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INTERNATIONAL STANDARD

NORME INTERNATIONALE

BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

Fire hazard testing –
Part 8-2: Heat release – Summary and relevance of test methods

Essais relatifs aux risques du feu –
Partie 8-2: Dégagement de chaleur – Résumé et pertinence des méthodes d'essais

IEC 60695-8-2:2016-11(en-fr)

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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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International Standard IEC 60695-8-2 has been prepared by IEC technical committee 89: Fire hazard testing.

This first edition cancels and replaces IEC TR 60695-8-2 published in 2008. This edition constitutes a technical revision.

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

FDIS	Report on voting
89/1343/FDIS	89/1349/RVD

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

This document 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.

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.

This International Standard is to be used in conjunction with IEC 60695-8-1.

IEC 60695-8 consists of the following parts:

- Part 8-1: Heat release – General guidance
- Part 8-2: Heat release – Summary and relevance of test methods

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

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- withdrawn,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

INTRODUCTION

In the design of an electrotechnical product, the risk of fire and the potential hazards associated with fire need to be considered. In this respect the objective of component, circuit and equipment design, as well as the choice of materials, is to reduce the risk of fire to a tolerable level even in the event of reasonably foreseeable (mis)use, malfunction or failure. IEC 60695-1-10, IEC 60695-1-11, and IEC 60695-1-12 provide guidance on how this is to be accomplished.

Fires involving electrotechnical products can also be initiated from external non-electrical sources. Considerations of this nature are dealt with in an overall fire hazard assessment.

The aim of the IEC 60695 series of standards is to save lives and property by reducing the number of fires or reducing the consequences of the fire. This can be accomplished by:

- trying to prevent ignition caused by an electrically energised component part and, in the event of ignition, to confine any resulting fire within the bounds of the enclosure of the electrotechnical product;
- trying to minimise flame spread beyond the product's enclosure and to minimise the harmful effects of fire effluents including heat, smoke, and toxic or corrosive combustion products.

Fires are responsible for creating hazards to life and property as a result of the generation of heat (thermal hazard), toxic and/or corrosive compounds and obscuration of vision due to smoke. The severity of a fire increases as the heat released increases, possibly leading to a flashover fire.

One of the most important measurements in fire testing is the measurement of heat release and it is used as an important factor in the determination of fire hazard; it is also used as one of the parameters in fire safety engineering calculations.

The measurement and use of heat release data, together with other fire test data, can be used to reduce the likelihood of (or the effects of) fire, even in the event of foreseeable abnormal use, malfunction or failure of electrotechnical products.

When a material is heated by some external source, fire effluent can be generated and can form a mixture with air that can ignite and initiate a fire. The heat released in the process is carried away by the fire effluent-air mixture, radiatively lost or transferred back to the solid material, to generate further pyrolysis products, thus continuing the process.

Heat may also be transferred to other nearby products, which may burn, and then release additional heat and fire effluent.

The rate at which thermal energy is released in a fire is defined as the heat release rate. Heat release rate is important because of its influence on flame spread and on the initiation of secondary fires. Other characteristics are also important, such as ignitability, flame spread and other side effects of the fire (see the IEC 60695 series of standards).

FIRE HAZARD TESTING –

Part 8-2: Heat release – Summary and relevance of test methods

1 Scope

This part of IEC 60695-8 presents a summary of published test methods that are relevant to the determination of the heat released in fire tests on electrotechnical products or materials from which they are formed. 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 that were not developed by the IEC are not to be considered as endorsed by the IEC unless this is specifically stated.

Heat release data can be used as part of fire hazard assessment and in fire safety engineering, as discussed in IEC 60695-1-10, IEC 60695-1-11 [39] [1] and IEC 60695-1-12 [40].

This basic safety publication is primarily 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. It is not intended for use by manufacturers or certification bodies.

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

IEC 60695-8-1, *Fire hazard testing – Part 8-1: Heat release – General guidance*

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

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

ISO 13943:2008, *Fire safety – Vocabulary*

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1 Numbers in square brackets refer to the Bibliography.

3 Terms and definitions

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

3.1
combustion
exothermic reaction of a substance with an oxidizing agent

Note 1 to entry: Combustion generally emits fire effluent accompanied by flames and/or glowing.

[SOURCE: ISO 13943:2008, 4.46]

3.2
combustion product
product of combustion
solid, liquid and gaseous material resulting from combustion

Note 1 to entry: Combustion products can include fire effluent, ash, char, clinker and/or soot.

[SOURCE: ISO 13943:2008, 4.48]

3.3
complete combustion
combustion in which all the combustion products are fully oxidized

Note 1 to entry: This means that, when the oxidizing agent is oxygen, all carbon is converted to carbon dioxide and all hydrogen is converted to water.

Note 2 to entry: If elements other than carbon, hydrogen and oxygen are present in the combustible material, those elements are converted to the most stable products in their standard states at 298 K.

[SOURCE: ISO 13943:2008, 4.50]

3.4
effective heat of combustion
heat released from a burning test specimen in a given time interval divided by the mass lost from the test specimen in the same time period

Note 1 to entry: It is the same as the net heat of combustion if all the test specimen is converted to volatile combustion products and if all the combustion products are fully oxidized.

Note 2 to entry: The typical units are kilojoules per gram ($kJ \cdot g^{-1}$).

[SOURCE: ISO 13943:2008, 4.74]

3.5
fire
⟨general⟩ process of combustion characterized by the emission of heat and fire effluent and usually accompanied by smoke, flame, glowing or a combination thereof

Note 1 to entry: In the English language the term “fire” is used to designate three concepts, two of which, *fire* (3.6) and *fire* (3.7), relate to specific types of self-supporting combustion with different meanings and two of them are designated using two different terms in both French and German.

[SOURCE: ISO 13943:2008, 4.96]

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

[SOURCE: ISO 13943:2008, 4.97]

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

[SOURCE: ISO 13943:2008, 4.98]

3.8
fire effluent
totality of gases and aerosols, including suspended particles, created by combustion or pyrolysis in a fire

[SOURCE: ISO 13943:2008, 4.105]

3.9
fire hazard
physical object or condition with a potential for an undesirable consequence from *fire* (3.7)

[SOURCE: ISO 13943:2008, 4.112]

3.10
fire-safety engineering
application of engineering methods based on scientific principles to the development or assessment of designs in the built environment through the analysis of specific fire scenarios or through the quantification of risk for a group of fire scenarios

[SOURCE: ISO 13943:2008, 4.126]

3.11
fire test
test that measures behaviour of a fire or exposes an item to the effects of a fire

Note 1 to entry: The results of a fire test can be used to quantify fire severity or determine the fire resistance or reaction to fire of the test specimen.

[SOURCE: ISO 13943:2008, 4.132]

3.12
flashover
⟨stage of fire⟩ transition to a state of total surface involvement in a fire of combustible materials within an enclosure

[SOURCE: ISO 13943:2008, 4.156]

3.13
gross heat of combustion
heat of combustion of a substance when the combustion is complete and any produced water is entirely condensed under specified conditions

cf. *complete combustion* (3.3)

Note 1 to entry: The typical units are kilojoules per gram ($kJ \cdot g^{-1}$).

[SOURCE: ISO 13943:2008, 4.170]

3.14
heat of combustion
DEPRECATED: calorific potential
DEPRECATED: calorific value
thermal energy produced by combustion of unit mass of a given substance

cf. *effective heat of combustion* (3.4), *gross heat of combustion* (3.13) and *net heat of combustion* (3.19).

Note 1 to entry: The typical units are kilojoules per gram ($kJ \cdot g^{-1}$).

[SOURCE: ISO 13943:2008, 4.174]

3.15
heat release
thermal energy produced by combustion

Note 1 to entry: The typical units are joules (J).

[SOURCE: ISO 13943:2008, 4.176]

3.16
heat release rate
DEPRECATED: burning rate
DEPRECATED: rate of burning
rate of thermal energy production generated by combustion

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

[SOURCE: ISO 13943:2008, 4.177]

3.17
intermediate-scale fire test
fire test performed on a test specimen of medium dimensions

Note 1 to entry: A fire test performed on a test specimen for which the maximum dimension is between 1 m and 3 m is usually called an intermediate-scale fire test.

[SOURCE: ISO 13943:2008, 4.200]

3.18
large-scale fire test
fire test, that cannot be carried out in a typical laboratory chamber, performed on a test specimen of large dimensions

Note 1 to entry: A fire test performed on a test specimen of which the maximum dimension is greater than 3 m is usually called a large-scale fire test.

[SOURCE: ISO 13943:2008, 4.205]

3.19
net heat of combustion
heat of combustion when any water produced is considered to be in the gaseous state

Note 1 to entry: The net heat of combustion is always smaller than the gross heat of combustion because the heat released by the condensation of the water vapour is not included.

Note 2 to entry: The typical units are kilojoules per gram ($kJ \cdot g^{-1}$).

[SOURCE: ISO 13943:2008, 4.237]

3.20
oxidation
chemical reaction in which the proportion of oxygen or other electronegative element in a substance is increased

Note 1 to entry: In chemistry, the term has the broader meaning of a process that involves the loss of an electron or electrons from an atom, molecule or ion.

[SOURCE: ISO 13943:2008, 4.245]

3.21
oxidizing agent
substance capable of causing oxidation

Note 1 to entry: Combustion is an oxidation.

[SOURCE: ISO 13943:2008, 4.246]

3.22
oxygen consumption principle
proportional relationship between the mass of oxygen consumed during combustion and the heat released

Note 1 to entry: A value of 13,1 $kJ \cdot g^{-1}$ is commonly used.

[SOURCE: ISO 13943:2008, 4.247]

3.23
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 before flaming combustion 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]

3.24
small-scale fire test
fire test performed on a test specimen of small dimensions

Note 1 to entry: A fire test performed on a test specimen of which the maximum dimension is less than 1 m is usually called a small-scale fire test.

[SOURCE: ISO 13943:2008, 4.292]

3.25
test specimen
item subjected to a procedure of assessment or measurement

Note 1 to entry: In a *fire test* (3.11), the item may be a material, product, component, element of construction, or any combination of these. It may also be a sensor that is used to simulate the behaviour of a product.

[SOURCE: ISO 13943:2008, 4.321]

4 Summary of test methods

4.1 General

This summary does not replace published standards, which are the only valid reference documents.

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 the relevant IEC technical committee, as mandated by IEC Guide 104. The test method(s) selected shall be relevant to the fire scenario of concern. Guidance on the selection and relevance of fire tests for electrotechnical products is given in IEC 60695-1-10.

General guidance on heat release tests for electrotechnical products is given in IEC 60695-8-1.

4.2 Measurement of complete combustion

4.2.1 The bomb calorimeter

See ISO 1716 [1].

4.2.2 Purpose and principle

The purpose of the method is to measure the gross heat of combustion at constant volume. A test specimen of specified mass is burned under standardized conditions, at constant volume, in an atmosphere of oxygen, in a sealed calorimeter calibrated by combustion of certified benzoic acid. The heat of combustion determined under these conditions is calculated on the basis of the observed temperature rise, taking into account heat loss and the latent heat of vaporization of water.

4.2.3 Test specimen

The test specimen is typically a mixture of 0,5 g of finely powdered benzoic acid and, also in a finely divided state, 0,5 g of the material under test.

4.2.4 Test procedure

The “bomb” is a central vessel that is sufficiently strong to withstand high pressures so that its internal volume remains constant. The bomb is immersed in a stirred water bath, and the combination of bomb and water bath is the calorimeter. The calorimeter is also immersed in an outer water bath. During a combustion reaction, the temperature of the water in the calorimeter and in the outer water bath is continuously monitored and adjusted by electrical heating to the same value. This is to ensure that there is no net loss of heat from the calorimeter to its surroundings, i.e. to ensure that the calorimeter is adiabatic.

To carry out a measurement, a test specimen, consisting of a known mass of benzoic acid mixed with a known mass of test material, is placed in a crucible inside the bomb in contact with an electrical ignition wire. The vessel is filled with oxygen under pressure (3,0 MPa to 3,5 MPa), sealed and allowed to attain thermal equilibrium. The sample is then ignited using a measured input of energy. Combustion is complete because it takes place in an excess of high pressure oxygen. The heat released is calculated from the known heat capacity of the calorimeter and the rise of temperature that occurs as a result of the combustion reaction.

The experiment gives the heat released at constant volume, i.e. the change in internal energy, ΔU. The gross heat of combustion at constant pressure is the enthalpy change, ΔH, where

$\Delta H = \Delta U + \Delta(PV)$

$\Delta(PV)$ is calculated using the ideal gas law;

$\Delta(PV) = \Delta(nRT)$ [R = 8,314 J·K^{-1}·mol^{-1}]

In order to calculate ΔH, it is necessary to be able to define the nature of the combustion reaction, i.e. to know the chemical composition of the combustion products. This will not always be known. However, the difference between ΔU and ΔH is normally small and can be ignored for most fire science purposes. For example, in the case of carbon burning to form carbon dioxide.

ΔU = −32,76 kJ·g^{-1} and ΔH = −32,97 kJ·g^{-1}.

The net heat of combustion can be calculated if the hydrogen content of the test specimen is known. It is assumed that all the hydrogen is converted into water and the calculation uses a value of 2,449 kJ·g^{-1} for the latent heat of vaporization of water at 25 °C.

4.2.5 Repeatability and reproducibility

A round-robin exercise was conducted by CEN and the results are summarized in Annex B of ISO 1716:2010.

4.2.6 Relevance of test data

When measuring the heat of combustion in an oxygen bomb calorimeter, the entire sample is completely converted to fully oxidized products. In fires (see 3.7) this is rarely the case because some potentially combustible material is often left as char and products of combustion are often only partly oxidized, for example, soot particles in smoke, and carbon monoxide. Heat release in a fire will therefore normally be less than the theoretical maximum that can be calculated from heat of combustion data.

Heat of combustion data are fundamental to the science of thermochemistry and are of great importance in fire modelling and fire safety engineering.

In Europe, under the classification system [2] mandated by the Construction Products Regulation [3], materials are classified as non-combustible if they have a gross heat of combustion of ≤2 kJ·g^{-1} as measured in a bomb calorimeter according to ISO 1716, or if they meet defined requirements when tested to ISO 1182 [4].

Surface finish materials used in accommodation spaces of international trading merchant ships are required to have a calorific potential (heat of combustion) equal to or less than 45 MJ·m^{-2} measured by ISO 1716 in accordance with the SOLAS Convention [5].

4.3 Measurements of incomplete combustion

4.3.1 Cone calorimeter

4.3.1.1 Test methods

See ISO 5660-1 [6] and ASTM E1354 [7].

4.3.1.2 Purpose and principle

This small-scale test method for determining heat release is based on the oxygen consumption technique. It incorporates a load cell for mass loss determinations, a test specimen holder, a conical heater for applying a uniform flux to the test specimen surface and oxygen consumption measurement equipment.

This test method provides measurements of the rate of heat release, including peak and average values, total heat release, effective heat of combustion, mass loss, time to ignition and smoke obscuration. The exposures are made with and without spark ignition. The testing of specimens takes place in well-ventilated conditions.

The range of external heat flux in ASTM E1354 is from 0 $kW \cdot m^{-2}$ to 100 $kW \cdot m^{-2}$.in, and from 0 $kW \cdot m^{-2}$ to 75 $kW \cdot m^{-2}$ in ISO 5660-1.

ASTM D6113 [8] has been published as a test method on wires and cables.

4.3.1.3 Test specimen

The specimen holder can accommodate test specimens up to 100 mm × 100 mm × 50 mm thick. The normal orientation is horizontal, but vertical specimen holders also permit exposure in a vertical orientation.

4.3.1.4 Test procedure

During the test, a test specimen is exposed to a specified radiant flux from an electrical conical heater. Piloted ignition is achieved by using an external spark, which is moved into position over the test specimen until ignition occurs. The heat release rate is assessed by measuring the oxygen concentration in the exhaust duct and by using the principle of oxygen consumption (see 3.22 and IEC 60695-8-1).

4.3.1.5 Repeatability and reproducibility

Round-robin evaluation tests have been conducted on building products and on plastic materials. Details are available in ASTM RR E05-1008 [9].

Other round-robin evaluation tests have been conducted on building products and plastic materials (see Clauses C.1 to C.3 of ISO 5660-1:2015 [6]) and on plastic materials which intumesce or deform under heat exposure (see Clause C.4 of ISO 5660-1:2015).

No round-robin evaluation data are currently available on electrotechnical products.

4.3.1.6 Relevance of test data

Data obtained from these tests may be used as input to evaluate the contribution to the overall fire hazard, as input into fire safety engineering calculations, and for research and product development.

NOTE 1 In Japan, ISO 5660-1 has been used for the determination of building materials as non-combustible and quasi-non-combustible, and the cone calorimeter apparatus has been used to test small electrotechnical items.

NOTE 2 Although wires and cables can be installed in the test specimen holder and tested, no relationship to large-scale tests has been confirmed.

4.3.2 Microscale calorimetry

4.3.2.1 Test method

See ASTM D 7309 [10].

4.3.2.2 Purpose and principle

This small-scale fire test is used to determine the flammability characteristics of combustible materials, and is based on the oxygen consumption technique. The test is conducted in a laboratory environment using controlled heating of milligram specimens and complete thermal oxidation of the specimen gases. Specimens of known mass are thermally decomposed in an oxygen-free (anaerobic) or oxidizing (aerobic) environment at a constant heating rate.

The apparatus incorporates a temperature-controlled specimen chamber, a test specimen holder, a mixing chamber, a combustion chamber (combustor) and oxygen consumption measurement equipment.