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TECHNICAL REPORT

RAPPORT TECHNIQUE

BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

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

Essais relatifs aux risques du feu –
Partie 1-21: Lignes directrices pour l'évaluation des risques du feu des produits électrotechniques – Allumabilité – Résumé et pertinence des méthodes d'essais

IEC/TR 60695-1-21:2008

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FIRE HAZARD TESTING –

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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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IEC/TR 60695-1-21, which is a technical report, has been prepared by IEC technical committee 89: Fire hazard testing.

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

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
89/804/DTR	89/812A/RVC

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

This technical report is to be read in conjunction with IEC 60695-1-20 [1)].

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

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

Part 1 consists of the following parts:

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

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

Part 1-20[1]: 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 maintenance result date indicated on the IEC web site 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.

1) Under consideration.

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 that need 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.

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[2], together with its companion, IEC 60695-1-11 [2], provide guidance on how this is to be accomplished.

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 the overall risk assessment.

2) Under consideration.

For these reasons there are many tests used to evaluate the ignitability of electrotechnical products and of the materials used in their construction. This technical report describes ignitability test methods in common use to assess electrotechnical products, or materials used in electrotechnical products. It also includes test methods in which, by design, ignitability is a significant quantifiable characteristic. It forms part of the IEC 60695-1 series, which gives guidance to product committees wishing to incorporate fire hazard test methods in product standards.

FIRE HAZARD TESTING –

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

1 Scope

This part of IEC 60695, which is a technical report, provides a summary of test methods that are used to determine the ignitability of electrotechnical products or materials from which they are formed. It also includes test methods in which, by design, ignitability is a significant quantifiable characteristic.

It represents the current state of the art of the test methods and, where available, includes special observations on their relevance and use. The list of test methods is not to be considered exhaustive, and test methods which were not developed by IEC TC 89 are not to be considered as endorsed by IEC TC 89 unless this is specifically stated.

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 referenced documents are indispensable for the application 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 60695-1-20 [3]), *Fire hazard testing – Part 1-20: Guidance for assessing the fire hazard of electrotechnical products – Ignitability – General guidance*

IEC 60695-1-30, *Fire hazard testing – Part 1-30: Guidance for assessing the fire hazard of electrotechnical products – Use of preselection testing procedures*

IEC Guide 104:1997, *The preparation of safety publications and the use of basic safety publications and group safety publications*

ISO/IEC Guide 51:1999, *Safety aspects – Guidelines for their inclusion in standards*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3) Under consideration.

3.1
combustion
exothermic reaction of a substance with an oxidiser

NOTE Combustion generally emits effluent accompanied by flames and/or visible light.

[ISO/IEC 13943, definition 23]

3.2
fire

a) process of combustion characterized by the emission of heat and effluent accompanied by smoke, and/or flame, and/or glowing;
b) rapid combustion spreading uncontrolled in time and space

[IEC 60695-4, definition 3.19]

3.3
fire hazard
(cause of fire) physical object or condition with a potential for an undesirable consequence from fire

3.4
fire point
minimum temperature at which a material ignites and continues to burn for a specified time after a standardized small flame has been applied to its surface under specified conditions

NOTE 1 It is expressed in degrees Celsius.

NOTE 2 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.

[ISO/IEC 13943, definition 53]

3.5
fire retardant (noun)
a substance added or a treatment applied to a material in order to suppress, reduce or delay the combustion of the material

[IEC 60695-4, definition 3.31]

3.6
fire scenario
a detailed description of conditions, including environmental, of one or more of the stages from before ignition to the completion of combustion in an actual fire at a specific location, or in a full-scale simulation

[IEC 60695-4, definition 3.32]

3.7
flame (noun)
zone of combustion in the gaseous phase, usually with emission of light

[ISO/IEC 13943, definition 60]

3.8
flame retardant (noun)
substance added, or a treatment applied, to a material in order to suppress or delay the appearance of a flame and/or reduce its propagation (spread) rate

NOTE The use of flame retardants does not necessarily suppress fire.

[ISO/IEC 13943, definition 65]

3.9
flaming combustion
combustion in gaseous phase, usually with emission of light

[ISO/IEC 13943, definition 72]

3.10
flash-ignition temperature (FIT)
the minimum temperature at which, under specified test conditions, sufficient flammable gases are emitted to ignite momentarily on application of a pilot flame

[ISO 871, definition 3.1]

3.11
flash-over
the rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure

[IEC 60695-4, definition 3.42]

3.12
flash point (°C)
minimum temperature to which a material or product must be heated for the vapours emitted to ignite momentarily in the presence of flame, under specified test conditions

NOTE It is expressed in degrees Celsius.

[ISO/IEC 13943, definition 76]

3.13
fully developed fire
state of total involvement of combustible materials in a fire

[ISO/IEC 13943, definition 80]

3.14
glowing combustion
combustion of a material in the solid phase without flame but with the emission of light from the combustion zone

[ISO/IEC 13943, definition 84]

3.15
ignitability
measure of the ease with which an item can be ignited, under specified conditions

[ISO/IEC 13943, definition 91]

3.16
ignition
initiation of combustion

NOTE The term "ignition" in French has a very different meaning [state of body combustion].

[ISO/IEC 13943, definition 96]

3.17
ignition source
source of energy that initiates combustion

[ISO/IEC 13943, definition 97]

3.18
ignition temperature (minimum)
the (minimum) temperature of a material or of an ignition source at which sustained combustion can be initiated under specified test conditions, as defined in the test method

NOTE Ignition requires a sufficient volume of flammable gas and oxidant (air). Sustained combustion requires a sufficient rate of production of flammable gas. The minimum ignition temperature implies thermal stressing to infinite time. For practical purposes, the standard should define the minimum ignition temperature appropriately.

[IEC 60695-4, definition 3.51]

3.19
lower flammability limit (LFL)
minimum concentration of fuel vapour in air below which propagation of a flame will not occur in the presence of an ignition source

NOTE The concentration of a gas or vapour is usually expressed as a volume fraction (%) at a defined temperature and pressure. The concentrations of solid and liquid aerosol, as well as mixtures of dust with air, are usually expressed as a density ($g \cdot m^3$).

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

[ISO 871, definition 3.2]

3.21
thermal inertia
product of thermal conductivity, density and specific heat capacity

NOTE 1 When a material is exposed to a heat flux, the rate of increase in 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 The typical units are $J^2 \cdot s^{-1} \cdot m^{-4} \cdot K^{-2}$.

3.22
tracking
progressive formation of conducting paths, which are produced on the surface and/or within a solid insulating material, due to the combined effects of electric stress and electrolytic contamination

[IEC 60112, definition 3.1]

3.23
upper flammability limit (UFL)
highest concentration of a flammable substance in air within which a self-propagating flame can occur

NOTE The concentration of a gas or vapour is usually expressed as a volume fraction (%) at a defined temperature and pressure. The concentrations of solid and liquid aerosol, as well as mixtures of dust with air, are usually expressed as a density ($g \cdot m^3$).

4 Summary of published test methods

This summary cannot be used in place of published standards which are the only valid reference documents. It represents the current state of the art of the test methods and, where available, includes special observations on their relevance and use. The list of test methods is not to be considered exhaustive, and test methods which were not developed by IEC TC 89 are not to be considered as endorsed by IEC TC 89 unless this is specifically stated.

Some test methods are material tests and some are end-product tests. Table A.1 in Annex A lists the test methods described below and distinguishes between material tests and end-product tests.

NOTE 1 Not all the following test methods are specifically ignition or ignitability tests, but some tests have been included because ignition data are, or can be, measured.

NOTE 2 Where no repeatability and reproducibility data are known to be available, the reader is recommended to contact the author/publisher of the relevant test method.

4.1 Tests using heated air or electrical heating

4.1.1 Determination of ignition temperature using a hot-air furnace, ISO 871

4.1.1.1 Purpose and principle

ISO 871 [1] [4] specifies a laboratory method for determining the flash-ignition temperature and spontaneous-ignition temperature of plastics using a hot-air furnace.

A specimen of the material is heated in a hot-air ignition furnace using various temperatures within the heated chamber, and the flash-ignition temperature is determined with a small pilot flame directed at the opening in the top of the furnace to ignite evolved gases. The spontaneous-ignition temperature is determined in the same manner as the flash-ignition temperature, but without the ignition flame.

4.1.1.2 Test specimen

Materials supplied in any form, including composites, may be used. A 3 g sample is used if the density is greater than 100 kg·m^{-3}. For cellular materials having a density less than 100 kg·m^{-3}, any outer skin is removed and a block of dimensions 20 mm × 20 mm × 50 mm is cut.

4.1.1.3 Test method

An air velocity of 25 mm·s^{-1} is set and an initial test temperature is chosen. At the end of 10 min the temperature is lowered or raised by 50 °C, depending on whether ignition has or has not occurred and a fresh sample is tested. When the range within which the ignition temperature lies has been determined, tests are begun 10 °C below the highest temperature within this range and continued by dropping the temperature in 10 °C steps until the temperature is reached at which there is no ignition during a 10 min period. The ignition temperature is recorded as the lowest test temperature at which ignition is observed.

4.1.1.4 Repeatability and reproducibility

Data are available in Annex A of ISO 871.

4.1.1.5 Relevance of test data

Tests made under the conditions of this method can be of considerable value in comparing the relative ignition characteristics of different materials. Values obtained represent the lowest

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4) Figures in square brackets refer to the bibliography.

ambient air temperature that will cause ignition of the material under the conditions of this test. Test values are expected to rank materials according to ignition susceptibility under actual use conditions.

4.1.2 Differential scanning calorimetry (DSC), ISO 11357

4.1.2.1 Introduction

Differential scanning calorimetry (DSC) is one of a number of thermal methods of analysis which are not used to directly measure ignition, but which are used to measure a number of properties which affect ignitability and which can be used in fire safety engineering studies and in fire modelling.

NOTE Other useful techniques include thermogravimetric analysis (TGA), differential thermal analysis (DTA), thermomechanical analysis (TMA), dynamic mechanical thermal analysis (DMTA), and pyrolysis gas chromatography [2], [3].

4.1.2.2 Purpose and principle

ISO 11357 [4] consists of seven parts, and describes methods using DSC to measure the following properties of polymeric materials such as thermoplastics and thermosetting plastics, including moulding materials and composite materials:

- Glass transition temperature
- Temperature and enthalpy of melting and crystallization
- Specific heat capacity
- Polymerization temperatures and/or times and polymerization kinetics
- Oxidation induction time
- Crystallization kinetics

The DSC method involves the measurement of the difference between the heat flow into a test specimen and that into a reference specimen as a function of temperature and/or time, while the test specimen and the reference specimen are subjected to a controlled temperature programme under a specified atmosphere.

4.1.2.3 Test specimen

Test specimens may be liquid or solid. The optimum test specimen mass varies depending on what parameter is being studied, but will typically be in the range 5 mg to 50 mg. The test specimen is placed in a sample pan which, if required, is sealed with a lid. The reference specimen is usually an identical empty sample pan.

4.1.2.4 Test method

The instrument is first calibrated, then the sample pans are inserted and the instrument is programmed to carry out the desired thermal cycle. Control operations and data analysis are according to the manufacturer's instructions.

4.1.2.5 Repeatability and reproducibility

Data are given in annexes to the various parts of ISO 11357.

4.1.2.6 Relevance of test data

DSC enables the measurement of two important parameters which are needed in fire models of ignition. These are a) specific heat capacity as a function of temperature, and b) the heat of gasification.