IEC/TR 60695-8-2

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# TECHNICAL REPORT

# RAPPORT TECHNIQUE



## 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



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## FOREWORD

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IEC 60695-8-2, which is a technical report, has been prepared by IEC technical committee 89: Fire hazard testing.

This second edition cancels and replaces the first edition of IEC 60695-8-2/TS published in 2000 and constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

– editorial changes throughout;

– revised terms and definitions;
– introduction of a new Subclause 4.1.1 – Bomb calorimeter;
– introduction of a new Table 1 dealing with vertical ladder tests;
– introduction of a new Subclause 4.2.4 – SBI test method;
– introduction of a new Subclause 4.2.6 – Open calorimetry fire tests.

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

This technical report is to be used in conjunction with IEC 60695-8-1.

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

| Enquiry draft | Report on voting |
|---|---|
| 89/808/DTR | 89/830A/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 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.



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- withdrawn,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.

# INTRODUCTION

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

The primary aims are as follows:

1) to prevent ignition caused by an electrically energized component part, and
2) 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 heat sources. Considerations of this nature are dealt with in the overall risk assessment.

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. Fire risk increases as the heat released increases, possibly leading to a flash-over 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 which 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).

1) Figures in square brackets refer to the bibliography.

# FIRE HAZARD TESTING –

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

## 1 Scope

This part of IEC 60695 presents a summary of published test methods that are relevant to determine heat release for electrotechnical products. 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 TC89 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 [1] and IEC 60695-1-11 [2].

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 60695-4:2005, *Fire hazard testing – Part 4: Terminology concerning fire tests for electrotechnical products*

IEC 60695-8-1:2001, *Fire hazard testing – Part 8-1: Heat release – General guidance*

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*

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

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. Other terms and definitions are as given in IEC 60695-4 and ISO 13943.

**3.1**
**combustion**
exothermic reaction of a substance with an oxidizing agent

NOTE Combustion generally emits fire effluent accompanied by flames and/or glowing.

[ISO/IEC 13943, definition 23 modified]

**3.2**
**combustion products**
solid, liquid and gaseous material resulting from combustion

NOTE Combustion products may include fire effluent, ash, char, clinker and/or soot.

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

NOTE 1 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 If elements other than carbon, hydrogen and oxygen are involved in the combustion process, then it may not be possible to uniquely define complete combustion.



**3.4**
**controlled fire**
fire which has been deliberately arranged to provide useful effects and which is controlled in its extent in time and space

**3.5**
**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 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 The typical units are $kJ \cdot g^{-1}$.

**3.6**
**fire**
process of combustion characterized by the emission of heat and fire effluent accompanied by smoke, and/or flame, and/or glowing

**3.7**
**fire effluent**
totality of gases and/or aerosols (including suspended particles) created by combustion or pyrolysis

[ISO/IEC 13943, definition 45]

**3.8**
**fire hazard**
physical object or condition with a potential for an undesirable consequence from fire

**3.9**
**fire safety engineering**
application of engineering methods based on scientific principles for 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

**3.10**
**fire test**
procedure designed to measure or assess either fire behaviour or the response of a test specimen to one or more aspects of fire

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

[ISO/IEC 13943, definition 77]

**3.12**
**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

[ISO/IEC 13943, definition 86.2]



**3.13**
**heat of combustion**
thermal energy produced by combustion of unit mass of a given substance

NOTE The typical units are $kJ \cdot g^{-1}$.

See also 3.5, 3.12 and 3.18.

**3.14**
**heat release**
thermal energy which is produced in a fire or fire test

NOTE The typical units are joules.

**3.15**
**heat release rate**
thermal energy released per unit time in a fire or fire test

NOTE The typical units are watts.

**3.16**
**intermediate-scale fire test**
fire test performed on a test specimen of medium dimensions

NOTE This definition usually applies to a fire test performed on a test specimen of which the maximum dimension is between 1 m and 3 m.

**3.17**
**large-scale fire test**
fire test, which cannot be carried out in a typical laboratory chamber, performed on a test specimen of large dimensions

NOTE This definition usually applies to a fire test performed on a test specimen of which the maximum dimension is greater than 3 m.

**3.18**
**net heat of combustion**
heat of combustion when any water produced is considered to be in the gaseous state

NOTE 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.

**3.19**
**oxidation**
chemical reaction in which the proportion of oxygen or other electronegative element in a substance is increased

NOTE In chemistry, the term has the broader meaning of a process which involves the loss of an electron or electrons from an atom, molecule or ion.

**3.20**
**oxidizing agent**
substance capable of causing oxidation

NOTE Combustion is an oxidation.

**3.21**
**oxygen consumption principle**
proportional relationship between the mass of oxygen consumed during combustion and the heat released

NOTE A value of 13,1 $kJ \cdot g^{-1}$ is commonly used.

**3.22**
**pyrolysis**
chemical decomposition of a substance by the action of heat

NOTE 1 The term is often used to refer to a stage of fire before flaming combustion has occurred.

NOTE 2 In fire science, no assumption is made about the presence or absence of oxygen.

**3.23**
**small-scale fire test**
fire test performed on a test specimen of small dimensions

NOTE This definition usually applies to a fire test performed on a test specimen of which the maximum dimension is less than 1 m.

**3.24**
**test specimen**
item subjected to a procedure of assessment or measurement

NOTE In a fire test, the item may be a material, product, component, element of construction, or any combination of these. It may also be a sensor which is used to simulate the behaviour of a product.

**3.25**
**uncontrolled fire**
fire which spreads uncontrolled in time and space

## 4 Summary of test methods

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

## 4.1 Measurement of complete combustion

### 4.1.1 The bomb calorimeter

#### 4.1.1.1 Test method

ISO 1716 [3]

#### 4.1.1.2 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.

#### 4.1.1.3 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.

#### 4.1.1.4 Test method

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, $\Delta U$. The gross heat of combustion at constant pressure is the enthalpy change, $\Delta H$, where

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

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

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

In order to calculate $\Delta H$, 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 $\Delta U$ and $\Delta H$ is normally small and can be ignored for most fire science purposes. For example, in the case of carbon burning to form carbon dioxide.

$\Delta U = -32{,}76\ \text{kJ}\cdot\text{g}^{-1}$ and $\Delta H = -32{,}97\ \text{kJ}\cdot\text{g}^{-1}$.