BS EN 60695-1-20:2016

BSI Standards Publication

Fire hazard testing

Part 1-20: Guidance for assessing the fire hazard of electrotechnical products — Ignitability — General guidance

bsi.

National foreword

This British Standard is the UK implementation of EN 60695-1-20:2016. It is identical to IEC 60695-1-20:2016. It supersedes DD IEC/TS 60695-1-20:2008 which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD

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English Version

Fire hazard testing - Part 1-20: Guidance for assessing the fire hazard of electrotechnical products - Ignitability - General guidance (IEC 60695-1-20:2016)

Essais relatifs aux risques du feu -
Partie 1-20: Lignes directrices pour l'évaluation des risques du feu des produits électrotechniques - Allumabilité - Lignes directrices générales
(IEC 60695-1-20:2016)

Prüfungen zur Beurteilung der Brandgefahr -
Teil 1-20: Anleitung zur Beurteilung der Brandgefahr von elektrotechnischen Erzeugnissen - Entzündbarkeit - Allgemeiner Leitfaden
(IEC 60695-1-20:2016)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

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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)	2016-12-02
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-03-02

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Endorsement notice

The text of the International Standard IEC 60695-1-20:2016 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/TS 62441	NOTE	Harmonized as CLC/TS 62441.
IEC 60112	NOTE	Harmonized as EN 60112.
IEC 60587	NOTE	Harmonized as EN 60587.
IEC 60099-4	NOTE	Harmonized as EN 60099-4.

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 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60695-1-10	-	Fire hazard testing - Part 1-10: Guidance for assessing the fire hazard of electrotechnical products - General guidelines	EN 60695-1-10	-
IEC 60695-1-11	-	Fire hazard testing - Part 1-11: Guidance for assessing the fire hazard of electrotechnical products - Fire hazard assessment	EN 60695-1-11	-
IEC 60695-1-12	-	Fire hazard testing - Part 1-12: Guidance for assessing the fire hazard of electrotechnical products - Fire safety engineering	EN 60695-1-12	-
IEC/TR 60695-1-21	-	Fire hazard testing - Part 1-21: Guidance for assessing the fire hazard of electrotechnical products - Ignitability - Summary and relevance of test methods	-	-
IEC 60695-2-11	-	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products (GWEPT)	EN 60695-2-11	-
IEC 60695-2-12	-	Fire hazard testing - Part 2-12: Glowing/hot-wire based test methods - Glow-wire flammability index (GWFI) test method for materials	EN 60695-2-12	-
IEC 60695-2-13	-	Fire hazard testing - Part 2-13: Glowing/hot-wire based test methods - Glow-wire ignition temperature (GWIT) test method for materials	EN 60695-2-13	-
IEC 60695-4	2012	Fire hazard testing - Part 4: Terminology concerning fire tests for electrotechnical products	EN 60695-4	2012
IEC 60695-11-5	-	Fire hazard testing - Part 11-5: Test flames - Needle-flame test method - Apparatus, confirmatory test arrangement and guidance	EN 60695-11-5	-

Publication	Year	Title	EN/HD	Year
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC/TS 60695-11-11	-	Fire hazard testing - Part 11-11: Test flames - Determination of the characteristic heat flux for ignition from a non-contacting flame source	-	-
IEC 60695-11-20	-	Fire hazard testing - Part 11-20: Test flames - 500 W flame test methods	EN 60695-11-20	-
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	-	Fire safety - Vocabulary	EN ISO 13943	-
ISO 871	2006	Plastics - Determination of ignition temperature using a hot-air furnace	-	-
ISO 2592	-	Determination of flash and fire points - Cleveland open cup method	EN ISO 2592	-
ISO 2719	-	Determination of flash point - Pensky-Martens closed cup method	EN ISO 2719	-
ISO 5657	-	Reaction to fire tests - Ignitability of building products using a radiant heat source	-	-
ISO 5660-1	-	Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part-1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)	-	-
ISO 10840	-	Plastics - Guidance for the use of standard fire tests	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIRE HAZARD TESTING –

Part 1-20: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – 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 60695-1-20 has been prepared by IEC technical committee 89: Fire hazard testing.

This first edition of IEC 60695-1-20 cancels and replaces the first edition of IEC TS 60695-1-20 published in 2008. This edition constitutes a technical revision.

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

a) ISO 5660-1 has been added to the normative references;
b) definitions of "pyrolysis" and "short-circuit" have been added to Clause 3;
c) some text from the introduction has been moved to Clause 5 and is now part of the normative text;

d) Clause 5 now contains several mandatory statements.

The text of this standard is based on the following documents:

FDIS	Report on voting
89/1296/FDIS	89/1302/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

In this standard, the terms defined in Clause 3 are printed in bold type.

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.

The IEC 60695-1 series, under the general title *Fire hazard testing*, consists of the following parts:

Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines

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

Part 1-12: Guidance for assessing the fire hazard of electrotechnical products – Fire safety engineering

Part 1-20: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – General guidance

Part 1-21: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – Summary and relevance of test methods

Part 1-30: Guidance for assessing the fire hazard of electrotechnical products – Preselection testing procedures – General guidelines

Part 1-40: Guidance for assessing the fire hazard of electrotechnical products – Insulating liquids

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

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

INTRODUCTION

Fires are responsible for creating hazards to life and property as a result of the generation of heat (thermal hazard), and also as a result of the production of toxic effluent, corrosive effluent and smoke (non-thermal hazard). Fires start with ignition and then can grow, leading in some cases to flash-over and a fully developed fire. Ignition resistance is therefore one of the most important parameters of a material to be considered in the assessment of fire hazard. If there is no ignition, there is no fire.

For most materials (other than metals and some other elements), ignition occurs in the gas phase. Ignition occurs when combustible vapour, mixed with air, reaches a high enough temperature for exothermic oxidation reactions to rapidly propagate. The ease of ignition is a function of the chemical nature of the vapour, the fuel/air ratio and the temperature.

In the case of liquids, the combustible vapour is produced by vaporization of the liquid, and the vaporization process is dependent on the temperature and chemical composition of the liquid.

In the case of solids, the combustible vapour is produced by pyrolysis when the temperature of the solid is sufficiently high. The vaporization process is dependent on the temperature and chemical composition of the solid, and also on the thickness, density, specific heat, and thermal conductivity of the solid.

The ease of ignition of a test specimen depends on many variables. Factors to be considered for the assessment of ignitability are:

a) the geometry of the test specimen, including thickness and the presence of edges, corners or joints;
b) the surface orientation;
c) the rate and direction of air flow;
d) the nature and position of the ignition source;
e) the magnitude and position of any external heat flux; and
f) whether the combustible material is a solid or a liquid.

The primary aims are to prevent ignition caused by an electrically energized component part, and in the event of ignition, to confine any resulting fire within the bounds of the enclosure of the electrotechnical product.

Secondary aims include the minimization of any flame spread beyond the product’s enclosure and the minimization of harmful effects of fire effluents including heat, smoke, and toxic or corrosive combustion products.

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.

This international standard gives an overview of ignitability and its relevance to the fire hazard of electrotechnical products.

FIRE HAZARD TESTING –

Part 1-20: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – General guidance

1 Scope

This part of IEC 60695 provides guidance on the ignitability of electrotechnical products and the materials from which they are formed. It gives guidance on:

a) the principles of ignitability;
b) the selection of appropriate test methods, and
c) the use and interpretation of results.

This part of IEC 60695 is intended for use by technical committees in 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 60695-1-10, *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 60695-1-12, *Fire hazard testing – Part 1-12: Guidance for assessing the fire hazard of electrotechnical products – Fire safety engineering*

IEC TR 60695-1-21, *Fire hazard testing – Part 1-21: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – Summary and relevance of test methods*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60695-2-12, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials*

IEC 60695-2-13, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

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

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC TS 60695-11-11, *Fire hazard testing – Part 11-11: Test flames – Determination of the characteristic heat flux for ignition from a non-contacting flame source*

IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame 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, *Fire safety – Vocabulary*

ISO 871:2006, *Plastics – Determination of ignition temperature using a hot-air furnace*

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

ISO 2719, *Determination of flash point – Pensky-Martens closed cup method*

ISO 5657, *Reaction to fire tests – Ignitability of building products using a radiant heat source*

ISO 5660-1, *Reaction to fire tests – Heat release smoke production and mass loss rate – Part 1: Heat release rate (cone calorimeter method)*

ISO 10840, *Plastics – Guidance for the use of standard fire tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943:2008 and IEC 60695-4:2012 (some of which are reproduced below), as well as the following, apply.

3.1
auto-ignition
spontaneous ignition
self-ignition CA, US
unpiloted ignition CA, US
DEPRECATED: spontaneous combustion
ignition (3.20) resulting from a rise in temperature without a separate **ignition source** (3.22)

Note 1 to entry: The ignition can be caused either by self-heating or by heating from an external source.

Note 2 to entry: In North America, “spontaneous ignition” is the preferred term used to designate ignition caused by self-heating.

[SOURCE: ISO 13943:2008, 4.18]

3.2
auto-ignition temperature
spontaneous ignition temperature
minimum temperature at which **auto-ignition** (3.1) is obtained in a fire test

Note 1 to entry: The typical units are degrees Celsius (°C).

[SOURCE: ISO 13943:2008, 4.19]

3.3
combustion
exothermic reaction of a substance with an oxidizing agent

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

[SOURCE: ISO 13943:2008, 4.46]

3.4
fire 〈general〉
process of **combustion** (3.3) 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** (3.5) and **fire** (3.6), 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]

3.5
fire 〈controlled〉
self-supporting **combustion** (3.3) 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]

3.6
fire 〈uncontrolled〉
self-supporting **combustion** (3.3) 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]

3.7
fire hazard
physical object or condition with a potential for an undesirable consequence from **fire** (3.4)

[SOURCE: ISO 13943:2008, 4.112]

3.8
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).

Note 3 to entry: See **flash point** (3.16)

[SOURCE: ISO 13943:2008, 4.119]

3.9
fire retardant, noun
substance added, or a treatment applied, to a material in order to delay **ignition** (3.20) or to reduce the rate of **combustion** (3.3)

Note 1 to entry: The use of (a) fire retardant(s) does not necessarily suppress **fire** (3.4) or terminate **combustion (3.3)**.

Note 2 to entry: See **flame retardant** (3.12)

[SOURCE: ISO 13943:2008, 4.123]

3.10
fire scenario
qualitative description of the course of a **fire** (3.6) 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** (3.20) and fire growth processes, the **fully developed fire** (3.17) 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** (3.3) in a gaseous medium, usually with emission of light

[SOURCE: ISO 13943:2008, 4.133 – modified – The words "zone in which there is" have been added at the beginning of the definition.]

3.12
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

Note 1 to entry: The use of (a) flame retardant(s) does not necessarily suppress **fire** (3.6) or terminate **combustion** (3.3).

Note 2 to entry: See fire retardant (3.9).

[SOURCE: ISO 13943:2008, 4.139]

3.13
flaming combustion
combustion (3.3) in the gaseous phase, usually with emission of light

[SOURCE: ISO 13943:2008, 4.148]

3.14
flash-ignition temperature
FIT
minimum temperature at which, under specified test conditions, sufficient flammable gases are emitted to ignite momentarily on application of a pilot **flame** (3.11)

Note 1 to entry: This note applies to the French language only.

[SOURCE: ISO 871:2006, 3.1]

3.15
flashover, ⟨stage of fire⟩
transition to a state of total surface involvement in a **fire** (3.4) of combustible materials within an enclosure

[SOURCE: ISO 13943:2008, 4.156]

3.16
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 test conditions

Note 1 to entry: The typical units are degrees Celsius (˚C).

[SOURCE: ISO 13943:2008, 4.154]

3.17
fully developed fire
state of total involvement of combustible materials in a **fire** (3.6)

[SOURCE: ISO 13943:2008, 4.164]

3.18
glowing combustion
combustion (3.3) of a material in the solid phase without **flame** (3.11) but with emission of light from the combustion zone

[SOURCE: ISO 13943:2008, 4.169]

3.19
ignitability
ease of ignition
measure of the ease with which a test specimen can be ignited, under specified conditions

[SOURCE: ISO 13943:2008, 4.182]

3.20
ignition, ⟨general⟩
DEPRECATED: sustained ignition
initiation of **combustion** (3.3)

[SOURCE: ISO 13943:2008, 4.187]

3.21
ignition, ⟨flaming combustion⟩
DEPRECATED: sustained ignition
initiation of sustained **flame** (3.11)

[SOURCE: ISO 13943:2008, 4.188]

3.22
ignition source
source of energy that initiates **combustion** (3.3)

[SOURCE: ISO 13943:2008, 4.189]

3.23
lower flammability limit
LFL
minimum concentration of fuel vapour in air below which propagation of a **flame** (3.11) does not occur in the presence of an **ignition source** (3.22)

Note 1 to entry: The concentration is usually expressed as a volume fraction at a defined temperature and pressure, and expressed as a percentage.

[SOURCE: ISO 13943:2008, 4.216]

3.24
minimum ignition temperature
ignition point
minimum temperature at which sustained **combustion** (3.3) 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** (3.4) before **flaming combustion** (3.13) 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
short-circuit
unintended connection of two nodes of an electrical circuit

Note 1 to entry: Current flow might occur, which could cause circuit damage, overheating, fire or explosion.

3.27
spontaneous-ignition temperature
SIT
minimum temperature at which, under specified test conditions, **ignition** (3.20), is obtained by heating, in the absence of any additional **ignition source** (3.22)

[SOURCE: ISO 871:2006, 3.2]

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, 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]

3.29
upper flammability limit
UFL
maximum concentration of fuel vapour in air above which propagation of a **flame** (3.11) will not occur in the presence of an **ignition source** (3.22)

Note 1 to entry: The concentration is usually expressed as a volume fraction at a defined temperature and pressure, and expressed as a percentage.

[SOURCE: ISO 13943:2008, 4.349]

4 Principles of ignitability

4.1 Gases

4.1.1 Overview

Ignition of a gas depends on how the gas is mixed with air. If the gas is mixed with air before ignition, the subsequent reaction is known as premixed combustion. In a burner, the combustion is controlled, but if a large volume of a gas/air mixture is ignited, a gas explosion results.

In most fires, ignition results in the development of diffusion flames where combustible gas comes in contact with air without being previously mixed.

Gas mixtures can be ignited in two basic ways:

a) auto-ignition – where the temperature of all the gas mixture is raised, and
b) piloted ignition – where a local source of heat is introduced, e.g. a flame or an electrical spark.

Some fires are the result of the ignition of a material which is already in the gaseous state, but combustible gases can also be produced by the vaporization of liquids (see 4.2) or by the pyrolysis of solids (see 4.3).

4.1.2 Flammability limits

Flame propagation cannot occur in a fuel/air gas mixture if the fuel concentration is too low or too high. The limiting concentration values are known as the lower flammability limit (LFL) and the upper flammability limit (UFL). These limits arise because flames need a minimum temperature to exist. Too much air or fuel prevents the temperature being maintained at a sufficiently high level. Flammability limits are normally expressed as the percentage of fuel, by volume, in the fuel/air mixture.

4.1.3 Arc fires

Faults in some electrical equipment such as junction boxes and power transformers can result in disruptive electrical discharges (electric arcs) which can pyrolyse insulation materials to produce high temperature combustible gases. Such gases expand rapidly and in contact with air can result in an explosion (see 5.3.4.4).

4.2 Liquids

4.2.1 Overview

With the exception of some unstable or reactive substances, bulk liquids do not generally ignite. Normally it is combustible vapour which ignites. The combustible vapour is produced by vaporization of the liquid, and the vaporization process is dependent on the temperature and chemical composition of the liquid.

4.2.2 Ignition parameters

Temperature is normally used to define the ignitability of a liquid. Three different temperatures are used. These are the auto ignition temperature (see 3.2), the fire point (see 3.8) and the flash point (see 3.16). Auto-ignition refers to ignition in the absence of a localized heat source. Flash point concerns momentary ignition. Fire point concerns sustained combustion after ignition.

Several different test methods are used to measure these characteristic temperatures. The measured temperature depends on the particular details of the test apparatus used. It is therefore important to define the test method when quoting these parameters.

4.2.3 Insulating liquids

4.2.3.1 Flash point measurement

ISO 2719 (Pensky-Martens closed cup method) is cited in IEC standards for the measurement of the flash point of insulating liquids. It measures the flash point in a confined space and is intended to detect minor amounts of volatile material. An alternative method is ISO 2592 (Cleveland open cup method) which is used to measure the flash point over an open liquid surface. The flash point measured by ISO 2592 is significantly lower than that measured by ISO 2719.

4.2.3.2 Cone calorimeter measurements

IEC 60695-8-3 was developed to measure the quantity of heat released from burning insulating liquids. The test specimen is exposed to a uniform heat flux in the presence of a spark ignition source. Ignition related properties can be defined as the time to ignition at a specified heat flux, or the minimum incident heat flux that will support ignition.

NOTE IEC 60695-8-3 is to be withdrawn. The ISO intends to develop a related test method with a wider scope.

4.3 Solids

4.3.1 Overview

With some exceptions (see below) solids do not generally ignite. Normally, the material that ignites is in the gas phase and can be a mixture of gases, aerosols and suspended particles. The combustible vapour is produced by pyrolysis of the solid, and the vaporization process is dependent on the temperature and chemical composition of the solid.

The exceptions to this general statement are:

– metals (see 4.3.3);
– some non-metallic elements, for example carbon (see 4.3.4), sulphur and phosphorous;
– certain reactive substances (see 4.3.5); and
– dust clouds (see 4.3.6).

4.3.2 Parameters affecting ignition

In the case of a solid, the generation of flammable volatiles from the material is function of the temperature of that material. This is affected by the nature of the heat input which may be, for example, a radiant heat flux, a convective heat flux, a conductive heat flux, an imposed flame, a hot wire or a combination of these sources.

The ease of ignition will also depend on the chemical nature of the flammable volatiles, which in turn will depend on the chemical nature of the solid.

The rate of heating of the material is a function of a number of properties of the solid:

a) thickness;
b) thermal conductivity, (k);
c) density, (ρ);
d) specific heat, (c);
e) absorptivity (in the case of radiative heating).

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 specimen, conduction of heat from the surface is negligible, and so resistance to ignition is lower.

Thermoplastic materials have a tendency to melt away from the heat source (e.g. flame or hot-wire) often resulting in non-ignition. Because of this behaviour special consideration should be given to the testing of the ignitability of thermoplastics. The problems that can arise when thermoplastics are tested in standard fire tests are discussed in ISO 10840.

The product, $k \cdot \rho \cdot c$, 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, e.g. 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.

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 and on whether there is a continuing imposed heat flux, 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.

4.3.3 Metals

When a metal burns in air the product of combustion is the metal oxide. Many metals have a film of metal oxide on the surface which is formed from low temperature oxidation. The oxide film cannot burn because it is already the product of the metal's oxidation and so before the bulk metal can burn, the surface layer of oxide must be removed in some way.

Metals can be classified into three groups with respect to their ignition characteristics.

a) Metals that ignite at or below their melting point (for example iron and magnesium). These metals all have melting points above 650 °C. These metals generally do not form a protective oxide layer.

b) Metals that ignite after they melt (for example aluminium, lead, tin and zinc). These metals all have melting points below 660 °C. These metals generally form a protective oxide layer.

c) Metals of low reactivity which do not ignite (for example mercury, silver, gold and platinum).

The ease of ignition is also governed by the surface area/volume ratio of the metal. Thin films of metal and finely divided powders are much easier to ignite than bulk pieces of metal. This is because the heat released by the oxidation process is proportional to the burning surface area, whereas the initial removal of heat from the surface by conduction is proportional to the volume of the metal.

4.3.4 Carbon (graphite) and carbonaceous char

4.3.4.1 Graphite

Pure carbon in the form of graphite can ignite in air above a temperature of about 800 °C. In the range 800 °C to 1 200 °C, non-flaming surface combustion (glowing combustion) is found to occur. Above about 1 200 °C flaming combustion occurs with a CO flame being observed.

4.3.4.2 Carbonaceous char

Carbonaceous chars are impure forms of carbon. Volatile content and porosity are two important variables which contribute to the wide range of observed ignition temperatures. As with graphite both flaming combustion and non-flaming combustion may be observed. Many carbon-containing materials tend to form a carbonaceous char on their surface when they burn, and at the early stages of fire this char layer can, to some extent, protect the underlying material. A correlation has been observed between ignition resistance, as measured by limiting oxygen index, and char yield for a range of organic polymers [1].[1]

4.3.5 Reactive substances

In most fires the oxidising agent is the oxygen in air. However, in some materials the oxidising agent, usually oxygen, is part of the molecular structure of the material or is mixed with the solid fuel in the form of a solid oxidising agent. These materials are usually deliberately made to be combustible or explosive. Some examples are:

– “blue touch paper” (cellulose and potassium nitrate);
– gunpowder (carbon, sulphur and potassium nitrate);
– cigarettes (tobacco and potassium nitrate);
– TNT (trinitrotoluene).

4.3.6 Dust clouds

Dust clouds are mixtures of air (or some gas or gases) and fine solid particles which are microscopically dispersed in it, and their ignition behaviour is more like that of a premixed gas than that of a solid.

5 Consideration for the selection of test methods

5.1 General

Important factors to be considered when selecting the test method to be used include; the fire scenario or scenarios of concern, the possible ignition sources, the type of test specimen, and the type of test procedure and apparatus.

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1 Numbers in square brackets refer to the bibliography.

IEC TR 60695-1-21 gives a summary and relevance of test methods associated with ignitability.

5.2 Fire scenario

In the design of any 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 to acceptable levels the potential risks of fire even in the event of foreseeable abnormal use, malfunction or failure. IEC 60695-1-10, IEC 60695-1-11 and IEC 60695-1-12 provide guidance on how this is to be accomplished.

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

a) the geometry of the test specimen, including thickness and the presence of edges, corners or joints;
b) any anisotropy;
c) the surface orientation;
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; and
g) whether the flammable material is a solid or a liquid.

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 TC 89 in accordance with IEC Guide 104.

5.3 Ignition sources

5.3.1 General

The ignition source used in a laboratory test shall 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) a primary internal source of heat of ohmic nature and a secondary source of heat in the form of a small flame which may occur as result of ignition caused by the primary (ohmic) source of ignition;
b) from sources of flame or excessive heat which are external to electrotechnical equipment and systems.

In both cases a possible type of ignition specific to electrotechnical equipment is arc ignition. This is discussed in 5.3.4.

5.3.2 Internal ignition sources

If the ignition source under evaluation is within a product or located inside a component or an apparatus, suitable test methods are those which are able to simulate the overheating caused by:

a) the internal metallic parts (e.g. electrical contacts, conductors, etc.);
b) a small flame with a low heat transfer, caused by combustion started within the product or located inside the component or the apparatus under evaluation;
c) electrical arcs (see 5.3.4).

The following test methods can be used, as appropriate, to measure and describe the properties of a material, product, component or apparatus in response to heat and/or flame under controlled laboratory conditions.

ISO 871 specifies a laboratory method for determining the flash-ignition temperature and spontaneous-ignition temperature of plastics using a hot-air furnace. It is one of a number of methods in use for evaluating the resistance of plastics to the effects of ignition sources.

The glow wire test methods (IEC 60695-2-11, IEC 60695-2-12 and IEC 60695-2-13) simulate the first cause of ignition due to overheating by contact with a heated part, without an open flame.

IEC 60695-2-11 (GWEPT) applies to end products. It provides a qualitative evaluation of the ignition behaviour and, above the minimum ignition temperature, it provides a pass/fail criterion by assessing the burning duration under specified temperature conditions.

IEC 60695-2-12 (GWFI) and IEC 60695-2-13 (GWIT) are suitable for the preselection of insulating materials. The GWFI test is designed to assess the maximum temperature at which a material, when ignited, has a limited duration of burning without spreading fire from the test specimen. The GWIT test is designed to assess the resistance to ignition by measuring the minimum ignition temperature.

IEC 60695-11-5 is suitable to simulate ignition by a small flame. It is applicable to electrotechnical equipment, its sub-assemblies and components and to solid electrical insulating materials or other combustible materials. This test evaluates the ignitability of a given test specimen and measures its ability to self-extinguish.

IEC 60695-11-10 and IEC 60695-11-20 each provide a slightly different test method. Both of these test methods involve direct contact of an open flame onto the surface of the test specimen. The materials are rated depending on the length of time they burn (or glow) after removal of the test flame and whether or not flaming droplets are produced.

In IEC 60695-11-10, a 50 W test flame is used. In IEC 60695-11-20, a 500 W test flame is used and the flame application time is longer. In both cases the test methods provide classification systems which may be used for quality assurance, or the pre-selection of component materials of products.

NOTE The scopes of IEC 60695-11-10 and IEC 60695-11-20 do not refer to the simulation of either internal or external ignition.

IEC 60695-11-11 is suitable to simulate ignition by the heat flux from a small non-contacting flame.

5.3.3 External ignition sources

If the ignition source under evaluation is located outside the electrotechnical equipment, suitable test methods are those that are able to simulate the thermal stress caused by:

a) direct impingement of an open flame upon the surface of the equipment;
b) direct contact of high thermal stress (overheated metallic part) on the surface of the equipment;
c) indirect thermal heat flux
    i) radiant,
    ii) convective,
d) electrical arcs (see 5.3.4).

The methods described in 5.3.2 can also be used to simulate external ignition as well as internal ignition. The difference is the location of the application of the thermal stress. IEC 60695-11-5, which simulates ignition by a small flame (see 5.3.2) has gained acceptance in evaluating external ignition sources such as open candle flames (see IEC TS 62441 [2]).

Additional test methods could be:

IEC 60695-11-10 and IEC 60695-11-20: Both these test methods involve direct contact of an open flame onto the surface of the test specimen. Materials are rated depending on the length of time they burn (or glow) after removal of the test flame and whether or not flaming droplets are produced. In IEC 60695-11-10 a 50 W test flame is used. In IEC 60695-11-20 a 500 W test flame is used and the flame application time is longer. In both cases the test methods provide classification systems which may be used for quality assurance, or the pre-selection of component materials of products.

NOTE The scopes of IEC 60695-11-10 and IEC 60695-11-20 do not refer to the simulation of either internal or external ignition.

Indirect thermal flux, as from an item burning nearby, can be evaluated by the following methods.

IEC 60695-11-11 (see 5.3.2) simulates ignition caused by the heat flux from a small non-contacting flame.

ISO 5657: This is a small-scale test method that is typically used to assess materials rather than products. However, if the product size is less than 100 mm, it can be tested directly. The test specimen is heated by a conical electrical resistance heater, and after ignition the heat release rate is measured.

ISO 5660-1 specifies a method, using the Cone Calorimeter apparatus, to assess the heat release rate of a specimen exposed in the horizontal orientation to controlled levels of irradiance. Time to ignition as a function of the imposed heat flux can be measured and can be used to calculate useful ignition related parameters such as the thermal inertia of materials.

5.3.4 Arc ignition of materials

5.3.4.1 Arc ignition of gases

Arc ignition of a flammable gas needs a minimum energy. This property is exploited for instance in “intrinsically safe” cables. The voltage and inductance of these cables limits the energy of any sparks, which might be caused by short-circuits or relays, to a value below that which could cause ignition. Similar principles are used in specifying voltages and currents in cables used in fuel tanks.

Where it is desired to ignite a flammable gas or aerosol mixture, a high voltage source is normally used to power a spark plug or an ignition device as used in gas or oil furnaces.

5.3.4.2 Arc ignition of liquids

In general, a liquid needs to be volatilised in order for arc ignition to occur. An example is a high voltage power arc burning across the air/liquid surface of transformer oil. Radiant heat transfer may easily generate a high enough temperature in the liquid to volatilise and ignite it. It is highly desirable to exclude this possibility by design.

5.3.4.3 Arc ignition of solids

Arc ignition of a solid, in either wet or dry conditions, may be caused by any combination of high or low current or voltage. There are several tests available to evaluate both materials and finished products under the appropriate conditions.

Test method IEC 60112 [3] is used to evaluate tracking up to 600 V on materials.

NOTE IEC 60112 is not a test of ignitability, but If ignition occurs followed by persistent flaming within the test period, this constitutes failure of the test.

Test methods EN 3475-603 [4] and EN 3475-604 [5] are for wires used in the aerospace industry and they simulate wet and dry arc propagation, respectively, in electrical wiring. Momentary short-circuit arcs between a defective insulated wire and another conductor may, through ohmic heating, thermally pyrolyse and char the insulating material. The charred insulation, being conductive, is capable of sustaining the short-circuit arc. The sustained arc may propagate along the wire through continuous pyrolysis of the insulation (arc tracking). If the arcing wire is part of a multiple wire bundle, the insulation of other wires within the bundle may become thermally charred and also start to arc track. Therefore, arc tracking may lead to complete failure of an entire wire bundle or harness.

For low current/high voltages, the IEC 60587 [6] inclined plane wet tracking test is a suitable protocol and it is worth noting that PTFE (polytetrafluoroethylene) is reported as igniting on this test which would be inconceivable in a flame ignition test.

In all these tests, initial leakage currents are of the order of milliamps.

An additional condition which occurs on high voltage / high current equipment is ignition by power arcs of hundreds or thousands of amperes. Such arcs can generate considerable radiant heat and also molten/flaming droplets. This mode of ignition is usually covered by mode of failure testing on the complete equipment where a fault is deliberately introduced and rated fault currents put through the fault circuit. An example would be IEC 60099-4 [7] on surge arrestors where a power arc cuts through the polymeric housing and may ignite it. The specification allows a maximum afterburn of 2 min.

5.3.4.4 Arc fires in power transformers

Faults in some electrical equipment such as junction boxes and power transformers can result in disruptive electrical discharges (electric arcs) which can pyrolyse insulation materials to produce high temperature combustible gases. Such gases expand rapidly and in contact with air can result in an explosion.

Power transformers which contain oil for insulation are prone to such problems. Tests carried out at several high-power laboratories seem to indicate that power transformers larger than 100 MVA are not safe if an internal fault causes a short-circuit. The fault causes the pyrolysis of some of the oil and the production of a gaseous mixture containing saturated hydrocarbons. The pyrolysis reaction generates a rapidly growing quantity of gas at high pressure and temperature inside the transformer, often resulting in the structural failure of the transformer together with a subsequent explosion.

Annex A contains some examples of real accidents caused by arc fires in underground hydroelectric power plants or urban substations.

5.4 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), materials as specified in the relevant specification (solid or liquid), or a composite of materials.

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

5.5 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 shall be able to test the actual electrotechnical product, a simulated product, a material or a composite, as described in 5.4.

The test apparatus shall 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 igniter or a premixed gas-air flame have been found to be suitable.

An air flow rate which is relevant to the fire scenario of concern shall be used.

6 Use and interpretation of results

The occurrence of ignition and whether or not there is subsequent sustained burning both depend on a large number of factors as discussed above. It is most important that the selection of variables in a test for ignitability should reflect the nature of the fire scenario that is being considered.

The following are some of the parameters that can be used for fire safety engineering purposes:

a) auto-ignition temperature,
b) fire point,
c) flash point,
d) ignition temperature,
e) upper and lower flammability limits, and
f) thermal inertia.

The determination of the difficulty or ease of ignition under a defined set of conditions an important factor in the assessment of the relative hazard expected in fires of electrotechnical products. The assessment is based on the principle that the greater the resistance to ignition, the lower the expected hazard. A high resistance to ignition is always desirable.

Annex A
(informative)

Examples of accidents due to arc fires in underground hydroelectric power plants or urban substations

A.1 General

Gas explosion accidents in underground hydroelectric power plants or urban substations may occur as a consequence of electric faults in oil-insulated components such as transformers.

An electric arc inside the component causes the pyrolysis of part of the oil, and the gaseous pyrolysis products can then escape from the component to mix with air.

Due to the chemical composition of the mixture, an explosion can occur giving rise to a pressure shock wave which, if not suitably confined by blast-resistant barriers, can propagate through the power plant or substation.

A.2 Examples which are generally available (non-exhaustive list)

A.2.1 Underground hydroelectric power plants

Tonstad, Norway, 1973 – Outside spark-over on the cable porcelain terminal with a flash. Explosion of reactive gases and oil mist: 3 people killed, 1 heavy burn injury.

Bardufoss, Norway, 1975 – Short-circuit in the control cable connection to one of the unit. Explosion: heavy damages in the powerhouse.

Roncovalgrande, Italy, 1988 – Ground discharge in the insulator. Explosion of reactive gases and oil mist: damage to equipment and structures.

Skjomen, Norway, 1998 – Material and system defects in the control systems. Explosion and oil fireball: transformer totally damaged.

Aroy, Norway, 2001 – Operational mistake and material weakness in the windings or winding insulation. No explosion or fire.

A.2.2 Urban substations (non-exhaustive list)

Toronto, Canada, 1999 – Toronto Hydro, Windsor Station

Sydney, Australia 1999 – Chatswood substation

Sydney, Australia 2000 – Paddington substation

Chicago, USA 2000 – Chicago downtown

Pittsburgh, USA 2000 – Pittsburgh downtown

Brisbane, Australia 2001 – Tennyson substation

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[5] EN 3475-604, *Aerospace series. Cables, electrical, aircraft use. Test methods. Resistance to dry arc propagation*

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