of the term "specific" does not denote "per unit mass" but rather denotes a quantity associated with a particular test apparatus and area of the exposed surface of the test specimen.

Note 3 to entry: The specific optical density of smoke is dimensionless.

[SOURCE: ISO 13943:2017, 3.360]

3.1.15
visibility
maximum distance at which an object of defined size, brightness and contrast can be seen and recognized

[SOURCE: ISO 13943:2017, 3.420]

3.2 Symbols

Symbol	Quantity	Typical units
A	exposed area of test specimen	m^2
D	linear decadic absorption coefficient (commonly called optical density per metre)	m^{-1}
D'	*optical density of smoke*	dimensionless
D_{mass}	*mass optical density of smoke*	$m^2\ kg^{-1}$
D_s	*specific optical density of smoke*	dimensionless
D_{max} (also D_m)	maximum *specific optical density of smoke*	dimensionless
I	intensity of incident light	cd
I/T	*opacity of smoke* (ratio of incident light to transmitted light)	dimensionless
k	linear Napierian absorption coefficient (commonly called *extinction coefficient*)	m^{-1}
L	light path length through *smoke*	m
Δm	mass loss of test specimen	kg
$\dot{m}$	mass loss rate	$kg\ s^{-1}$

Symbol	Quantity	Typical units
S	*extinction area of smoke (also total smoke)*	m^2
$\dot{S}$	*smoke production rate* (rate of change of extinction area)	$m^2\ s^{-1}$
t	time	s
Δt	sampling time interval	s
T	intensity of transmitted light	cd
V	volume of chamber	m^3
$\dot{V}$	volume flow rate of *smoke*	$m^3\ s^{-1}$
σ_f	*specific extinction area of smoke*	$m^2\ kg^{-1}$
γ	a constant of proportionality between *visibility* and *extinction coefficient*	dimensionless
ω	*visibility*	m

NOTE 1 The quantities based on $\log_{10}$, i.e. D, D', D_{max}, D_{mass} and D_s, have similar symbols but they are different quantities and have different units.

NOTE 2 The use of the term "specific" in the case of *specific optical density of smoke*, D_s, does not denote "per unit mass".

4 General aspects of smoke test methods

4.1 Fire scenarios and physical fire models

During recent years, major advances have been made in the analysis of fire effluents. It is recognized that the composition of the mixture of combustion products is particularly dependent upon the nature of the combusting materials, the prevailing temperatures and ventilation conditions, especially access of oxygen to the seat of the fire. Table 1 shows how the different types of fire relate to the changing atmosphere. Conditions for use in laboratory tests (small or large-scale) can be derived from the table in order to correspond, as far as possible, to real-scale fires.

Fire involves a complex and interrelated array of physical and chemical phenomena. As a result, it is difficult to simulate all aspects of a real-scale fire in a smaller scale apparatus. This problem of *physical fire model* validity is perhaps the single most perplexing technical problem associated with all fire testing.

General guidance for assessing the fire hazard of electrotechnical products is given in IEC 60695-1-10 and IEC 60695-1-11.

After ignition, fire development may occur in different ways depending on the environmental conditions, as well as on the physical arrangement of the combustible materials. However, a general pattern can be established for fire development within a compartment, where the general temperature-time curve shows three stages, plus a decay stage (see Figure 1).

Stage 1 is the incipient stage of the fire prior to sustained flaming, with little rise in the fire room temperature. Ignition and *smoke* generation are the main hazards during this stage. Stage 2 (developing fire) starts with ignition and ends with an exponential rise in the fire room temperature. Spread of flame and heat release are the main hazards in addition to *smoke* during this stage. Stage 3 (fully developed fire) starts when the surface of all of the combustible contents of the room has decomposed to such an extent that sudden ignition occurs all over the room, with a rapid and large increase in temperature (flash-over).

At the end of stage 3, the combustibles and/or oxygen have been largely consumed and hence the temperature decreases at a rate which depends on the ventilation and the heat and mass transfer characteristics of the system. This is known as decay.

In each of these stages, a different mixture of decomposition products may be formed and this, in turn, influences the *smoke* produced during that stage. In order to select an appropriate fire test, information is required on the fire scenario being considered, in particular the conditions of incident heat flux, oxygen availability and the facilities for venting the *smoke*.

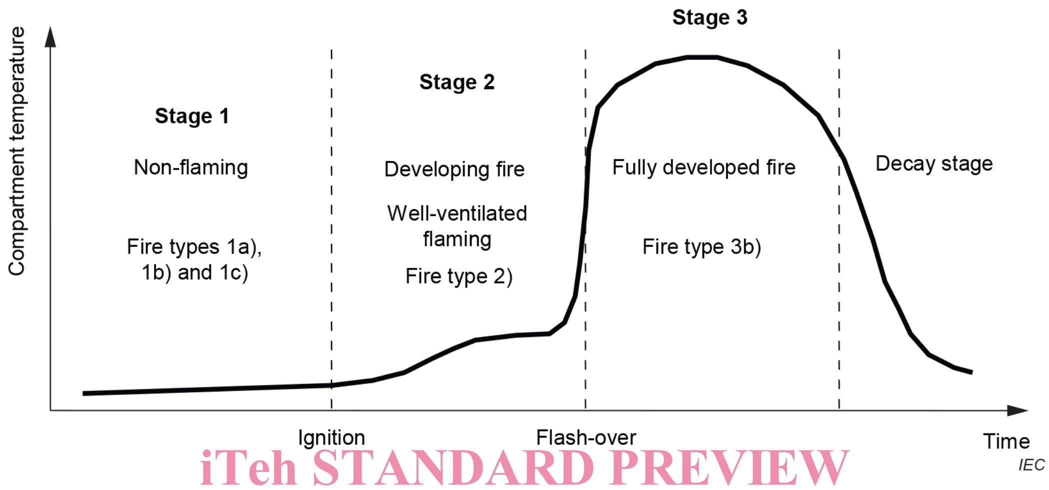

Figure 1 – Different phases in the development of a fire within a compartment

4.2 Factors affecting smoke production

4.2.1 General

Many factors affect the production of *smoke* and the properties of *smoke*. A full description of such properties is not possible, but the influence of several important variables is recognized.

4.2.2 Modes of decomposition

Smoke is a consequence of combustion. Combustion may be flaming or non-flaming, including smouldering, and these different modes of combustion may produce quite different types of *smoke*. In non-flaming combustion, volatiles are evolved at elevated temperatures. When they mix with cool air, they condense to form spherical droplets which appear as a light-coloured *smoke* aerosol.

Flaming combustion produces a black carbon-rich *smoke* in which the particles have a very irregular shape. The *smoke* particles from flaming combustion are formed in the gas phase and in regions where oxygen concentrations are low enough to cause incomplete combustion. The carbonaceous *smoke* particles in the flames emit radiant energy (as black-body emission) which is seen as yellow luminosity.

The particle size of the spherical droplets from non-flaming combustion is generally of the order of 1 µm, whereas the size of the irregular soot particles from flaming combustion is often larger but much harder to determine and is dependent on the measuring technique.

It is often observed for wood fires that the amount of *smoke* is less with flaming combustion than with non-flaming combustion. For plastics, however, no such generalization can be made: the *smoke* produced under non-flaming conditions can be less or more than under flaming conditions. For these reasons, it is important to record in a *smoke* test whether ignition occurs, as well as the times of ignition and extinction of flames on the test specimen.

In addition, cold *smoke* may be generated from the rear of composites; this may differ substantially in colour and composition from the *smoke* produced from the exposed surface.