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Guidelines for assessing the fire threat to people

Lignes directrices pour l'évaluation des dangers du feu pour les personnes

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 19706 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 3, *Fire threat to people and environment*.

This first edition of ISO 19706 cancels and replaces ISO/TS 19706:2004, which has been technically revised.

Introduction

All fires produce toxic gases, smoke and heat. Whether the fire occurs in a residence, a commercial building, or a transportation vehicle, exposure to this effluent can have serious consequences for the occupants, responding fire safety personnel, and for larger fires, people in the environment surrounding the structure.

It is necessary to anticipate the effects of a possible fire on the safety of the occupants when considering both the design and construction of the enclosure, and also the burning behaviour of the contents. Building codes and similar documents for transportation vehicles generally provide for the egress or refuge of occupants: it is necessary that the time available for escape exceed the time required for escape. Underestimating the effects of fire effluent on the former can result in not providing the intended degree of safety or in overestimating the impact of fire-mitigation tactics, whereas overestimating the threat can inappropriately limit the use of construction, finish and furnishing materials and products, as well as constrain occupancy design options and escalate costs.

Thus, it is important in the fire safety engineering of facilities to include the effects of fire effluent and to include them accurately and in full awareness of available knowledge. From a complementary perspective, it is necessary that information on fire effluent toxic potency be combined with additional consideration of design fire scenarios, the combined effects of ignitability, heat release and mass loss rate, smoke density, the occupancy and the occupants themselves in a fire hazard or risk assessment, rather than selecting, banning or demeaning a construction or furnishing material or product based on its smoke production and toxic potency alone.

All measurements, calculations and assumptions are characterized by a degree of uncertainty. The utility of the outcome of a fire hazard or risk assessment, or the evaluation of the toxic potency of the fire effluent from products and materials, depends on knowing the uncertainties in the assessment methodology and the uncertainties in the input data. This International Standard addresses the uncertainty in the characterization of fire effluent, the measurement of effluent effects and the accuracy of the measurements.

The purpose of this International Standard is to provide general guidelines for estimating the fire threat to people and to the development of quantitative information on effluent potency for use in fire hazard and risk assessment and for the determination of the toxic potency of the fire effluent from burning products and materials.

Guidelines for assessing the fire threat to people

1 Scope

This International Standard is intended to serve as general guidelines for the assessment of the fire threat to people. It encompasses the development, evaluation and use of relevant quantitative information for use in fire hazard and risk assessment. This information, generally obtained from fire-incidence investigation, fire statistics, real-scale fire tests and from physical fire models, is intended to be used in conjunction with computational models for analysis of the initiation and development of fire, fire spread, smoke formation and movement, chemical species generation, transport and decay, and people movement, as well as fire detection and suppression [ISO/TR 13387 (all parts)]. Aspects of the methodology described here are further amplified in ISO 13571 and ISO 13344.

This International Standard is intended to facilitate addressing the consequences of a single acute human exposure to fire effluent. Other effects of the heat, gases and aerosols (such as effects on electronic equipment and effects of frequent, multiple environmental exposures of people), which are of importance in fire safety design, are addressed elsewhere.

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.

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

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.

3.1
asphyxiant
toxicant causing loss of consciousness and ultimately death resulting from hypoxic effects, particularly on the central nervous and/or cardiovascular systems

3.2
concentration-time curve
plot of the concentration of a gaseous toxicant or fire effluent as a function of time

NOTE The typical units for the concentration of the toxic gas are microlitres per litre and for fire effluent, grams per cubic metre. The units of microlitre per litre are numerically identical to parts per million (ppm), the use of which is discouraged.

3.3
escape
effective action by occupants to accomplish their own arrival at a place of safe refuge

3.4
incapacitation
inability to take effective action to accomplish one's own escape from a fire

3.5
EC_{50}
concentration of a toxic gas or fire effluent statistically calculated from concentration-response data to produce an effect in 50 % of a population of a given species within a specified exposure and post-exposure time

NOTE 1 The concentration of the toxic gas is expressed as a volume fraction and that of the fire effluent in grams per cubic metre.

NOTE 2 The observed effect is usually a behavioural response, incapacitation, or death. The EC_{50} for an incapacitating exposure is termed the IC_{50}. The EC_{50} for a lethal exposure is termed the LC_{50}.

3.6
safe refuge
location where the subject is free from incurring further harm from the fire

3.7
time available for escape
interval between the time of ignition and the time after which conditions become untenable, such that occupants are unable to take effective action to accomplish their own escape to a place of safe refuge

NOTE The time available for escape, as used in this International Standard, differs from the commonly used term ASET (Available Safe Escape Time) in that the latter implies that the occupant escapes unharmed, while the former enables the user to define an acceptable level of personal safety.

3.8
time required for escape
time required for occupants to travel from their location at the time of ignition to a place of safe refuge

NOTE As used in this International Standard, time required for escape is intended to be equivalent to the commonly used term RSET (Required Safe Escape Time). See ISO/TR 13387-8.

4 General principles

4.1 Fire effluent and escape time

4.1.1 Life safety in a fire is greatly enhanced if the time available for occupants to escape exceeds the time required for them to escape and is threatened if the time required exceeds the time available.

4.1.1.1 As specified in ISO/TR 13387-8, the time required for escape includes the time from ignition of a fire to its detection, the time from its detection to an evacuation warning to occupants, an occupant's pre-movement time (the time between becoming aware of an emergency and initiating egress) and the actual travel time to a place of safety.

4.1.1.2 The time available for escape is the interval between the time of ignition and the time after which conditions become untenable such that occupants are unable to take effective action to accomplish their own escape to a place of safe refuge. Guidelines for estimation of the time available for escape are specified in ISO 13571. It involves procedures to evaluate the life threat components of fire hazard analysis, e.g. toxic gases, heat and smoke obscuration, in terms of the status of exposed subjects at discrete time intervals. The time at which occupants' exposure exceeds a threshold criterion represents the time available for escape. Users of ISO 13571 have the flexibility to set such criteria according to their chosen life safety objectives. Thus, an estimated time available for escape might or might not be equivalent to an ASET.

4.1.2 The quantity and nature of the fire effluent are prime factors in estimating the time available for escape. The effluent nature is a function not only of the product from which it is generated, but also of the conditions under which the product participates in the fire and the nature of the fire.

4.2 Effects of fire effluent on people

During and following a fire, the products of combustion can have lethal and sub-lethal effects on occupants of the facility and responders to the fire. The severity of the effects depends on the composition of the effluent, the extent of the exposure and the physical condition of the subject. Information relative to the effects on people can be extracted from physical and chemical characterization of the effluent (e.g. using ISO 13571), from estimation of the toxic potency of fire effluent (e.g. using ISO 13344) or from accidental exposures of people to the chemical and thermal components of the effluent.

The effects of the effluent on people are not deterministic in severity or immediacy, but fall into a distribution. This is due to the range of sensitivity of people to the fire effluent and variations in the progress of a fire.

4.3 Use of fire-effluent data

Because the effect of the fire effluent on people depends on factors beyond the combustible(s) as a source of the effluent, it is necessary that the fire-effluent composition data be combined with additional information about the facility, the fire and the people into a fire hazard or risk assessment, rather than being used alone as an indicator of fire hazard or risk.

4.4 Data accuracy and uncertainty

All measurements, calculations and assumptions are characterized by a degree of uncertainty. The utility of the outcome of a fire hazard or risk assessment depends on knowing the uncertainties in the assessment methodology and the uncertainties in the input data. This International Standard addresses the uncertainty in the characterization of fire effluent, the measurement of effluent effects and the accuracy of the measurements.

5 Significance and use

5.1 The projected response of people to fire effluent frequently determines the fire-safety design limits for occupancy. This International Standard provides guidelines on the type of effluent information needed to enable such a projection and how to use the data.

5.2 The information derived using the guidelines in this International Standard is for use in fire hazard and risk assessment, e.g. as given by ISO/TR 13387.

5.3 The methodologies developed using the guidelines in this International Standard cannot be validated from fire experiments using people. Thus, there is some uncertainty in the accuracy of the quantitative exposure/response relationship. It is necessary that this uncertainty be included in the estimation of the overall uncertainty of a fire hazard or risk analysis. The user can then perform a sensitivity analysis and determine the significance of the uncertainty in the human effects in the context of the problem at hand.

6 Generation and nature of effluent

6.1 Gases, liquid aerosol, soot particles and heat are generated during the flaming combustion and non-flaming pyrolysis of products during a fire. Calculation methods for the calculation of effluent yields are found in ISO 19703.

6.2 The yield and nature of the effluent are determined by the involved fuels and the prevalent thermal and oxygen conditions in the current stage of the fire. These conditions affect the burning rate of the products and the degree of oxidation of the emitted effluent. The stages of fire are characterized in Table 1.

NOTE The divisions between the fire stages are approximate.

Table 1 — Characteristics of fire stages

Fire type	Heat flux to fuel surface kW/m²	Max. temperature °C		Oxygen volume %		Fuel/air equivalence ratio (plume)	$\frac{[CO]}{[CO_2]}$ v/v	$\frac{100 \times [CO_2]}{([CO_2]+[CO])}$ % efficiency
		Fuel surface	Upper layer	Entrained	Exhausted			
1. Non-flaming								
a. self-sustaining (smouldering)	n.a.	450 to 800[1,2,3]	25 to 85 [4] d	20	0,20	—	0,1 to 1[4]	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[5]	b	0	0	>> 1	c	c
2. Well-ventilated flaming d	0 to 60[6]	350 to 650[7]	50 to 500	≈ 20	0,20	< 1	< 0,05 e	> 95
3. Under-ventilated flaming f								
a. small, localized fire, generally in a poorly ventilated compartment	0 to 30[6]	300 to 600 a	50 to 500[8]	15 to 20[9,10]	5 to 10[8,9,10]	> 1	0,2 to 0,4[9,10,11]	70 to 80
b. post-flashover fire	50 to 150[12]	350 to 650 g	> 600	< 15[9,10]	< 5[9,11]	> 1 h	0,1 to 0,4 [9,10,11,13],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 burning 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.

6.3 The yield and nature of the effluent are affected by human or mechanical interventions in the fire. These include the opening or closing of doors and windows, application of fire suppressant, movement of the burning products, etc.

6.4 The harmful components of fire effluent are the following:

a) asphyxiant gases: carbon monoxide (CO), carbon dioxide (CO_2), hydrogen cyanide (HCN), oxygen-depleted air;

b) irritant gases: halogen acids (HCl, HBr, HF), partially oxidized organic molecules (e.g. acrolein, formaldehyde), nitrogen oxides, other fuel-specific gases;

c) aerosols and soot particles, particularly those of a size that are readily respirable and those that scatter light efficiently;

d) heat (radiative and convective) and elevated temperature.

NOTE Carbon dioxide and some other gases also have an effect on the rate of uptake of toxicants.

7 Sources of data on fire effluent

7.1 Laboratory data

7.1.1 General

For a given product, quantitative information on effluent and effluent components, needed as input to the calculations of the effect on people, cannot routinely be obtained from accidental fires. It is obtained from real-scale fire tests and from physical fire models. In each case, the uncertainty and repeatability of the measurements shall be reported. Furthermore, if a physical fire model is used, the accuracy of the results shall be reported. The conditions under which all data are developed shall be compatible with the fire conditions in the computational fire model in which they are used (ISO 16312-1).

7.1.2 Specimen mass loss

This measurement enables calculation of the yields of effluent components. It is most desirable to weigh the specimen continuously during the test, since the yields of effluent components can well vary as the chemistry of the remaining specimen fraction changes. Obtaining the initial and final mass of the test specimen allows a determination of the average yields over the full combustion period.

7.1.3 Yields of toxic gases

Concentration of a gas or the mass of the gas produced during a fire experiment or from a physical fire model can be obtained using any of several analytical chemical techniques documented in ISO 19701 and ISO 19702. It is preferable that concentrations or masses be obtained as a function of time during the test, although integrated values are sufficient. Since the transport, dilution and loss of these gases are a function of facility geometry, it is common practice to convert the concentration or mass generated into a yield using the mass-lost or mass-changed information from 7.1.2.

7.1.4 Yields of condensed phase smoke

The mass of generated solid and liquid aerosols can be obtained using appropriate equipment, such as a filter collector, a cascade impactor (which also provides particle/droplet size information), or a tapered element oscillating microbalance (which also provides time-dependent mass information); see Reference [14].

7.1.5 Optical density of smoke

The obscuration of smoke over a chosen distance is obtained by measuring the degree of interruption of a light beam across a known path length. The scattering by the aerosol is wavelength-dependent, so it is