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Generation and analysis of toxic gases in fire — Calculation of species yields, equivalence ratios and combustion efficiency in experimental fires

Production et analyse des gaz toxiques dans le feu — Calcul des taux de production des espèces, des rapports d'équivalence et de l'efficacité de combustion dans les feux expérimentaux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 3, *Fire threat to people and environment*.

This third edition cancels and replaces the second edition (ISO 19703:2010), which has been technically revised.

The main changes compared to the previous edition are as follows:

— redundant symbols have been deleted;

— missing symbols have been added;

— units of some symbols in formulae and tables have been corrected to conform with the ISO/IEC Directives, Part 2;

— unnecessary formulae have been deleted;

— mistakes in formulae have been corrected.

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Introduction

It is the view of committees ISO TC 92/SC 3, ISO TC 92/SC 4, and IEC TC 89 that commercial products should not be regulated solely on the basis of the toxic potency of the effluent produced when the product is combusted in a bench-scale test apparatus (physical fire model). Rather, the information that characterizes the toxic potency of the effluent should be used in a fire risk or hazard assessment that includes the other factors that contribute to determining the magnitude and impact of the effluent. It is intended that the characterization of

a) the apparatus used to generate the effluent, and

b) the effluent itself

be in a form usable in such a fire safety assessment.

As described in ISO 13571, the time to incapacitation in a fire is determined by the integrated exposure of a person to the fire effluent components. The toxic species concentrations depend on both the yields originally generated and the successive dilution in air. The former are commonly obtained using a bench-scale apparatus (in which a specimen from a commercial product is burned) or a real-scale fire test of the commercial product. These yields, expressed as the mass of effluent component per mass of fuel consumed, are then inserted into a fluid mechanical model which estimates the rate of fuel consumption, transport and dilution of the effluent throughout the building as the fire evolves.

For the engineering analysis to produce accurate results, it is preferred that the yield data come from an apparatus that has been demonstrated to produce yields comparable to those produced when the full product is burned. In addition to depending on the chemical composition, conformation and physical properties of the test specimen, toxic-product yields are sensitive to the combustion conditions in the apparatus. Thus, one means of increasing the likelihood that the yields from a bench-scale apparatus are accurate is to operate it under combustion conditions similar to those expected when the real product burns. As described in ISO 19706, the important conditions include whether the fuel is flaming or non-flaming, the degree of flame extension, the fuel/air equivalence ratio and the thermal environment. Similarly, these parameters should be known for a real-scale fire test.

The yields of toxic gases, the combustion efficiency and the equivalence ratio are likely to be sensitive to the manner in which the test specimen is sampled from the whole commercial product. There can be difficulty or alternative ways of obtaining a proper test specimen. That is not the subject of this document, which presumes that a specimen has been selected for study and characterizes the combustion conditions and the yields of effluent species for that specimen.

For those experimental fires in which time-resolved data are available, the methods in this document should be used to produce either instantaneous or averaged values. The application can be influenced by changes in the chemistry of the test specimen during combustion. For those fire tests limited to producing time-averaged gas concentrations, the calculated values produced by the methods in this document are limited to being averages as well. In real fires, combustion conditions, the fuel chemistry and the composition of fire effluent from many common materials and products vary continuously during the course of the fire. Thus, how well the average yields obtained using these methods correspond to the yields in a given real fire has much to do with the stage of the fire, the pace of fire development and the chemical nature of the materials and products exposed.

This document 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. Sample calculations for practical cases are provided.

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Generation and analysis of toxic gases in fire — Calculation of species yields, equivalence ratios and combustion efficiency in experimental fires

1 Scope

This document 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. Sample calculations for practical cases are provided. The methods are intended to be used to produce either instantaneous or averaged values for those experimental fires in which time-resolved data are available.

This document is intended to provide guidance to fire researchers for

— recording appropriate experimental fire data,

— calculating average yields of gases and smoke in fire effluents in fire tests and fire-like combustion in reduced scale apparatus,

— characterizing burning behaviour in experimental fires in terms of equivalence ratio and combustion efficiency using oxygen consumption and product generation data.

This document does not provide guidance on the operating procedure of any particular piece of apparatus or interpretation of data obtained therein (e.g. toxicological significance of results).

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.

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
mass concentration of gas
mass of gas per unit volume

Note 1 to entry: The mass concentration of a gas shall be derived directly from the measured volume fraction and its molar mass or measured directly.

Note 2 to entry: Mass concentration is typically expressed in units of grams per cubic metre.

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3.2
mass concentration of particles
mass of solid and liquid aerosol particles per unit volume

Note 1 to entry: Mass concentration of particles is typically expressed in units of grams per cubic metre.

3.3
molar mass
mass of 1 mole

Note 1 to entry: Molar mass is normally expressed in units of grams per mole.

3.4
recovery of element
⟨in a specified combustion product⟩ degree of conversion of an element in the test specimen to a corresponding gas

Note 1 to entry: It is the ratio of the actual yield to notional yield of the gas containing that element.

3.5
relative atomic mass
average mass of one atom of an element divided by one twelfth of the mass of one atom of carbon (isotope ^{12}C)

3.6
stoichiometric oxygen-to-fuel mass ratio
amount of oxygen needed by a material for complete combustion

Note 1 to entry: Stoichiometric oxygen-to-fuel mass ratio is typically expressed in units of grams of oxygen per gram or kilogram of burnt material.

3.7
uncertainty
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurement

Note 1 to entry: The description and propagation of uncertainty in measurements are described in ISO/IEC Guide 98-3[24].

[SOURCE: ISO/IEC Guide 98-3:2008, 2.2.3, modified—The term has been changed from “uncertainty (of measurement)” to “uncertainty”; “uncertainty of measurement” has been added as an admitted term; the original Notes 1, 2 and 3 to entry have been deleted and a new Note 1 to entry has been added.]

3.8
expanded uncertainty
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurement

Note 1 to entry: Adapted from ISO/IEC Guide 98-3:2008, 2.3.5.

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