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TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

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

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

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FIRE HAZARD TESTING –

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

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60695-1-20, which is a technical specification, 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.

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

Enquiry draft	Report on voting
89/807/DTS	89/827/RVC

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

This technical specification is to be used in conjunction with IEC 60695-1-21 .

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

A list of all the parts in the IEC 60695 series, under the general 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: 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
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INTRODUCTION

Fires are responsible for creating hazards to life and property as a result of the generation of heat (thermal hazard), and also 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 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.

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

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FIRE HAZARD TESTING –

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

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1 Scope

IEC 60695-1-20, which is a technical specification 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 technical specification is intended for use by technical committees in preparation of standards in accordance with the principles laid down 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 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 60695-1-10, *Fire hazard testing – Part* 1-10:*Guidance for assessing the fire hazard of electrotechnical products – General guidelines*[3]

IEC 60695-1-11, *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*[3]

IEC 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*

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

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

IEC 60695-4:2005, *Fire hazard testing – Part 4: Terminology concerning fire tests in electrotechnical equipment*

IEC 60695-8-3, *Fire hazard testing – Part 8-3: Heat release – Heat release of insulating liquids used in electrotechnical products*[4]

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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 60695-11-11 , *Fire hazard testing – Part 11-11: Test flames – Determination of the ignition characteristic heat flux from a flame source*[5]

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

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

EN 14522, *Determination of the auto ignition temperature of gases and vapours*

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

ISO/IEC 13943:2000, *Fire safety – Vocabulary*

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

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

ISO 2719, *Petroleum products and lubricants - 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 10840, *Plastics – Guidance for the use of standard fire tests*

3 Terms and definitions

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

3.1
auto ignition temperature
lowest temperature (of a hot surface) at which under specified test conditions an ignition of a flammable gas or flammable vapour in mixture with air or air/inert gas occurs

[EN 14522, definition 3.1]

3.2
combustion
exothermic reaction of a substance with an oxidizer

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

[ISO/IEC 13943:2000, definition 23]

3.3
fire
a) 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 60695-4:2005, definition 3.19]

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3.4
fire hazard
⟨cause of fire⟩ physical object or condition with a potential for an undesirable consequence from fire

3.5
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 13943:2000, definition 53]

3.6
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 60695-4:2005, definition 3.31]

3.7
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 60695-4:2005, definition 3.32]

3.8
flame (noun)
zone of combustion in the gaseous phase, usually with emission of light

[ISO/IEC 13943:2000, definition 60]

3.9
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 13943:2000, definition 65]

3.10
flaming combustion
combustion in gaseous phase, usually with emission of light

[ISO/IEC 13943:2000, definition 72]

3.11
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]

3.12
flash-over
the rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure

[IEC 60695-4:2005, definition 3.42]

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3.13
flash point
the minimum temperature to which a product must be heated for the vapours emitted to ignite momentarily in the presence of flame, under specified test conditions

NOTE Expressed in °C.

[IEC 60695-4:2005, definition 3.43]

3.14
fully developed fire
state of total involvement of combustible materials in a fire

[ISO/IEC 13943:2000, definition 80]

3.15
glowing combustion
combustion of a material in the solid phase without flame but with the emission of light from the combustion zone

[ISO/IEC 13943:2000, definition 84]

3.16
ignitability
measure of the ease with which an item can be ignited, under specified conditions

[ISO/IEC 13943:2000, definition 91]

3.17
ignition
initiation of combustion

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

[ISO/IEC 13943:2000, definition 96]

3.18
ignition source
source of energy that initiates combustion

[ISO/IEC 13943:2000, definition 97]

3.19
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 60695-4:2005, definition 3.51]

3.20
lower flammability limit (LFL)
lowest concentration of a flammable substance in air within which a self-propagating flame can occur

3.21
spontaneous-ignition temperature (SIT)
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]

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3.22
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 $J^2 \cdot s^{-1} \cdot m^{-4} \cdot K^{-2}$.

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

4 Principles of ignitability

4.1 Gases

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).

4.1.1 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.

4.1.2 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 5.3.3.4).

4.2 Liquids

4.2.1 Introduction

With the exception of some unstable or reactive substances, 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 3.1), the fire point (see 3.5) and the flash point (see 3.13). Auto ignition refers to ignition in the absence of a localized heat

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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) 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) 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 is being 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 piloted 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.

4.3 Solids

4.3.1 Introduction

With some exceptions (see below) solids do not generally ignite. Normally it is combustible vapour which ignites. 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 other 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, this cannot happen and so resistance to ignition is lower.

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This general rule does not, however, apply to most thermoplastic materials. These have a tendency to melt away from the heat source (e.g. flame or hot-wire) often resulting in non-ignition. This can result in giving a false impression of a high resistance to ignition. Because of this behaviour special considerations 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, $k\rho c$, is known as 'thermal inertia'. If the thermal inertia is high, for example as in the case of a solid metal, the rate of surface heating will be relatively low and it will therefore take a relatively long time for the ignition temperature to be reached. If the thermal inertia is low, 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

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