IEC 60695-8-1

Edition 3.0 2016-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

Fire hazard testing –
Part 8-1: Heat release – General guidance

Essais relatifs aux risques du feu –
Partie 8-1: Dégagement de chaleur – Guide général

IEC 60695-8-1:2016-11(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 13.220.40; 29.020

ISBN 978-2-8322-3749-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FIRE HAZARD TESTING –

Part 8-1: Heat release – General guidance

FOREWORD

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International Standard IEC 60695-8-1 has been prepared by IEC technical committee 89: Fire hazard testing.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

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

a) a modified Introduction;
b) reference to IEC 60695-1-12;
c) updated normative references;
d) revised terms and definitions;
e) new text in 4.2.2, 4.2.3, 6.1 and 6.4, including several mandatory statements;
f) mandatory statements in a new Subclause 6.5.

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

FDIS	Report on voting
89/1342/FDIS	89/1348/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.

This standard is to be used in conjunction with IEC 60695-8-2.

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.

IEC 60695-8 consists of the following parts:

Part 8-1: *Heat release – General guidance*

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

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- withdrawn,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

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 the risk of fire to a tolerable level even in the event of reasonably foreseeable (mis)use, malfunction or failure. IEC 60695-1-10 [1][1] provides guidance on how this is to be accomplished.

Fires involving electrotechnical products can be initiated from external non-electrical sources. Considerations of this nature are dealt with in an overall risk 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. 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 reasonably foreseeable (mis)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 the side-effects of the fire (see the IEC 60695 series of standards).

1 Numbers in square brackets refer to the Bibliography.

FIRE HAZARD TESTING –

Part 8-1: Heat release – General guidance

1 Scope

This part of IEC 60695-8 provides guidance on the measurement and interpretation of heat release from electrotechnical products and materials from which they are constructed.

Heat release data can be used as part of fire hazard assessment and in fire safety engineering, as described in IEC 60695-1-11 [2] and IEC 60695-1-12 [3].

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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60695-4:2012, *Fire hazard testing – Part 4: Terminology concerning fire tests for electrotechnical products*

IEC 60695-8-2, *Fire hazard testing – Part 8-2: Heat release – Summary and relevance of 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 13943:2008, *Fire safety – Vocabulary*

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
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: The value is the same as the net heat of combustion if the entire 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

[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, 4.112]

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 for 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 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·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: The term is often used to refer to a stage of fire before flaming combustion has occurred.

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 for 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, 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.

[SOURCE: ISO 13943: 2008, 4.321]

4 Principles of determining heat release

4.1 Complete combustion measured by the oxygen bomb calorimeter

The most important device for measuring heats of combustion is the adiabatic constant volume bomb calorimeter. The “bomb” is a central vessel which 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 known mass of sample is placed inside the bomb in contact with an electrical ignition wire. The vessel is filled with oxygen under pressure, 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 which 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 is the enthalpy change, ΔH, where:

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

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

$$\Delta(PV) = \Delta(n\mathrm{R}T)$$

NOTE Bomb calorimeter measurement of the heat of combustion of building products is described in ISO 1716 [4].

4.2 Incomplete combustion

4.2.1 Measurement techniques

Combustion in fires, which usually occur in air and at atmospheric pressure, is almost always incomplete and therefore the heat released will be less than the combined heats of combustion of the materials involved.

The heat released can be determined indirectly using one of the following techniques:

a) oxygen consumption;

b) carbon dioxide generation;

c) gas temperature increase.

4.2.2 Heat release by oxygen consumption

For a large number of organic fuels, an approximately constant amount of heat is released per unit of oxygen consumed [5], [6]. The average value for this constant is 13,1 $\mathrm{kJ \cdot g^{-1}}$ of oxygen and this value is widely used for practical applications both in small-scale and large-scale testing. This relationship implies that it is sufficient to measure the oxygen consumed in a combustion system, and the mass flow rate in the exhaust duct in order to determine heat release.

Table 1 lists some net heat of combustion values [6]. With the exception of three materials: ethene, ethyne and poly(oxymethylene), all the calculated heats of combustion per gram of oxygen consumed lie between 12,5 kJ and 13,6 kJ. The values in Table 1 are calculated assuming complete combustion. However, Huggett [6] does discuss the effects of possible incomplete combustion and calculates values of ΔH_c for several such cases. For example, in the case of cellulose burning to give a 9:1 ratio of CO2 to CO:

$$(C_6H_{10}O_5) + 5{,}7\ O_2 \rightarrow 5{,}4\ CO_2 + 0{,}6\ CO + 5\ H_2O \quad \Delta H_c = -13{,}37\ \mathrm{kJ \cdot g^{-1}\ of\ O_2}$$

or burning to give an appreciable amount of carbonaceous char:

$$(C_6H_{10}O_5) + 3\ O_2 \rightarrow 3\ CO_2 + 3\ C + 5\ H_2O \quad \Delta H_c = -13{,}91\ \mathrm{kJ \cdot g^{-1}\ of\ O_2}$$

compared with complete combustion:

$$(C_6H_{10}O_5) + 6\ O_2 \rightarrow 6\ CO_2 + 5\ H_2O \quad \Delta H_c = -13{,}59\ \mathrm{kJ \cdot g^{-1}\ of\ O_2}$$

Huggett discusses several other examples and concludes that the assumption of a constant heat release per unit of oxygen consumed will be sufficiently accurate for most applications.

If the correct value of ΔH_c per gram of O_2 is known for a particular material then this shall be used instead of the approximate value.

Table 2 lists some heat of combustion values for insulating liquids.

There is a variety of fire tests that use the oxygen consumption method. They vary from the micro-scale, e.g. ASTM D 7309 [7], to the large-scale, e.g. EN 50289-4-11 [8].

Heat release fire tests that are of relevance to the testing of electrotechnical products are described in IEC 60695-8-2.

4.2.3 Heat release by carbon dioxide generation

This technique is based on the concept that the energy released in a combustion reaction is approximately proportional to the amount of carbon dioxide generated, provided that combustion is complete or nearly complete (i.e. with very small CO/CO_2 ratios). The average value for the proportionality constant is 13,3 $kJ \cdot g^{-1}$ of carbon dioxide generated. If a more accurate value is known for the material or product, it shall be used in calculating heat release.

In general, heat release values determined by carbon dioxide generation agree well with heat release rate values determined by oxygen consumption.

4.2.4 Heat release by increase of gas temperature

The gas temperature technique is based on the assumptions that there are no heat losses and that all the heat generated by the fire is used to increase the temperature of the hot flowing mixture of air and fire effluent, and that their temperatures can be determined downstream from the flaming zone. If the heat losses, mainly from thermal radiation, are negligible, then the gas temperature rise technique (also called the thermopile technique) would represent the same heat release value as the oxygen consumption or the carbon dioxide generation method. The heat release is determined by measuring the increase in the temperature of the gases, at the thermopile, with respect to a reference temperature, generally the ambient temperature. This is converted to heat release by means of measurements of the total flow of the air and fire effluent mixture using the specific heat of the mixture at the appropriate air temperature, or simply by calibration with a constant flow of a material of well-known heat release, such as methane.

In general, heat release values determined by temperature measurement are lower than heat release values determined by oxygen consumption or carbon dioxide generation calorimetry techniques, because heat losses are generally not negligible. In a small-scale test, these heat losses can, with care, be minimized by attempting to make the system as adiabatic as possible.

A method of obtaining heat release values by temperature measurement has been developed as ISO 13927 [22] which uses the same heating system and specimen mounting system as ISO 5660-1 and can be used for production control and/or comparison purposes for research and development. The test apparatus is both relatively easy to use and is of relatively low cost.