BS EN 60695-7-2:2011

BSI Standards Publication

Fire hazard testing

Part 7-2: Toxicity of fire effluent — Summary and relevance of test methods

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National foreword

This British Standard is the UK implementation of EN 60695-7-2:2011. It is identical to IEC 60695-7-2:2011. It supersedes PD IEC/TR 60695-7-2:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/89, Fire hazard testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Foreword

The text of document 89/1059/FDIS, future edition 1 of IEC 60695-7-2, prepared by IEC/TC 89 "Fire hazard testing" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60695-7-2:2011.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-07-04
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Endorsement notice

The text of the International Standard IEC 60695-7-2:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

ISO 5659-2	NOTE Harmonized as EN ISO 5659-2.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60695-7-1	2010	Fire hazard testing - Part 7-1: Toxicity of fire effluent - General guidance	EN 60695-7-1	2010
IEC/TS 60695-7-3	-	Fire hazard testing - Part 7-3: Toxicity of fire effluent - Use and interpretation of test results	-	-
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 13344	-	Estimation of the lethal toxic potency of fire effluents	-	-
ISO 13571	2007	Life-threatening components of fire - Guidelines for the estimation of time available for escape using fire data	-	-
ISO 13943	-	Fire safety - Vocabulary	-	-
ISO 16312-1	2010	Guidance for assessing the validity of physical fire models for obtaining fire effluent toxicity data for fire hazard and risk assessment - Part 1: Criteria	-	-
ISO/TR 16312-2	2007	Guidance for assessing the validity of physical fire models for obtaining fire effluent toxicity data for fire hazard and risk assessment - Part 2: Evaluation of individual physical fire models	-	-
ISO 19701	-	Methods for sampling and analysis of fire effluents	-	-
ISO 19702	-	Toxicity testing of fire effluents - Guidance for analysis of gases and vapours in fire effluents using FTIR gas analysis	-	-
ISO 19703	2010	Generation and analysis of toxic gases in fire -- Calculation of species yields, equivalence ratios and combustion efficiency in experimental fires	--	-
ISO 19706	-	Guidelines for assessing the fire threat to people	-	-

CONTENTS

INTRODUCTION

The IEC 60695-7 series provides guidance to IEC product committees on the adoption and implementation of the recommendations of ISO/TC 92, for the minimization of toxic hazard from fires involving electrotechnical products.

Electrotechnical products, primarily as the objects of a fire, may contribute to the fire hazard due to release of toxic effluent, which may be a significant contributing factor to the overall fire hazard.

IEC product committees incorporating requirements for the assessment of toxic hazard from fire in product standards should note that toxic potency and other measurements of toxicity which are described in this international standard should not be used directly in product specifications. Data from toxic potency test methods should only be used as part of a toxic hazard assessment, in conjunction with other product-based reaction to fire data such as mass loss rate.

FIRE HAZARD TESTING –

Part 7-2: Toxicity of fire effluent – Summary and relevance of test methods

1 Scope

This part of IEC 60695 gives a brief summary of the test methods that are in common use in the assessment of acute toxic potency, and other toxicity tests. It includes special observations on their relevance to real fire scenarios and gives recommendations on their use.

It advises which tests provide toxic potency data that are relevant to real fire scenarios, and which are suitable for use in fire hazard assessment and fire safety engineering.

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 60695-7-1:2010, *Fire hazard testing – Part 7-1: Toxicity of fire effluent – General guidance*

IEC/TS 60695-7-3, *Fire hazard testing – Part 7-3: Toxicity of fire effluent – Use and interpretation of test results*

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

ISO/IEC 13943, *Fire safety – Vocabulary*

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

ISO 13344, *Estimation of the lethal toxic potency of fire effluents*

ISO 13571:2007, *Life-threatening components of fire – Guidelines for the estimation of time available for escape using fire data*

ISO 16312-1:2010, *Guidance for assessing the validity of physical fire models for obtaining fire effluent toxicity data for fire hazard and risk assessment – Part 1: Criteria*

ISO/TR 16312-2:2007, *Guidance for assessing the validity of physical fire models for obtaining fire effluent toxicity data for fire hazard and risk assessment – Part 2: Evaluation of individual physical fire models*

ISO 19701, *Methods for sampling and analysis of fire effluents*

ISO 19702*, Toxicity testing of fire effluents – Guidance for analysis of gases and vapours in fire effluents using FTIR gas analysis*

ISO 19703:2010*, Generation and analysis of toxic gases in fire – Calculation of species yields, equivalence ratios and combustion efficiency in experimental fires*

ISO 19706, *Guidelines for assessing the fire threat to people*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 13943:2008, some of which are reproduced below for the user's convenience, as well as the following, apply.

3.1
acute toxicity
toxicity that causes rapidly occurring toxic effects

cf. **toxic potency** (3.45).

[ISO/IEC 13943:2008, definition 4.5]

3.2
burn, intransitive verb
undergo combustion

[ISO/IEC 13943:2008, definition 4.28]

3.3
burn, transitive verb
cause combustion

[ISO/IEC 13943:2008, definition 4.29]

3.4
combustible, adjective
capable of being ignited and burned

[ISO/IEC 13943:2008, definition 4.43]

3.5
combustible, noun
item capable of combustion

[ISO/IEC 13943:2008, definition 4.44]

3.6
combustion
exothermic reaction of a substance with an oxidizing agent

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

[ISO/IEC 13943:2008, definition 4.46]

3.7
combustion efficiency
ratio of the amount of heat release in incomplete combustion to the theoretical heat of complete combustion

NOTE 1 Combustion efficiency can be calculated only for cases where complete combustion can be defined.

NOTE 2 Combustion efficiency is dimensionless and is usually expressed as a percentage.

[ISO/IEC 13943:2008, definition 4.47]

3.8
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 present in the combustible material, those elements are converted to the most stable products in their standard states at 298 K.

[ISO/IEC 13943:2008, definition 4.50]

3.9
concentration
mass per unit volume

NOTE 1 For a fire effluent the typical units are grams per cubic metre ($g \times m^{-3}$).

NOTE 2 For a toxic gas, concentration is usually expressed as a volume fraction at T = 298 K and P = 1 atm, with typical units of microlitres per litre (μL/L), which is equivalent to cm^3/m^3 or 10^{-6}.

NOTE 3 The concentration of a gas at a temperature, T, and a pressure, P, can be calculated from its volume fraction (assuming ideal gas behaviour) by multiplying the volume fraction by the density of the gas at that temperature and pressure.

[ISO/IEC 13943:2008, definition 4.52]

3.10
enclosure
⟨built environment⟩ volume defined by bounding surfaces, which may have one or more openings

[ISO/IEC 13943:2008, definition 4.77]

3.11
equivalence ratio
fuel/air ratio divided by the fuel/air ratio required for a stoichiometric mixture

NOTE 1 Standard, dry air contains 20,95 % oxygen by volume. In practice, the oxygen concentration in entrained air can vary and calculation of the equivalence ratio to a standard, dry air basis is required.

NOTE 2 The equivalence ratio is dimensionless.

[ISO/IEC 13943:2008, definition 4.81]

3.12
exposure dose
measure of the maximum amount of a toxic gas or fire effluent that is available for inhalation, calculated by integration of the area under a concentration-time curve

NOTE 1 For fire effluent, typical units are grams times minutes per cubic metre ($g \times min \times m^{-3}$).

NOTE 2 For a toxic gas, typical units are microlitres times minutes per litre ($\mu L \times min \times L^{-1}$) (at T = 298 K and P = 1 atm); see 'volume fraction' 3.49.

[ISO/IEC 13943:2008, definition 4.89]

3.13
exposure time
length of time for which people, animals or test specimens are exposed under specified conditions

[ISO/IEC 13943:2008, definition 4.90]

3.14
F factor
minimum concentration of a toxic gas irritant that is expected to seriously compromise the ability to escape from a fire

NOTE The concentration is usually expressed as a volume fraction at T = 298 K and P = 1 atm, in which case the typical units are microlitres per litre (μL/L), which is equivalent to cm^3/m^3 or 10^{-6}.

[ISO/IEC 13943:2008, definition 4.94]

3.15
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

[ISO/IEC 13943:2008, definition 4.96]

3.16
fire effluent
totality of gases and aerosols, including suspended particles, created by combustion or pyrolysis in a fire

[ISO/IEC 13943:2008, definition 4.105]

3.17
fire hazard
physical object or condition with a potential for an undesirable consequence from fire

[ISO/IEC 13943:2008, definition 4.112]

3.18
fire hazard assessment
evaluation of the possible causes of fire, the possibility and nature of subsequent fire growth, and the possible consequences of fire

3.19
fire plume
plume
buoyant gas stream and any materials transported within it, above a fire

[ISO/IEC 13943:2008, definition 4.118]

3.20
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

[ISO/IEC 13943:2008, definition 4.126]

3.21
fire scenario
qualitative description of the course of a fire with respect to time, identifying key events that characterise the studied fire and differentiate it from other possible fires

NOTE It typically defines the ignition and fire growth processes, the fully developed fire stage, the fire decay stage, and the environment and systems that impact on the course of the fire.

[ISO/IEC 13943:2008, definition 4.129]

3.22
fire test
test that measures behaviour of a fire or exposes an item to the effects of a fire

NOTE 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.

[ISO/IEC 13943:2008, definition 4.132]

3.23
flame retardance
property of a material whereby flaming combustion is slowed, terminated or prevented

NOTE 1 Flame retardance can be an inherent property of the basic material or it may be imparted by specific treatment.

NOTE 2 The degree of flame retardance exhibited by a material during testing can vary with the test conditions.

[ISO/IEC 13943:2008, definition 4.138]

3.24
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 the flame-spread rate

NOTE The use of (a) flame retardant(s) does not necessarily suppress fire or terminate combustion.

[ISO/IEC 13943:2008, definition 4.139]

3.25
flame retarded
treated with a flame retardant

[ISO/IEC 13943:2008, definition 4.141]

3.26
flashover
(stage of fire) transition to a state of total surface involvement in a fire of combustible materials within an enclosure

[ISO/IEC 13943:2008, definition 4.156]

3.27
fractional effective concentration
FEC
ratio of the concentration of an irritant to that concentration expected to produce a specified effect on an exposed subject of average susceptibility

NOTE 1 As a concept, fractional effective concetration may refer to any effect, including incapacitation, lethality or other endpoints.

NOTE 2 When not used with reference to a specific irritant, the term “FEC” represents the summation of FEC values for all irritants in a fire-generated atmosphere.

NOTE 3 The FEC is dimensionless.

[ISO/IEC 13943:2008, definition 4.159]

3.28
fractional effective dose
FED
ratio of the exposure dose for an asphyxiant to that exposure dose of the asphyxiant expected to produce a specified effect on an exposed subject of average susceptibility

NOTE 1 As a concept, fractional effective dose may refer to any effect, including incapacitation, lethality or other endpoints.

NOTE 2 When not used with reference to a specific asphyxiant, the term “FED” represents the summation of FED values for all asphyxiants in a combustion atmosphere.

NOTE 3 The FED is dimensionless.

[ISO/IEC 13943:2008, definition 4.160]

3.29
fully developed fire
state of total involvement of combustible materials in a fire

[ISO/IEC 13943:2008, definition 4.164]

3.30
heat flux
amount of thermal energy emitted, transmitted or received per unit area and per unit time

NOTE The typical units are watts per square metre ($W \times m^{-2}$).

[ISO/IEC 13943:2008, definition 4.173]

3.31
ignition source
source of energy that initiates combustion

[ISO/IEC 13943:2008, definition 4.189]

3.32
incapacitation
state of physical inability to accomplish a specific task

NOTE An example of a specific task is to accomplish escape from a fire.

[ISO/IEC 13943:2008, definition 4.194]

3.33
lethal concentration 50
$\boldsymbol{LC_{50}}$
concentration of a toxic gas or fire effluent, statistically calculated from concentration-response data, that causes death of 50 % of a population of a given species within a specified exposure time and post-exposure time

NOTE 1 For fire effluent, typical units are grams per cubic metre ($g \times m^{-3}$).

NOTE 2 For a toxic gas, the typical units are microlitres per litre (μL/L) at T = 298 K and P = 1 atm; see ‘volume fraction’ 3.49.

[ISO/IEC 13943:2008, definition 4.207]

3.34
lethal exposure dose 50
***LCt*$_{50}$**
product of LC_{50} and the exposure time over which it is determined

cf. **concentration** (3.9) and **exposure dose** (3.12).

NOTE 1 LCt_{50} is a measure of lethal toxic potency.

NOTE 2 For fire effluent, the typical units are grams times minutes per cubic metre (g × min × m^{-3}).

NOTE 3 For a toxic gas, typical units are microlitres times minutes per litre (μL × min × L^{-1}) at T = 298 K and P = 1 atm; see 'volume fraction' 3.49.

[ISO/IEC 13943:2008, definition 4.208]

3.35
lethal toxic potency
toxic potency where the specific toxic effect is death

cf**. lethal exposure dose 50**, LCt_{50} (3.34).

3.36
mass loss concentration
⟨closed system⟩ mass of the test specimen consumed during combustion divided by the test chamber volume

NOTE The typical units are grams per cubic metre (g × m^{-3}).

[ISO/IEC 13943:2008, definition 4.222]

3.37
mass loss concentration
⟨open system⟩ mass of the test specimen consumed during combustion divided by the total volume of air passed through the test apparatus

NOTE 1 The definition assumes that the mass is dispersed in the air flow uniformly over time.

NOTE 2 The typical units are grams per cubic metre (g × m^{-3}).

[ISO/IEC 13943:2008, definition 4.223]

3.38
physical fire model
laboratory process, including the apparatus, the environment and the fire test procedure intended to represent a certain phase of a fire

[ISO/IEC 13943:2008, definition 4.251]

3.39
pyrolysis
chemical decomposition of a substance by the action of heat

NOTE 1 Pyrolysis is often used to refer to a stage of fire before flaming combustion has begun.

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

[ISO/IEC 13943:2008, definition 4.266]

3.40
real-scale fire test
fire test that simulates a given application, taking into account the real scale, the real way the item is installed and used, and the environment

NOTE Such a fire test normally assumes that the products are used in accordance with the conditions laid down by the specifier and/or in accordance with normal practice.

[ISO/IEC 13943:2008, definition 4.273]

3.41
smoke
visible part of fire effluent

[ISO/IEC 13943:2008, definition 4.293]

3.42
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 that is used to simulate the behaviour of a product.

[ISO/IEC 13943:2008, definition 4.321]

3.43
thermal decomposition
process whereby the action of heat or elevated temperature on an item causes changes to the chemical composition

NOTE This is different from thermal degradation.

[ISO/IEC 13943:2008, definition 4.323]

3.44
toxic
poisonous

NOTE A poisonous substance produces adverse effects upon a living organism, e.g. irritation, narcosis or death.

[ISO/IEC 13943:2008, definition 4.335]

3.45
toxic hazard
potential for harm resulting from exposure to toxic combustion products

cf. **fire hazard** (3.17).

[ISO/IEC 13943:2008, definition 4.337]

3.46
toxic potency
measure of the amount of toxicant required to elicit a specific toxic effect

cf. **lethal exposure dose 50** (3.34).

NOTE A small value of toxic potency corresponds to a high toxicity, and vice versa.

[ISO/IEC 13943:2008, definition 4.338]

3.47
toxicant
toxin
toxic substance

[ISO/IEC 13943:2008, definition 4.340]

3.48
toxicity
toxic quality

cf. **acute toxicity** (3.1) and **toxic potency** (3.46).

[ISO/IEC 13943:2008, definition 4.341]

3.49
volume fraction
⟨gas in a gas mixture⟩ ratio of

– the volume that the gas alone would occupy at a defined temperature and pressure, to:
– the volume occupied by the gas mixture at the same temperature and pressure

NOTE 1 The concentration of a gas at a temperature, T, and a pressure, P, can be calculated from its volume fraction (assuming ideal gas behaviour) by multiplying the volume fraction by the density of the gas at that temperature and pressure.

NOTE 2 Unless stated otherwise, a temperature of 298 K and a pressure of 1 atm are assumed.

NOTE 3 The volume fraction is dimensionless and is usually expressed in terms of microlitres per litre (μL/L), which is equivalent to cm^3/m^3 or 10^{-6}), or as a percentage.

[ISO/IEC 13943:2008, definition 4.351]

3.50
volume yield
volume, at 298 K and 1 atm, of a component of fire effluent divided by the mass loss of the test specimen associated with the production of that volume

NOTE The typical units are cubic metres per gram ($m^3 \times g^{-1}$).

[ISO/IEC 13943:2008, definition 4.352]

4 Role of small-scale toxicity tests

4.1 General

Small-scale toxicity tests, and toxic potency tests in particular, serve a very specific purpose – to generate data to be used in toxic hazard assessments, fire hazard assessments, or fire-safety engineering calculations.

These tests are often wrongly interpreted as providing data which give a direct indication of the toxicity or toxic hazard associated with a material or product. Such interpretations are invalid and are contrary to the guidance given in ISO 19706 and IEC 60695-7-1, and are likely to lead to incorrect assumptions about the contribution of a given material or product to toxic hazard.

Therefore, the data from small-scale toxicity tests should not be used directly in product specifications, or to imply in isolation, any level of toxic hazard.

Data from toxic potency test methods should only be used as part of a toxic hazard assessment in conjunction with other product based reaction to fire data such as mass loss rate.

4.2 Toxic potency

The term toxic potency is a specific technical term in fire science. It is the measure of the amount of toxicant required to elicit a specific toxic effect. One specific toxic potency that is

commonly used is the exposure dose that causes the death of 50 % of exposed organisms. This is known as the LCt_{50} (lethal exposure dose 50).

The exposure dose of the i^{th} toxic component, $[D]_i$, in a mixture of toxic components, is defined by the following equation:

$$[D]_i = \int C_i \, dt = X_i \frac{1}{V} \int m \, dt = X_i \, D_m$$

or, if the volume fraction of the i^{th} toxic component is constant over time,

$$[D]_i = C_i \times t$$

where

C_i is the volume fraction of the i^{th} toxic component;

X_i is the volume yield of the i^{th} toxic component from a toxic potency test;

D_m is the mass loss concentration integral, which is the integral of the mass lost over the exposure time, t, divided by the volume of the fire effluent;

m is the mass of the test specimen lost during the time of exposure;

t is the exposure time, and

V is the volume into which the fire effluent is dispersed.

In both cases the exposure dose has units of volume fraction × time, e.g. min.

In some cases, m/V, known as "mass loss concentration", is used instead of the volume fraction, in which case the exposure dose has units of concentration × time, e.g. g × min × m^{-3}.

Suppose that a 30 min exposure to a mass loss concentration of 20 g × m^{-3} causes the defined effect, then the toxic potency of the material is 600 g × min × m^{-3}. This means that, for example, an exposure of 10 min to a mass loss concentration of 60 g × m^{-3} is assumed to cause the defined effect. Similarly, an exposure of 20 min to a mass loss concentration of 30 g × m^{-3} is also assumed to cause the same defined effect.

The toxic potency of the fire effluent from a given material will vary according to the physical fire model used to generate the fire effluent. In particular, temperature and ventilation conditions are critical variables. This is discussed further in 5.1.

4.3 Fractional effective dose (*FED*) and toxic hazard

Toxic potency is only one of the factors which determines the toxic hazard posed in any given fire scenario in that it defines the toxic effect caused by the fire effluent, expressed per unit of mass loss. To estimate the toxic hazard posed by a particular product in a given scenario, it is equally important to have the data which define how much fire effluent is released, as a function of time (the mass loss characteristics of the product), and to know the volume into which this fire effluent is dispersed.

For a given dispersal volume, the toxic hazard is proportional to the product of the toxic potency and the mass loss rate characteristics of the product in question. Therefore a material with a high toxic potency and low end product mass loss rate could pose a similar toxic hazard to a material with low toxic potency and high end product mass loss rate.

4.4 Fractional effective concentration (FEC)

For sensory and/or upper respiration irritants, the basic principle for assessing the toxic hazard involves only the concentration of each irritant. Fractional effective concentrations ($FECs$) are determined for each irritant at each discrete increment of time. The time at which their sum exceeds a specified threshold value represents the time available for escape relative to chosen safety criteria (see ISO 13571).

4.5 Generic toxic potencies

It is important to realise that to carry out a toxic hazard assessment it is not always necessary to have toxic potency data on the material(s) in question. Extensive work in ISO and work published elsewhere has shown that most materials produce fire atmospheres of similar toxic potency.

Therefore, for the purpose of an initial toxic hazard assessment of any fire scenario, it is recommended that a generic toxic potency of 900 g $\times$ min $\times$ m^{-3} is assumed for all materials in well-ventilated pre-flashover fires and 450 g $\times$ min $\times$ m^{-3} for vitiated post-flashover fires (see 7.4 of ISO 13571:2007). The robustness of assuming a generic toxic potency can then be evaluated by repeating the assessment, using toxic potency values of 50 % and 200 % of the assumed generic value. If the alternative toxic potency values significantly change the outcome of the assessment, then further, more accurate toxic potency data may be required.

5 General aspects of small-scale toxicity tests

5.1 General

Small-scale toxicity tests are comprised, essentially, of two parts:

a) decomposition conditions (the physical fire model), which should be such that they generate fire effluent which has the same relative composition as that which would be produced in a specific stage of a real fire, and
b) evaluation methods for the fire effluent to assess or calculate toxic potency, which can be carried out by either exposing animals to the fire effluent, in a controlled manner, and monitoring their response, or by carrying out chemical analyses of the fire effluent and estimating toxic potency from their concentrations.

A critical part of any method is to be able to relate the toxic effect or concentrations observed to the mass loss of the material under test.

5.2 Physical fire models

A given material does not have a single toxic potency associated with it.

The composition of the fire effluent from a given material is not an inherent property of that material, but is critically dependent on the conditions under which that material is burnt. Therefore, the toxic potency of fire effluent is dependent on burning conditions. Decomposition temperature and the amount of ventilation are the main variables which affect the composition of fire effluent, and hence the toxic potency.

These variables have a critical effect because they affect the nature and the amounts of both asphyxiant and irritant species that are produced. For example, if a material contains nitrogen, then in vitiated conditions ammonia and hydrogen cyanide tend to be formed, whereas in well-ventilated conditions oxides of nitrogen tend to be produced.

Burning conditions also affect the efficiency of the conversion of carbon to oxides of carbon (carbon monoxide and carbon dioxide – the CO_2/CO ratio). A lower CO_2/CO ratio indicates a

higher proportion of carbon monoxide, which will result in a lower toxic potency value (i.e. more toxic)

It is critical to show that the test conditions defined in a standardized test method (the physical fire model) are relevant to, and replicate, the desired fire type in the fire scenario of concern. ISO has published a general classification of fire types in ISO 19706, as shown in Table 1. The important factors affecting the toxic potency of fire effluent are oxygen concentration and irradiance/ temperature.

In ISO 16312-1 guidance is given concerning the criteria for the assessment of the validity of physical fire models for obtaining fire effluent toxicity data for fire hazard and risk assessment and ISO/TR 16312-2 gives evaluations of individual physical fire models.

ISO 19703 provides definitions and equations for the calculation of toxic product yields and the fire conditions under which they have been derived in terms of equivalence ratio and combustion efficiency.

Table 1 – Characteristics of fire types (ISO 19706)

Fire type	Heat flux to fuel surface kW/m^2	Max. temperature °C		Oxygen volume %		Fuel/air equivalence ratio (plume)	$\frac{[CO]}{[CO_2]}$	$\frac{100\times[CO_2]}{([CO_2]+[CO])}$
		Fuel surface	Upper layer	Entrained	Exhausted		v/v	% efficiency
1. Non-flaming								
a) self-sustaining (smouldering)	not applicable	450 to 800	25 to 85 [d]	20	20	—	0,1 to 1	50 to 90
b) oxidative pyrolysis from externally applied radiation	—	300 to 600 [a]	[b]	20	20	< 1	[c]	[c]
c) anaerobic pyrolysis from externally applied radiation	—	100 to 500	[b]	0	0	>> 1	[c]	[c]
2. Well-ventilated flaming [d]	0 to 60	350 to 650	50 to 500	≈ 20	≈ 20	< 1	< 0,05 [e]	> 95
3. Under-ventilated flaming [f]								
a) small, localized fire, generally in a poorly ventilated compartment	0 to 30	300 to 600 [a]	50 to 500	15 to 20	5 to 10	> 1	0,2 to 0,4	70 to 80
b) post-flashover fire	50 to 150	350 to 650 [g]	> 600	< 15	< 5	> 1 [h]	0,1 to 0,4 [i]	70 to 90

a The upper limit is lower than for well-ventilated flaming combustion of a given combustible.

b The temperature in the upper layer of the fire room is most likely determined by the source of the externally applied radiation and room geometry.

c There are few data; but for pyrolysis, this ratio is expected to vary widely depending on the material chemistry and the local ventilation and thermal conditions.

d The fire's oxygen consumption is small compared to that in the room or the inflow, the flame tip is below the hot gas upper layer or the upper layer is not yet significantly vitiated to increase the CO yield significantly, the flames are not truncated by contact with another object, and the combustion rate is controlled by the availability of fuel.

e The ratio may be up to an order of magnitude higher for materials that are fire-resistant. There is no significant increase in this ratio for equivalence ratios up to ≈ 0,75. Between ≈ 0,75 and 1, some increase in this ratio may occur.

f The fire's oxygen demand is limited by the ventilation opening(s); the flames extend into the upper layer.

g Assumed to be similar to well-ventilated flaming.

h The plume equivalence ratio has not been measured; the use of a global equivalence ratio is inappropriate.

i Instances of lower ratios have been measured. Generally, these result from secondary combustion outside the room vent.

5.3 Fire stages in a compartment fire

A general pattern can be established for fire development within a compartment, where the general temperature-time curve shows three stages, plus a decay stage (see Figure 1 and Table 1).

Stage 1 (non-flaming decomposition) is the incipient stage of the fire prior to sustained flaming, with little rise in the fire room temperature. Smoke and toxic effluent production are the main threats during this stage. Fire types 1a, 1b and 1c can all occur during this stage. Stage 2 (developing fire) starts with ignition and ends with an exponential rise in fire room temperature. Spread of flame, heat release and the production of smoke and toxic effluent are the main threats during this stage. Fire type 2 corresponds to this stage. Stage 3 (fully developed fire) starts when the surface of all of the combustible contents of the room has decomposed to such an extent that sudden ignition occurs all over the room, with a rapid and large increase in temperature (flashover). Fire type 3b corresponds to this stage.

At the end of Stage 3, the combustibles and/or oxygen have been largely consumed and hence the temperature decreases at a rate which depends on the ventilation and the heat and mass transfer characteristics of the system. This is known as the decay stage.

In each of these stages, a different mixture of decomposition products may be formed and this, in turn, will influence the toxicity of the fire effluent produced during that stage.

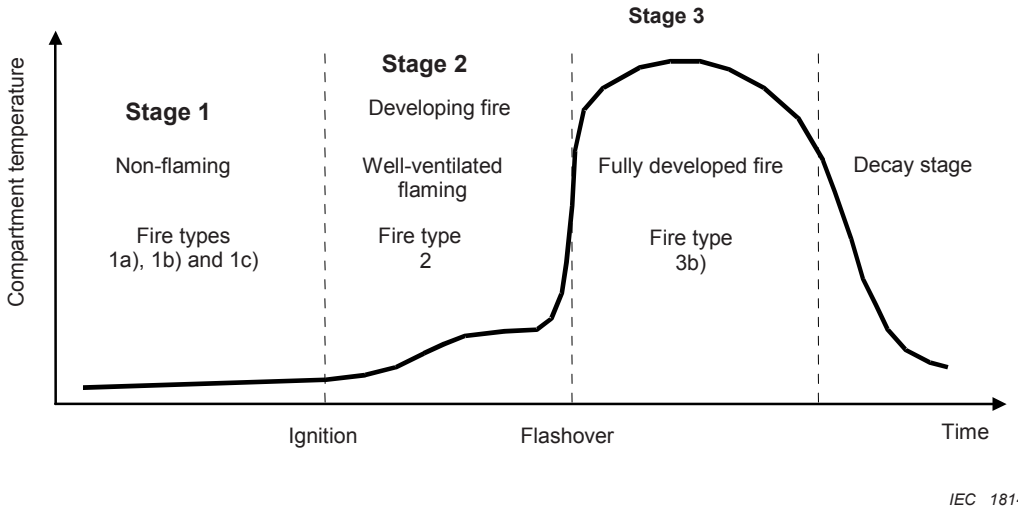

Figure 1 – Different phases in the development of a fire within a compartment

5.4 Methods of analysis

Early studies on the toxicity of fire effluent were based largely on the chemical analysis of fire gases and often gave faulty conclusions because of the poor quality of the data concerning the toxic potency of individual gases, and the lack of appreciation of the role of decomposition temperature and ventilation.

Work in the 1970s and early 1980s focused on animal tests on the basis that a complete understanding of the potential interactions between the individual components of fire effluent, and the possible presence of products exhibiting unusually high specific toxicity, could only be determined by animal exposure.

The conclusions from this work are that there are only moderately interactive effects between the constituents of fire effluent, and that there has not been an example of the presence of

products exhibiting unusually high specific toxicity in fire effluent. Toxic potencies of fire effluent from most materials have been found to be within one and a half orders of magnitude.

It is possible to calculate toxic potencies of fire gas mixtures reasonably accurately, based on the results of chemical analyses, and the toxicological data already available from animal testing. This avoids the need to use animals in the routine measurement of toxic potency, although it is recognized that some limited use of animal based tests may be necessary when the base toxicological data for a particular fire effluent are not available.

5.4.1 Chemical analysis based methods

Chemical analysis based methods use conventional laboratory analytical techniques to measure, either statically or dynamically, the concentrations of various gases in the fire effluent generated by the physical fire model [1][1].

There are several factors which have a critical impact on the accuracy of chemical analysis based techniques:

a) the effluent species selected for analysis should be broad enough to cover the species that could reasonably be expected to be released, based on knowledge of the composition of the material under test.

   In all cases, carbon dioxide, carbon monoxide and oxygen should be measured.

b) there shall be a reliable method to assess the mass loss of the test specimen during the test, in order to be able to convert the gas concentrations measured to concentrations per unit mass loss of test specimen;

c) it shall be possible to convert the measured gas concentrations and mass loss into toxic potency values. See IEC 60695-7-3 for a calculation method.

In ISO 19701, methods for the sampling and analysis of fire effluents are reviewed, and in ISO 19702 guidance is given on the use of FTIR (Fourier transform infra-red analysis).

5.4.2 Methods based on animal exposure

It is not recommended that any further work should be conducted on methods based on animal testing.

NOTE If test specimen mass loss is not measured in an animal exposure test, then the yields of toxic components cannot be calculated.

6 Summary of published chemical analysis based test methods

6.1 General

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

The chemical analysis based test methods reviewed in this clause were selected on the basis that they are published international, national or industry standards, and are in common use in the electrotechnical field. It is not intended to review all possible test methods.

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1 Numbers in square brackets refer to the bibliography.

6.2 UK Ministry of Defence – Defence Standard (DS)

6.2.1 Summary

The test described in DS 02-713 [2] explores the toxicity of products of combustion in terms of small molecular species arising when a small sample of a material is completely burnt in excess air under specified conditions.

6.2.2 Purpose and principle

Analytical data of certain small molecular gaseous species arising from the complete combustion under flaming conditions of the material under test are mathematically computed using the exposure level (volume fraction) of each gas to cause death within 30 min as a base, to derive a combined toxicity index.

6.2.3 Test specimen

A sufficient number of test specimens (normally three) are cut from the material under test. The mass of the test specimen is chosen so as to provide optimum analytical precision, dependent on the nature of the combustion products and the sensitivity of the analytical procedure.

6.2.4 Test method

The apparatus is an airtight enclosure of at least 0,7 m^3 lined with opaque plastic sheeting such as polypropylene. The chamber is equipped with a mixing fan. A methane bunsen burner having a temperature of 1 150 °C ± 50 °C is the heat source, and the test specimen is supported to locate it within the flame boundary. The burn period is continued to ensure complete combustion of the whole test specimen, and the time is recorded.

The test chamber atmosphere is sampled using colorimetric gas detection tubes. After complete combustion, the burner is extinguished. For a period of 30 s a mixing fan is used. This is switched off and the gases are sampled. Tests for halogen containing gases are performed first. The gases monitored are: carbon monoxide, carbon dioxide, hydrogen sulphide, ammonia, formaldehyde, hydrogen chloride, acrylonitrile, sulphur dioxide, oxides of nitrogen (NO_x), phenol, hydrogen cyanide, hydrogen bromide, hydrogen fluoride, and phosgene.

A background correction factor for the gases to be measured is also determined using a test run with no sample present.

The results are expressed as a toxicity index, based on a weighted calculation as follows:

$$\text{Toxicity index} = \sum C_\theta / C_f$$

where

C_f is the volume fraction of the gas considered lethal for a 30 min exposure time as shown in Table 2;

C_θ is the volume fraction of each gas produced when 100 g of material is burnt and the combustion products are dispersed into 1 m^3 of air.

Table 2 – C_f values taken from DS 02-713 for various gases

Gas	C_f value × 10^6
Carbon dioxide	100 000
Carbon monoxide	4 000
Hydrogen sulphide	750
Ammonia	750
Formaldehyde	500
Hydrogen chloride	500
Acrylonitrile	400
Sulphur dioxide	400
Nitrogen oxides	250
Phenol	250
Hydrogen cyanide	150
Hydrogen bromide	150
Hydrogen fluoride	100
Phosgene	25

6.2.5 Repeatability and reproducibility

No data are available.

Early versions of the test suffered from poor reproducibility due to the inadequate specification of the test chamber. The use of colorimetric tubes also introduces significant errors both due to the lack of precision of the tubes, and also the time delay caused by the sequential analysis method. There can be significant decay in the gas concentrations during the sampling period, which can be as long as 30 min.

6.2.6 Relevance of test data and special observations

This test method is now widely criticized (see e.g. 6.5.10 of ISO 16312-2:2007 and reference [3]):

a) the combination of flame temperature and ventilation conditions mean that the physical fire model used in this method does not correspond to any of the fire types described in Table 1;

b) the weighting values used in the calculation of the overall toxicity index are outdated and liable to cause unjustified bias against certain classes of materials, and

c) the data are expressed in a format which is unsuitable for use in toxic hazard assessment.

Overall, this method is not recommended as the basis for further development for electrotechnical products. It should not be used as the basis for regulation or other controls on the toxic hazard for electrotechnical products, because of the limitations of the physical fire model, the calculation method and the format of the final data. The data from this test should not be used as input to toxic hazard assessments, fire hazard assessments or fire safety engineering calculations.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

This test method is discussed in ISO 16312-2.

The UK Ministry of Defence intends to replace this test with NATO AFAP-3 (see 6.4.6).

6.2.7 Reference document

DS 02-713 [2].

6.3 Airbus industry

6.3.1 Summary

Airbus ABD 0031 [4] contains the fire worthiness design criteria for use inside the pressurized section of the fuselage of Airbus commercial aeroplanes. It specifies the fire-smoke-toxicity (FST) requirements and the applicable test methods. The following relates to the toxicity requirements only.

6.3.2 Purpose and principle

Non-metallic parts and sub-assemblies that are intended to be used inside the pressurized portion of the fuselage of transport category aircraft, except for materials used in small parts such as knobs, handles, rollers, fasteners, clips, grommets, rubber strips, pulleys and small electrical parts, are tested as described in 6.3.4.

6.3.3 Test specimen

The test method uses the same size test specimens as described in IEC 60695-6-30 [5], i.e. 76,2 mm × 76,2 mm × the intended installation thickness.

6.3.4 Test method

The test is performed in combination with (not simultaneously) the smoke density test in the NBS (National Bureau of Standards) smoke chamber according to ASTM E-662 [6].

The gas sampling procedure starts immediately after the 4 min smoke test run and after 16 min for electrical wire/cable insulation materials.

At least two test specimens are tested for each test condition (flaming and non-flaming).

Methods used for chemical analysis are e.g. ion chromatography or gas chromatography. Other methods may be used but it has to be demonstrated by comparison tests that equivalent results are obtained.

The observed volume fractions of the following gases are compared against the specification limits. The average volume fraction of the following gas components of smoke should not exceed the limits listed in Table 3 within the relevant test duration (4 min and 16 min respectively), under both flaming and non-flaming conditions.

Table 3 – Volume fraction limits for gas components

Gas component	Limit of volume fraction × 10^6
Hydrogen fluoride	100
Hydrogen chloride	150
Hydrogen cyanide	150
Sulfur dioxide	100
Nitrous gases	100
Carbon monoxide	3 500

6.3.5 Repeatability and reproducibility

No data are available.

6.3.6 Relevance of test data and special observations

Fire and ventilation conditions do not allow a comparison between this physical fire model and any of the fire types described in Table 1.

Only a limited number of gas components is considered.

6.3.7 Reference documents

ASTM E-662 [6]

AITM 2.0007 [7]

AITM 2.0008 [8]

AITM 3.0005 [9]

6.4 Comitato Elettrotecnico Italiano (CEI)

6.4.1 Summary

The test described in CEI 20-37/7 [10] is used for the determination of opacity and corrosivity of smoke, and a toxicity index of gases evolved during the combustion of electric cables and their compounds.

6.4.2 Purpose and principle

This test is used to measure the quantity of various gases evolved during the combustion of a small test specimen of material in a tube furnace with continuous air flow.

A toxicity index is calculated based on measured gas concentrations and a series of weighting factors.

6.4.3 Test specimen

The test specimen, with a typical mass of 1,0 g, consists of a piece of material or a test specimen cut from an end-product.

6.4.4 Test method

The test specimen is introduced into a quartz tube in a tube furnace set at 800 °C ± 10 °C and an air flow of 120 $l \times h^{-1}$ ± 5 $l \times h^{-1}$ is passed through the tube and over the test specimen.

The fire effluent is passed through wash bottles, and the insoluble effluent is collected in a gas bag.

The gases monitored include: carbon monoxide, carbon dioxide, sulphur dioxide, formaldehyde, ammonia, hydrogen cyanide, hydrogen chloride, hydrogen bromide, hydrogen fluoride, hydrogen sulphide, acrylonitrile and nitrogen oxides.

Different methods are used for chemical analysis, e.g. spectrophotometry, gas chromatography, infrared analysis and potentiometry.

6.4.5 Repeatability and reproducibility

No data are available.

6.4.6 Relevance of test data and special observations

The test temperature and ventilation conditions in this method are such that the physical fire model does not correspond to any of the fire types described in Table 1. However, with modifications to either the test temperature or air flow rate, the physical fire model could be made to replicate fire types 2 or 3b (see Table 1).

The mass loss of the test specimen is not recorded during or after the test and, therefore, results cannot be expressed as toxic potency.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

A similar test, AFAP-3[11], has been developed by NATO, in which tests are carried out at 350 °C or 800 °C in an air flow of $2\ l \times min^{-1}$. In addition to the determination of carbon monoxide, carbon dioxide, hydrogen cyanide, hydrogen fluoride, hydrogen chloride, hydrogen bromide, nitrogen oxides and sulphur dioxide, this variant requires the determination of acrylonitrile, ammonia, phenol, benzene, styrene and toluene under both conditions, and also the determination of hydrogen sulphide, formic acid, carbon disulphide and acetaldehyde at 350 °C [12].

6.4.7 Reference documents

CEI 20-37/7 [10]

NATO AFAP-3 [11]

6.5 Norme Française (NF)

6.5.1 Summary

The tests described in NF C20-454 [13] and NF X70-100 [14], [15] are used for the determination of a toxicity index of gases evolved during the combustion of test specimens in a tube furnace. NF C20-454 is for materials used in electrotechnical applications, and NF X70-100 was developed for testing products and materials used in the railway industry.

6.5.2 Purpose and principle

This tests measure and quantify the different gases evolved during the combustion or pyrolysis of test specimens.

The gases monitored include: carbon monoxide, carbon dioxide, hydrogen chloride, hydrogen bromide, hydrogen fluoride, hydrogen cyanide, oxides of nitrogen (NO and NO_2), sulphur dioxide, formaldehyde and acrolein.

6.5.3 Test specimen

The test specimen, with a typical mass of 1,0 g, consists of a piece of material or a test specimen cut from an end-product.

6.5.4 Test method

The test specimen is placed in a porcelain boat inside a quartz combustion tube and introduced into an annular furnace set at 800 °C or, in the case of NF X70-100, 400 °C or 600 °C. An air flow of $120\ l \times h^{-1}$ is passed through the tube, over the test specimen.

A variety of analytical methods can be used, including chromatography, potentiometry, classical wet chemistry, IR and FTIR.

6.5.5 Repeatability and reproducibility

Data from interlaboratory testing are reported in NF X70-100-1 [14].

6.5.6 Relevance of test data and special observations

The test temperature and ventilation conditions in this method means that the physical fire model does not correspond to any of the fire types as described in Table 1. However, with modifications to either the test temperature or air flow rate, the physical fire model could be made to replicate fire types 2 or 3b (see Table 1).

The mass loss of the test specimen is not recorded during or after the test and, therefore, results cannot be expressed as toxic potency.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

Results from NF X70-100 tests have been compared with gas yields from real-scale fire tests of materials used in trains [16]. Some reasonable correlations were found for the toxicity of structural materials.

NF X70-100 is one of the toxicity test methods specified in CEN TS 45545-2 [17].

NF X70-100 is discussed in ISO 16312-2.

6.5.7 Reference documents

NF C20-454 [13]

NF X70-100-1 [14]

NF X70-100-2 [15]

CEN TS 45545-2 [17]

6.6 International Electrotechnical Commission (IEC)

6.6.1 Summary

IEC 60695-7-50 [18] describes the generation of fire effluent and the identification and measurement of its constituent combustion products. This test method uses a moving test specimen and a tube furnace at different temperatures and air flow rates. The method is designed to reproduce certain decomposition conditions in a range of fire types as characterized in Table 1.

This test method is designed to model closely fire types 1b, 2 and 3b (see Table 1), and also has the potential to model others, as necessary. In this test, the measurement of fire effluent is made using test specimens which may be taken from end-products, or, if the apparatus and method allows, may be an end-product.

6.6.2 Purpose and principle

The test method described is based upon the same concept as the DIN 53436-1 [19] method. The types of tube furnace and quartz furnace tube selected are those currently specified by IEC 60754-2 [20] which gives a known performance under the conditions of test and is widely available.

In this test method, a test specimen of material in the form of a strip, broken up in small pieces, is introduced into a quartz furnace tube at a constant rate, and a current of primary air is passed through the quartz furnace tube over the test specimen to support combustion. The

effluent is expelled from the quartz furnace tube into a mixing and measurement chamber where it is diluted with secondary air. The effluent is then analyzed and evacuated.

The decomposition conditions in the quartz furnace tube are set using different combinations of temperature and primary air flow rate in separate runs, to model the decomposition condition in a range of fire types as characterized in Table 1, or as required.

6.6.3 Test specimen

The test specimen is uniformly distributed along the length of the combustion boat, so that a constant flow of decomposition products is produced as the sample passes through the quartz furnace tube. The combustible loading should be approximately 10 g spread over 400 mm (25 g × m^{-1}).

In all cases, however, it is essential that the uniform distribution of the test specimen is maintained and that the combustible loading per unit length is known so that the rate of decomposition can be determined.

6.6.4 Test method

Each material should be tested under one or more of the decomposition conditions set out in Table 4:

Table 4 – Decomposition conditions

Fire type		T max °C	Primary air flow l × min^{-1}
1b	Non-flaming decomposition (oxidative)	350	1,1
2	Developing fire (flaming)	650	22,6
3b	Fully developed fire (flaming), relatively low ventilation	825	2,7

The furnace temperature is raised to the desired temperature at the desired primary air flow rate. The primary air should be clean and dry (relative humidity less than 1 % at 25 °C). The test specimen is spread uniformly along the combustion boat and the combustion boat is introduced into the quartz furnace tube so that the front end is 50 mm from the air inlet end of the tube furnace entrance. The required secondary air flow is set to give a total flow rate through the mixing chamber of 50 l × min^{-1}. The sampling and measurement equipment are calibrated, and the experimental run is started. The test specimen is moved through the quartz furnace tube at a rate of 40 mm × min^{-1}.

6.6.5 Sampling of effluent

Samples for analytical measurement are taken continuously from the chamber at a flow rate of 2 l × min^{-1} ± 0,05 l × min^{-1} through a drying agent and a smoke filtration system, through the appropriate analyzers, and the results recorded continuously together with the optional smoke optical density. For experiments with flames, observations are made down the quartz furnace tube to determine when ignition occurs, or to ensure that flaming is absent during non-flaming experiments. The fire condition can also be verified from the gas and smoke measurements. The outputs from the gas and smoke monitors are observed during the early stages of the run.

When these have reached constant levels, then dynamic steady state conditions have been achieved. The decomposition conditions should remain steady for a minimum of 10 min to enable the test specimen decomposition behaviour and toxic product yields to be characterized.

6.6.6 Repeatability and reproducibility

No data are available.

6.6.7 Relevance of test data and special observations

Results of this test method can be used to estimate toxic potency based on the fractional effective dose (FED) principle as described in IEC 60695-7-51 [21].

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

6.6.8 Reference documents

IEC 60695-7-50 [18]

DIN 53436-1 [19]

IEC 60754-2 [20]

IEC 60695-7-51 [21]

6.7 International Standards Organization (ISO)

6.7.1 Summary

ISO/TS 19700 [22] is a tube furnace test method based on the IEC test method IEC 60695-7-50. The ISO test was first developed in the UK as BS 7990 [23].

6.7.2 Purpose and principle

Samples of a material or product are combusted under steady-state conditions in one or more of four environments whose temperature and equivalence ratio are representative of a particular stage of a fire. The four types of fire to be represented are: oxidative pyrolysis, well-ventilated flaming developing fires, small flaming vitiated fires, and post-flashover vitiated fires, as defined in ISO/TS 19706.

6.7.3 Test specimen

The test specimen is uniformly distributed along the length of the combustion boat, so that a constant flow of decomposition products is produced as the sample passes through the quartz furnace tube. The combustible loading should be approximately 20 g spread over 800 mm (25 g $\times$ m^{-1}). Preferably the test specimen should be in the form of a rod of uniform cross-sectional area.

6.7.4 Test method

Each material is tested under one of the following conditions as listed in Table 5.

Table 5 – Decomposition conditions

Fire type (see Table 1)	Furnace temperature	Primary air flow	Equivalence ratio ϕ
1b, oxidative pyrolysis	350 °C	2 dm^3 $\times$ min^{-1}	N/A
2, well-ventilated flaming	650 °C	10 dm^3 $\times$ min^{-1} or 15 dm^3 $\times$ min^{-1}	$<$ 0,75
3a, small vitiated fire in a closed or poorly ventilated compartment	650 °C	variable	2,0
3b, post-flashover fire in an open compartment	825 °C	variable	2,0

6.7.5 Repeatability and reproducibility

Repeatability data are given for PMMA in ISO/TS 19700. Reproducibility had not been quantified when the ISO/TS 19700 was published.

6.7.6 Relevance of test data and special observations

Toxic potency data can be obtained under conditions corresponding to fire types 1b, 2, 3a and 3b. Annexes in ISO/TS 19700 show how the data obtained can be used in accordance with ISO 13344 and ISO 13571.

This test method involves preliminary tests so as to set the sample loading and air flow so that, during steady-state decomposition, the desired equivalence ratios of fuel to oxygen are achieved. It is probably the most technically sophisticated standardised toxic potency test currently available, but as a consequence is also technically complex, which can be viewed as a limitation.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

BS 7990 is discussed in ISO 16312-2.

6.7.7 Reference documents

IEC 60695-7-50 [18]

BS 7990 [23]

ISO/TS 19700 [22]

6.8 International Maritime Organization (IMO)

6.8.1 Summary

The IMO FTP [24] code smoke generation test is conducted in accordance with ISO 5659-2 [25]. Both smoke density and toxicity are measured during this test.

6.8.2 Purpose and principle

This test method with evaluation criteria is used as a mandatory test method for surface finish materials used on board ships under fire safety requirements of the International Convention of Safety of Life at Sea 1974 (SOLAS) as amended. The test method is specified in the International Code for Application of Fire Test Procedures (FTP Code) adopted by IMO as resolution MSC 61 (67) in 1996. For the chemical analysis of fire effluent, FTIR or another traceable analysis method is recommended.

6.8.3 Test specimen

The dimensions of the test specimen are 75 mm × 75 mm, as specified in ISO 5659-2 [25].

6.8.4 Test method

This test method is generally carried out in accordance with ISO 5659-2 [25]. The duration of the test is for a minimum of 10 min with the test extended for a further 10 min if the minimum light transmittance value has not been reached.

Three test specimens are tested as follows:

a) 25 kW × m^{-2} irradiance in the presence of a pilot flame;

b) 25 kW × m^{-2} irradiance in the absence of a pilot flame; and

c) 50 kW × m^{-2} irradiance in the absence of a pilot flame.

The results are expressed as gas volume fractions. Maximum permitted values are given below (see Table 6):

Table 6 – Volume fraction limits for gas component

Gas component	Limit of volume fraction × 10^6
Carbon monoxide	1 450
Hydrogen chloride	600
Sulphur dioxide	120
Nitrogen oxides	350
Hydrogen cyanide	140
Hydrogen bromide	600
Hydrogen fluoride	600

6.8.5 Repeatability and reproducibility

No data are available.

6.8.6 Relevance of test data and special observations

The equivalence ratio changes during the test. Chemical analysis methods are susceptible to error and interference. Fire gases pass through the conical heater and may accumulate in the upper part of the cabinet since fan stirring is not used. Deposition of gas on soot and on the walls of the chamber can occur. There are no reported comparisons of toxic gas generation with data from real-scale fire tests.

Whilst relatively easy to perform, this method is of questionable value for generating effluent toxicity data for use in fire hazard analysis.

A toxicity test using the same chamber is specified in CEN/TS 45545-2 [17].

Tests using this smoke chamber are discussed in ISO 16312-2.

6.8.7 Reference documents

IMO FTP Code [24]

ISO 5659-2 [25]

CEN/TS 45545-2 [17]

6.9 Toxicity test for rolling stock cables

6.9.1 Summary

The test described in 9.2 of EN 50305 [44] is used to measure the toxicity of combustion products produced when a small sample of a material is completely burnt in excess air under specified conditions. The material is from the insulation or sheath or other non-metallic component taken from a rolling stock cable.

It only applies to materials defined as ‘halogen-free’. Quantitative analyses for sulphur dioxide and oxides of nitrogen are only undertaken if preliminary qualitative tests (by sodium fusion) have shown that sulphur and nitrogen are present in the material.

NOTE ‘Halogen-free’ is as defined in Clause 3 of EN 50306-1 [45].

6.9.2 Purpose and principle

Analytical data of certain small molecular gaseous species arising from the combustion at 800 °C of the material under test are mathematically computed, using for each species a ‘critical concentration for a 30 min exposure’, to derive a combined toxicity index.

6.9.3 Test specimen

The test specimen is approximately 1 g and is a piece of the insulation or sheath or other non-metallic component taken from a rolling stock cable.

6.9.4 Test method

The apparatus is a tube furnace as described in EN 50267-1 [46].

The combustion tube is maintained at a temperature of 800 °C. A test specimen of material is introduced into the combustion tube and a current of air is passed through the tube over the test specimen to support combustion. The effluent is then analysed for carbon monoxide, carbon dioxide and hydrogen cyanide. If the test sample has been shown to contain sulphur, sulphur dioxide is also analysed. If the test sample has been shown to contain nitrogen, oxides of nitrogen are also analysed.

The air supply can be pushed or pulled. In the latter case air gas bags are used to collect gases at the end of the circuit. When air is pushed, continuous analysis is possible for carbon monoxide, carbon dioxide, hydrogen cyanide and sulphur dioxide. Discontinuous analysis is also possible for these gases as well as for oxides of nitrogen. Details of methods of analysis are given in Annex E of EN 50305.

The results are expressed as a toxicity index, ITC, based on a weighted calculation as follows:

$$\boldsymbol{ITC} = \frac{100\ \mathrm{g \cdot m^{-3}}}{m} \sum (M_z / CC_z)$$

where

m is the mass of the test specimen;

M_z is the mass of gas z produced by the combustion of the test specimen, and

CC_z is the critical concentration for a 30 min exposure of gas z (see Table 7).

Table 7 – CC_z values taken from EN 50305

Gas	cc_z / mg·m^{-3}
Carbon dioxide	90 000
Carbon monoxide	1 750
Sulphur dioxide	260
Nitrogen oxides	90
Hydrogen cyanide	55

6.9.5 Repeatability and reproducibility

No data are available.

6.9.6 Relevance of test data and special observations

The test temperature and ventilation conditions in this test method means that the physical fire model does not correspond to any of the fire types as described in Table 1. However, with modification to the test temperature, the physical fire model could be made to replicate fire type 2.

The weighting values used in the calculation of the overall toxicity index are outdated.

The mass loss of the test specimen is not recorded during or after the test and, therefore, results cannot be expressed as toxic potency.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

6.9.7 Reference document

EN 50305, 9.2 and Annex E.

7 Summary of published test methods relating to animal exposure

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

7.1 Deutsches Institut für Normung (DIN)

7.1.1 Summary

The test method described in the DIN 53436 series of standards [19], [27], [28] serves to thermally decompose solid and liquid material under defined conditions in a stream of air, and to assess the relative acute inhalation toxicity of these thermal decomposition products.

7.1.2 Purpose and principle

This test method is used for the generation of thermal decomposition products from materials in an air stream and the determination of toxicity by inhalation of the decomposition and combustion products.

7.1.3 Test specimen

Strip-like test specimens measuring 400 mm × 15 mm × 2 mm are used.

If the density is less than 400 kg × m^{-3}, the thickness of the test specimen is measured so that the length related mass (g × cm^{-1}) is equal to that of a material with a density of 400 kg × m^{-3}.

7.1.4 Test method

The apparatus continuously decomposes a strip-like test specimen in a 1 300 mm long quartz tube. The quartz tube, which has an outside diameter of 40 mm and a wall thickness of 2 mm, is enclosed by a 100 mm long temperature-controlled annular furnace. The furnace is moved at a rate of 10 mm × min^{-1} along the axis of the tube. In doing so it passes over the test specimen, which is in a quartz glass cuvette at the bottom of the quartz tube. A stream of air (variable) is blown over the test specimen opposite to the direction in which the furnace moves.

The contrary motion of the furnace and airflow prevents the hot decomposition gases from preheating the not yet decomposed parts of the test specimen. The test temperature is set between 200 °C and 900 °C and measured by a reference body. This reference body is a 200 mm long steel rod on which thermocouple is welded and is placed in the test specimen holder. The temperature is fixed by running three tests with the reference body at the same furnace temperature. The test itself is run and, at the end of the quartz tube, the effluent is cooled with fresh air, diluted, and fed into the inhalation chamber where the nose or whole body of the rat is exposed. Gas analysis is also possible during the test.

7.1.5 Repeatability and reproducibility

An evaluation of this method involving three laboratories has been performed [29], [30].

7.1.6 Relevance of test data and special observations

The decomposition model of the DIN 53436-1 [19] tubular furnace has been used by different researchers for the determination of LC_{50} (lethal concentration 50) data. This physical fire model offers the possibility to decompose materials in strip form under the conditions relevant to fire types 1b, 3a and 3b (see Table 1). The same mass or volume of the material to be tested is decomposed under the specific conditions. Concentration response relationships are easily obtainable, with concentration being varied by dilution of the fire effluents with air.

The method is useful for obtaining toxicological data and gas yields from the combustion or pyrolysis of homogeneous materials. The lethal toxic potency data associated with 30 min exposure under specific conditions of the test procedure are determined. The toxicological findings can thus be referred to the test specimen mass, volume or surface area used.

It is also possible to calculate LC_{50} data analytically using the concentration values of the major fire gas components. The number of tests involving animals can therefore be reduced to the absolute minimum.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

No comparisons of toxic potency and gas yield data with real-scale fire test data have been published.

This test method is discussed in ISO 16312-2.

7.1.7 Reference documents

DIN 53436-1 [19]

DIN 53436-2 [27]

DIN 53436-3 [28]

7.2 National Bureau of Standards (NBS)

7.2.1 Summary

The "NBS Cup" furnace test is used for the assessment of the acute toxicity of inhaled combustion products.

7.2.2 Purpose and principle

This test method is used for the determination of toxic potency through the generation of flaming and non-flaming decomposition effluents in a static closed system utilizing an electrically heated 1 l cup-type crucible furnace attached directly to a 200 l exposure chamber with six animal (rat) exposure ports, and sampling provisions for effluent analysis.

The reported result is the LC_{50} for a 30 min exposure plus a 14 day post exposure period, expressed as the mass of test specimen exposed per unit chamber volume.

7.2.3 Test specimen

The test specimen with a typical mass of up to 8 g can be a piece of material, or a test specimen cut from an end-product.

7.2.4 Test method

A 1 l, stainless steel, electrically heated cup furnace is set to a pre-determined temperature, and the test specimen (typically 1 g to 8 g) is dropped into the furnace, and the resulting effluent is allowed to fill the chamber by convection.

Two modes of combustion, flaming and non-flaming, are prescribed. In the non-flaming mode, the furnace temperature is set to 25 °C below the ignition temperature of the test specimen and in the flaming mode it is set to 25 °C above the ignition temperature of the test specimen. The ignition temperature of the test specimen is determined in the cup furnace prior to the test.

The test is conducted in a 200 l clear plastic test chamber which contains the cup furnace, whose open top is flush with the floor of the test chamber, the animal exposure ports and provision for analytical sampling.

Rats are exposed nose-only to the atmosphere of the test chamber for a period of 30 min, beginning with the introduction of the test specimen into the combustion chamber. Animals which are not dead at the end of the exposure period are observed for a further 14 days. Any deaths within that time are deemed to be the result of combustion product exposure and counted in the LC_{50} determination.

Oxygen, carbon monoxide and carbon dioxide concentrations are continuously monitored.

The results are expressed as LC_{50} under flaming and non-flaming conditions: 30 min chamber exposure plus 14 days post exposure observation, reported as milligrams of sample loaded

per litre of chamber volume. The LCt_{50} is calculated by multiplying the LC_{50} by the 30 min exposure time.

Other information recorded includes chamber conditions, maximum temperature and the concentrations of oxygen, carbon monoxide and carbon dioxide.

7.2.5 Repeatability and reproducibility

NBS reports indicate relatively good repeatability with this method.

7.2.6 Relevance of test data and special observations

The NBS test has now been largely superseded by the NIST (National Institute of Standards and Technology) test (see 7.3).

The NBS test has been criticized because the cup furnace is best suited for homogeneous materials and does not readily accommodate composite or laminated test specimens. The closed cup geometry means that large, highly-combustible test specimens can lead to rapid temperature build-up and oxygen depletion, both of which can affect the animals' response to combustion products, and hence the relevance of the results.

In addition, it is often difficult to characterize the fire conditions under which the test specimen is decomposed. Air can only enter the cup furnace from the top, so test specimens which burn vigorously and take up a sizeable fraction of the furnace volume may sometimes get comparatively less oxygen than do smaller or less combustible test specimens.

Although carbon monoxide yields tend to vary, little data exist which compare toxic potency measured by this test method to that under full-scale conditions, so the practical effect of this limitation is not known.

The results are expressed as mass concentration on the basis of the amount of test specimen loaded, instead of the amount converted to volatile effluents. Therefore, when the test specimen is not completely consumed, the expressed results overstate the actual mass concentration in the fire effluent and, hence, understate the effluent's toxic potency. This can be remedied by weighing the test specimen residue after the test and correcting appropriately, but such a step is not part of the published procedure.

This test method is discussed in ISO 16312-2.

7.2.7 Reference documents

Hartzell [31]

Levin, B.C. et al [32]

Levin, B.C., Paabo, M. and Birky, M.M. [33]

7.3 National Institute of Standards and Technology (NIST)

7.3.1 Summary

The NIST radiant furnace method is used for toxic potency determinations through the generation of flaming and non-flaming decomposition effluents in a static closed system. It is used in NFPA 269 [34] and ASTM E 1678 [35].

The lethal toxic potency is first estimated from the combustion atmosphere analytical data utilizing FED calculations. This is done so as to minimize the amount of animal testing required for biological response confirmations.

The reported result is the LCt_{50} from the N-gas model for a 30 min exposure plus a 14-day post exposure period, expressed as the product of mass loss of test specimen multiplied by the exposure time per unit test chamber volume.

7.3.2 Purpose and principle

The combustion device consists of a horizontally mounted cylindrical quartz combustion cell, 130 mm inside diameter and approximately 320 mm in length. It is connected to an animal exposure chamber through a stainless steel chimney, which is approximately 30 mm × 300 mm × 300 mm. External to the combustion cell are four tungsten-quartz radiant heat lamps focused onto the plane of the test specimen. A platform, accommodating test specimens of 76 mm × 127 mm and up to 51 mm thick, is connected to a load cell located underneath the combustion chamber in order to continuously monitor the mass of the test specimen. A high energy spark is used as an ignition source.

7.3.3 Test specimen

The test specimen, with a typical mass of up to 8 g, can be a piece of material or a test specimen cut from an end-product. The test specimen platform can accommodate test specimens measuring 76 mm × 127 mm and up to 51 mm thick.

7.3.4 Test method

The vertically oriented cup furnace of the NBS test is replaced by a radiantly heated horizontal combustion cell, which can accommodate a variety of test specimen geometries, and is mounted on a load cell for continuous measurement of mass loss. It is connected to the exposure chamber by means of a stainless steel chimney and a shutter. The test specimen receives radiant heat of a pre-determined intensity through the quartz walls of the combustion cell from two externally mounted radiant lamps, and the effluent passes up the chimney and into the exposure chamber. After 15 min of irradiation, the chimney shutter is closed and the heat lamps are turned off.

In the first part of the test, no animals are used. Instead, a conveniently sized test specimen (typically 5 g) is exposed to the radiant heat load. The composition of the effluent in the test chamber is monitored by the continuous analysis of carbon monoxide, carbon dioxide, oxygen and any other toxic gases whose presence is predicted from the composition of the test specimen (e.g. organics, hydrogen halides, hydrogen cyanide). The animal monitoring period is the 30 min following the exposure of the test specimen, the last 15 min of which are with the lamps turned off and the chimney shutter closed. At the end of the monitoring period, the N-gas model and the analytical data are used to calculate the lethal FED of effluent which animals in the chamber would have received if they had been exposed. The test specimen size is adjusted to correspond to a FED of approximately 1,1 and the test is repeated for verification.

Once the correlation between test specimen size and FED has been established, the procedure is repeated twice using the animals and exposure conditions described above for the NBS test. In the first test, the test specimen size is adjusted to give an expected FED of 1,4. If the N-gas model is a good predictor of toxic potency, then, at the end of the 14-day post exposure period, one or two animals will have died as a result of the first test and all six as a result of the second. If the N-gas model fails to predict mortality, then the effluent contains agents that are not included in the N-gas model and the actual LCt_{50} is determined using the apparatus and animals in accordance with standard toxicological techniques.

Time-integrated chamber concentrations are determined for carbon oxides by infrared spectroscopy and, when appropriate, for hydrogen halides and hydrogen cyanide; the minimum oxygen concentration in the chamber is determined by a paramagnetic analyzer, and the mass loss of the test specimen is determined by a load cell.

The heat flux level of the test specimen exposure, the time to ignition of the test specimen and the extinction time for the flame are reported.

7.3.5 Repeatability and reproducibility

The NIST reports relatively good repeatability with this method, but no inter-laboratory evaluation of this method has been performed.

7.3.6 Relevance of test data and special observations

The NIST test, the results of which are expressed as LCt_{50} values, is designed to be used directly as input to fire hazard calculations. It eliminates many of the shortcomings of the NBS test, especially test specimen accommodation difficulties and localized oxygen depletion associated with the NBS cup furnace. Thermal decomposition occurs under well ventilated conditions and permits simulation of fire types 1b (if the test specimen does not auto-ignite), 2, 3a and 3b (see Table 1), depending upon the radiant flux level selected. It is a useful test for obtaining quantitative toxic potency data for materials and end products for input to fire hazard models.

Based on NIST research, it is claimed that post-flashover toxic potencies measured with this test agree with those from full-scale fires within approximately a factor of two [36].

This NIST test method is based on the principle that chemical analysis cannot always be relied upon to detect all the toxic components in fire effluent. As a result, efforts have been made to minimize the need for animals in measuring toxic potency, but the dependence on animals has not been completely eliminated.

This test is discussed in ISO 16312-2.

7.3.7 Reference documents

NFPA 269 [34]

ASTM E 1678 [35]

Hartzell, G.E. [31]

Alexeeff, G.V. and Packham, S.C. [37]

7.4 University of Pittsburgh (Upitt)

7.4.1 Summary

The UPitt box furnace (described in reference [38]) can be used for measuring the toxic potency of products resulting from the decomposition conditions of developing fires.

7.4.2 Purpose and principle

This test method is used for concentration response and toxic potency determinations utilizing a dynamic flow through system with a ramped heating of test specimens in a muffle furnace that is connected to four animal (mice) exposure chambers with sampling ports for effluent analysis.

This test method used to be required in the United States by the state of New York for certain construction, electrical and interior finishing materials and products.

7.4.3 Test specimen

The test specimens can be pieces of material or a test specimen cut from an end-product. Effluent concentration is varied by changing the mass charged to the furnace, typically in the range of 1 g to 10 g.

7.4.4 Test method

The test specimen is placed on a load cell and is decomposed in a furnace whose temperature is increased at 20 °C·min^{-1} beginning at room temperature, and through which a stream of air is pulled at a rate of 11 l·min^{-1}. After the test specimen loses 1 % of its mass, the effluent from the furnace is diluted with more air and passed into the animal exposure chamber.

The fire effluent is passed into a 4 dm^3 glass animal exposure chamber. Analytical samples are taken from the exposure chamber.

Mice are exposed nose-only to the diluted effluent for 30 min. The 30 min animal exposure period begins when the test specimen weight loss begins. Animals which die during the test and within a 10 min post exposure period are counted in determining the dose response and the resulting toxic potency.

Continuous chamber oxygen concentration (paramagnetic analysis) and infrared determined carbon monoxide concentration, plus continuous analysis of other toxic combustion gases, such as hydrogen halides and hydrogen cyanide, as appropriate, can be conducted.

7.4.5 Repeatability and reproducibility

Multiple submittals of similar materials and products indicate that the repeatability of this test is very good.

7.4.6 Relevance of test data and special observations

The test method begins in a non-flaming oxidative mode, and at some stage transition to flaming usually occurs. At this stage, the CO_2/CO ratios tend to be low (under 20:1, usually less than 10:1), while the temperature is still low (less than 600 °C). This combination of conditions does not, therefore, fit well into the scheme of fire types shown in Table 1. It therefore does not produce usable input data for fire hazard models.

In common with many physical fire models, no indication is given about the rate of combustion, so flame retarded materials can be forced to undergo combustion at the same rate as materials without any flame retardance. Therefore, additional data input on combustion rates in different fire types is required for fire hazard assessments.

LC_{50} values have been reported and filed with New York State for over 15 000 products [39]. It is of interest that 96 % of the LC_{50} values range over less than one order of magnitude; 63,3 % of the LC_{50} values fall between 5 g to 12,5 g, with another 32,7 % being in the range of 12,5 g to 28,1 g.

This test is discussed in ISO 16312-2.

7.4.7 Reference documents

Alarie, Y.C. and Anderson, R.C. [38]

New York State [39]

Kaplan, H.L., Grand, A.F., Hartzell, G.E. [40]

Hartzell, G.E. [31]

Levin, B.C., Paabo, M. and Birky, M.M. [33]

7.5 Japanese fire toxicity test for building components

7.5.1 Summary

Under the Japanese Building Standards Law, revised in 2000, fire safety evaluation and certification is done by fire test and evaluation organizations, which are recognized by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Such recognized organizations establish methods and criteria for evaluation and certification. Many recognized organizations use a toxicity fire test [41] [42], which uses a combustion system similar to BS 476-6 [43]. The combustion effluent of the test specimen is fed into a mixing chamber and then into an animal exposure chamber. The time required for all eight mice to become incapacitated is measured. The result is compared to a specified time.

NOTE For this test, incapacitation is defined as the cessation of movement of both the mouse and the cage for a minimum of 30 s.

7.5.2 Purpose and principle

This is a comparative toxicity test method for the designation of semi-combustible and flame retardant materials used in the construction industry, using mice under gas exposure conditions. The test apparatus consists of a furnace, a pre-mixing chamber and an animal exposure chamber with eight rotary cages.

7.5.3 Test specimen

The test specimen can be a piece of the material or a test specimen cut from an end-product measuring 22 cm × 22 cm × 1,5 cm maximum thickness. The area exposed for testing is 18 cm × 18 cm.

7.5.4 Test method

The animal exposure chamber temperature is set to 30 °C and each of the eight cages is loaded with mice. The test specimen is then heated initially by the supplementary heat source for 3 min followed by the addition of the main heat source for a further 3 min. The combustion gas is introduced into the animal exposure chamber at a rate of 10,0 litres·min^{-1}. The monitoring time continues for a period of 15 min after the start of the heating test. The time required for each mouse to become incapacitated is recorded.

Test specimens are judged to have passed the test if the mean time to incapacitation exceeds a specified time.

7.5.5 Repeatability and reproducibility

In a four laboratory examination of six materials, the inter-laboratory standard deviation of the time to incapacitation of mice was under 15 %. The agreement of duplicate tests within each laboratory was within 5 %.

7.5.6 Relevance of test data and special observations

The test method is not widely used today, because many recognized organizations accept that for materials that contain less than established limits of combustible content, a fire toxicity test is not required. Many recognized organizations also accept that a fire toxicity test is not required for materials of low combustibility or for fire-retarded materials, because they consider that low heat release materials release low levels of toxic effluents.

The mass loss of the test specimen is not recorded during or after the test and, therefore, results cannot be expressed as toxic potency.

The test method is useful for screening the incapacitation potency of fire effluent from various products, but the test conditions only simulate fires of type 3a (see Table 1).

This method is discussed in ISO 16312-2.

7.5.7 Reference documents

Japanese Ministry of Construction (JMC) [41]

BS 476-6 [43]

Annex A
(informative)

Overview of toxicity test methods

See Table A.1 for an overview of toxicity test methods.

Table A.1 – Overview of toxicity test methods

Type of test method	Clause	Test method	Provides toxic potency data	Could be adapted to provide toxic potency data	Relevant to fire types in Table 1					
					1a	1b	1c	2	3a	3b
Chemical analysis	6.1	DS 02-713	No	No	No	No	No	No	No	No
	6.2	ABD 0031	No	No	No	No	No	No	No	No
	6.3	CEI 20-37/7	No	Yes	No	No	No	No	No	No
	6.4	NF C20-454 NF X70-100	No	Yes	No	No	No	[a]	No	No
	6.5	IEC 60695-7-50	Yes	N/A	[a]	Yes	[a]	Yes	[a]	Yes
	6.6	ISO/TS 19700	Yes	N/A	[a]	Yes	[a]	Yes	Yes	Yes
	6.7	IMO FTP Code	No	Yes	No	Yes	No	No	Yes	No
	6.8	EN 50305 clause 9.2	No	Yes	No	No	No	[a]	No	No
Animal exposure	7.1	DIN 53436	Yes	N/A	No	Yes	No	No	Yes	Yes
	7.2	NBS Cup furnace	Yes	N/A	No	Yes	No	Yes	No	No
	7.3	NIST Radiant furnace	Yes	N/A	No	[b]	No	Yes	Yes	Yes
	7.4	UPitt Box furnace	Yes [c]	N/A	No	No	No	No	No	No
	7.5	Japanese test	Yes	N/A	No	No	No	No	Yes	No

[a] It is possible to simulate this fire type, but not under the standard conditions of the test method.

[b] This fire type will be simulated provided that the test specimen does not auto-ignite.

[c] Toxic potency data can be calculated but the physical fire model does not correspond to any of the fire types of Table 1.

Table A.1 *(continued)*

Type of test method	Clause	Test method	Comments
Chemical analysis	6.1	DS 02-713	This test method is now widely criticized. The data from this test should not be used as input to toxic hazard assessments, fire hazard assessments or fire safety engineering calculations.
	6.2	ABD 0031	Fire and ventilation conditions do not allow a comparison between this physical fire model and any of the fire types described in Table 1.
	6.3	CEI 20-37/7	The test temperature and ventilation conditions in these methods are such that the physical fire model does not correspond to any of the fire types described in Table 1. However, with modifications to either the test temperature or air flow rate, the physical fire model could be made to replicate fire types 2 or 3b.
	6.4	NF C20-454 NF X70-100	
	6.5	IEC 60695-7-50	Results of this test method can be used to estimate toxic potency based on the fractional effective dose (FED) principle as described in IEC 60695-7-51.
	6.6	ISO/TS 19700	The method is technically complex. Toxic potency data can be obtained under conditions corresponding to fire types 1b, 2, 3a and 3b. Annexes in ISO/TS 19700 show how the data obtained can be used in accordance with ISO 13344 and ISO 13571.
	6.7	IMO FTP Code	Whilst relatively easy to perform, this method is of questionable value for generating effluent toxicity data for use in fire hazard analysis.
	6.8	EN 50305 clause 9.2	With modification to the test temperature the physical fire model could replicate fire type 2.
Animal exposure	7.1	DIN 53436	The method is useful for obtaining toxicological data and gas yields from the combustion or pyrolysis of homogeneous materials.
	7.2	NBS Cup furnace	The NBS test has now been largely superseded by the NIST test (see 7.3).
	7.3	NIST Radiant furnace	This is a useful test for obtaining quantitative toxic potency data for materials and end products for input to fire hazard models.
	7.4	UPitt Box furnace	This test does not produce usable input data for fire hazard models.
	7.5	JMC	The test method is useful for screening the incapacitation potency of fire effluent from various products, but the test conditions only simulate fires of type 3a.

[a] It is possible to simulate this fire type, but not under the standard conditions of the test method.

[b] This fire type will be simulated provided that the test specimen does not auto-ignite.

[c] Toxic potency data can be calculated but the physical fire model does not correspond to any of the fire types of Table 1.

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[9] AITM 3.0005, *Airbus Industry Test Methods – Determination of specific gas components of smoke generated by aircraft interior materials*

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[46] EN 50267-1:1999, *Common test methods for cables under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 1: Apparatus*

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