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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 13571-3

Life-threatening components of fire —

Part 3: Guidelines for the estimation of time to compromised tenability and escape capability from exposure to smoke toxicants, Method B

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ISO/TC 92/SC 3

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This document is circulated as received from the committee secretariat.

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee [or Project Committee] ISO/TC 92, Subcommittee SC 3.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 13571 series is a set of standards developed for estimation of time to compromised tenability and escape capability for occupants when exposed to a fire environment. Different threats are evaluated separately for exposure to acute toxicants, heat and smoke. Potential interactions between the different threats have not been addressed in this series of standards.

Therefore, the time to compromised tenability is taken as the shortest of the determined times to compromised tenability from each of the different threats.

The ISO 13571 series is composed of 5 parts:

- ISO 13571-1 describes a model for smoke toxicity assessment of time to compromised tenability of 50 % of an exposed occupant population, and threshold tenability limits for sensitive members of an exposed population.
- ISO TR 13571- 2 (technical report) describes examples of application of the ISO 13571 series (to be revised).
- ISO 13571-3 describes a model for smoke toxicity assessment of time to compromised tenability based on lethality endpoints for an exposed occupant population.
- ISO TR 13571-4 (technical report) describes and gives examples of comparisons of the assessments of times to compromised tenability applying parts 1 and 3 in different fire scenarios.
- ISO 13571-5 describes models for assessment of time to compromised tenability for heat exposure, smoke obscuration, and a simplified model for toxicity assessment based on mass loss of combustibles.

Chronic health effects and environmental impacts are not covered in the ISO 13571 series.

The objective of this part of the ISO 13571 series is to define a standardized, pragmatic mathematical approach for use by fire experts for the estimation of time to compromised tenability for fire scenarios typical for enclosed fires which is following modern established emergency response principles.

The time from initiation of a fire to the point when tenability becomes compromised is the central component of fire safety design. Predicted hazards originating from fires refer to physical effects (heat, smoke) and toxicity-related fire gases (asphyxiants, irritants) severe enough to affect peoples' capabilities to evacuate an enclosed space. While physical factors are accounted for in ISO 13571-5, the primary focus of this standard is the protection of people from the toxicity-related 'incapacitation' and occurrence of post-exposure deaths. As a pragmatic approach, the toxicity-related hazards are considered to occur concentration×time ($C \times t$)-dependently. This mathematical process is applied for defining the threshold of incapacitation. Physical incapacitation effectively signals the end of individual's voluntary activity for escape,^[9]

Fire risks depend on additional variables which include the materials' rate of thermal decomposition and 'yields of toxicants' at specific fire growth stages. Typically, these range from smouldering combustion and early well-ventilated flaming, to fully-developed under-ventilated flaming^[51]. The fire gas components from each stage and category (physical- vs. toxicity-related factors) are used to calculate the cumulative fractional effective threshold dose ($FED = 1$) up to which compromised tenability is unlikely to occur in the targeted population addressed. The parameterization used in this standard protects from compromised tenability within a given probability of 99 % and even >99 % for post-exposure mortality at exposure durations exceeding ≈5 minutes. As also explained in ISO 13571-1 also for the models used in this document uncertainty increases at shorter exposures.

Depending on the nature, size, and distribution of the population addressed in each appraisal, additional uncertainty factors may apply for more susceptible sub-populations, if applicable. Unlike the commonly applied Emergency Response Standards focusing on the general public in which hyper-susceptible subpopulations need to be included,^[7,8] this document assumes that assistance for successful evacuation will be provided to hyper-susceptible subpopulations by individuals from the normal population. Accordingly, this document focuses on the normal population mentally and physically able to manage any defined evacuation paradigm. Hence, the purpose of the methodology described in this document is to provide a pragmatic framework for estimating the time at which compromised tenability may occur under

any given fire scenario within a reasonable degree of certainty. For more detailed consideration of factors potentially affecting variability within any specific population is advised to consult more pertinent sources of information for specialized cases shall be consulted [8].

Over the last decades bioassay testing guidelines have received significant refinement and harmonization with focus on minimal-animal-use approaches. Wherever experimentally feasible, animal-free modelling procedures should be given preference. Especially for Acute Emergency Response-like scenarios resembling '*once in a life-time*' exposures, transparent and standardized weight-of-evidence and formal approaches must be given preference.

This document seeks consistency with the established principles applied for deriving Acute Emergency Response values.[7,8] Accordingly, the cornerstones for human risk assessment stem from rationalized 'key studies' on animals following contemporary OECD testing guidance.[3,4] These guidelines state that data from studies on rats, ideally nose-only exposed, should be given preference by default[3-5]. From these studies the threshold dose or Point of Departure (POD) that can be tolerated without interference of the escape performance can be derived as defined in greater detail elsewhere[7], and therefore the non-lethal threshold concentration was taken as the unifying and most robust POD for estimating the most likely average time available for escape in the absence of post-exposure fatalities. Also time extrapolations are applied as recommended elsewhere for Emergency Scenarios serving the same purpose as this document. [1-3,7,8,56]

Throughout this document, the toxicity-related impairment of escape is assessed by the Toxic Load relationship, i.e., $C^n \times t = \text{constant effect}$. [1,2,6] Collectively, this standard uses the same Ct approach for asphyxiants and irritants. Carbon dioxide is not taken as an amplifier of the toxicity of CO and HCN. Rather, its marked incapacitation potency coming into play at >6 % CO₂ requires this component to be a separate rather than modifying toxicological entity.[10,11] As COHb is a 'biomarker of exposure' rather than a 'biomarker of effect' as called for by the contemporary Toxic Load approach,[1,2,7] the effect-based POD is used in this document. COHb may deliver important forensic information in context with post-mortem analyses; however, it cannot be used as a reference value in context with this standard.[12-15] The key studies selected for CO and HCN were those published by Sweeney et al. [16-18] and analysed post-hoc by Pauluhn. [10,11] These studies were most compliant with the criteria defined by both contemporary OECD testing guidelines [3-5] and those providing guidance to derive Emergency Response Guidance values.[7,8] The rats' breathing activity is that of heavy-breathing humans when kg-body-weight adjusted. Hence, the human variability of breathing activity does not require any further adjustments when using studies on rats [12].

Due to the acute toxic hazards of fire gases, the evacuation behaviour of evacuees may further be modulated by heat stress and smoke obscuration. All of them share the ability of reducing the time to attain compromised tenability.

Heat will be transferred by convective heat as well as by radiative transfer. The impact will depend from direct radiation from flames or from various construction elements, as well as from the height of hot smoke layers, and reradiating surfaces from heated ceilings and walls.

When exposed to fire smoke, occupants may in addition experience decreased visibility due to physical factors which are potentially superimposed by reflexively-induced nociceptive factors triggering lacrimation and blepharospasm.

Methods to assess these additional hazards are presented in ISO 13571-5.

This document presents a state-of-the-art compliant approach.

A reliable and transparent risk assessment mandates a $C \times t$ matrix of PODs from robust and cross-validated, standardized, and guideline compliant animal bioassays to define human surrogates of 'impairment of escape' or impact on health, including lethality. The most consistent and conclusive endpoint to protect from 'impairment of escape' to occur was shown to be the incapacitation-adjusted lethality-based biomarker of effect LCt01/3 from acute inhalation studies on rats.

The basis for this document therefore is:

- An assessment based on a data rich concentration time matrix generated from acute inhalation studies on rats which are the default species mandated by contemporary testing guidelines for toxicological hazard identification and risk assessment.
- Application of an FED model for asphyxiants taking into account CO, HCN and including the toxic effects of concentrations of CO₂ above 6 % on tenability and introduction of an FED model for irritants.

The adjustment factors in this document make sure, that heavy breathing human individuals are covered. Therefore, no additional adjustment for breathing changes depending on activity levels is needed.^[12]

This document is based on the following data and paradigms:

- The assessment of the effects of HCN and CO is based data from rat experiments, where the body-weight adjusted respiratory minute volume of rats resembles that of humans at heavy work and the additional assessment of CO₂ as toxicant is derived from human data (humans breathing normally). Thus, 99 % of the normal population is expected to pass the incapacitation paradigm.
- For irritants acting throughout the entire respiratory tract, lethality-based endpoints used as reference for irritant gases need to adjust the effect-related and inhaled-dose related uncertainties calling for a 1/30LC₀₁ or 1/10 SLOT-DTL The SLOT is defined to protect the general population from the occurrence of fatalities with a probability of 1 %. The additional assessment factor (AF) adjusts from the non-lethal threshold to the threshold of compromised tenability which follows the same Cⁿ×t paradigm.

Further information has been included in the appendices. Background information about the transparency, plausibility, and coherence with current guidance of the approach taken in this document is given in [Annex C](#).

Life-threatening components of fire —

Part 3:

Guidelines for the estimation of time to compromised tenability and escape capability from exposure to smoke toxicants, Method B

1 Scope

This document provides guidance for fire safety engineering that is applicable for fires in enclosed spaces. It is intended to be used in conjunction with models for analysis of the initiation and development of fire, fire spread, impact of heat, radiation, and limited visibility, smoke formation and movement, chemical species generation, transport and decay, and people movement, as well as fire detection and suppression, given in the normative references in [clause 2](#). This document is intended to be used only within this context.

This document establishes procedures to evaluate the effects of life-threatening components from fire environments in terms of the probability of compromised tenability of a targeted human population at accumulated time intervals. It makes possible the estimation of the time at which people can experience compromised tenability due to smoke, heat and toxic fire effluent. The most critical hazard is that which causes compromised tenability at the earliest time. The time-dependent production of smoke and toxic fire effluent and the thermal environment of a fire are determined by the rate of fire growth, the yields of the various fire gases produced from the involved fuels, the decay characteristics of those fire gases and the ventilation pattern (see [A.1](#)). Once these are determined, the methodology presented in this International Document can be used for the estimation of the time at which individuals can be expected to experience compromised tenability.

This document establishes procedures to evaluate the life-threatening components from fire environments in terms of the probability of a targeted human population at accumulated time intervals. It makes possible the estimation of the time at which people in enclosed spaces can experience compromised tenability (see [A.2](#)). It enables an estimation of compromised tenability for each predicted Cxt (Concentration x time) of components from fire environments. In addition, the time to untenability due to the impact of heat and of smoke (visibility) needs to be considered. The impact leading to attain compromised tenability at $FED = 1$ earliest is considered the most critical. The non-lethal threshold-based derivation of the occurrence of compromised tenability also protects from post-exposure mortality. Details for assessing the impact of heat and smoke will be given in ISO 13571-5.

This method is intended to assess the escape capability of people in an environment, where generally adult and not handicapped people are expected, as for example in industrial and working surroundings. In addition, susceptible people are covered in this document based on the already included adjustment factors explained below.

For the escape capability of hyper-susceptible people, no meaningful additional assessment factors can be defined, but this document can be applied in a meaningful way for places where it can be assumed that hyper-susceptible or helpless people will always get assistance for escape, like in child care units or hospitals.

This document covers all fire stages including smouldering fires or other scenarios where high emissions of CO_2 can be expected, as CO_2 is considered as a toxicant per se for higher concentrations. Recent fire tests have shown that in some fire scenarios CO_2 can be found in relevant concentrations [\[19-21\]](#) and has to be considered as a toxicant per se.

For applying this document the basic information given in ISO 13344, and in ISO 19706 also is relevant.[\[58,59\]](#)

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content 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 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

actual concentration

concentration of a chemical species in the test animal's breathing zone, commonly expressed in mass units per unit volume of air (mg/L, mg/m³, ppmV)

3.2

acute inhalation toxicity

adverse effects caused by an airborne test chemical following a single uninterrupted inhalation exposure of less than 24 hours

Note 1 to entry: Most regulatory acute inhalation toxicity studies are 4 hours in duration. Testing of multiple C_xt products with t<4 hours are supported to serve Emergency Response time extrapolations. After cessation of exposure, a post-exposure period of at least 14-days is mandated and must be extended if indicated by delayed signs and/or mortality.^[3] According to contemporary OECD testing guidelines ^[3,4] the nose-only exposed rat is the species of choice. The statistical hallmarks of this bioassay include the median lethal concentration (LC₅₀), the non-lethal threshold concentration (LC₀₁) and, if applicable, the Toxic Load exponent 'n' and constant 'k'.

3.3

adjustment factor

factor for the incorporation of quantitative data on interspecies differences or on human variability in either toxicokinetics (variability in inhaled dose and metabolism) or toxicodynamics (mode of action causing the critical effect) into the risk assessment procedure

3.4

adverse effect

change in biochemistry, morphology, physiology, growth, development, or lifespan of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to other environmental influences

3.5

Acute Exposure Guideline Levels values

AEGL values

values developed through the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL) describe the human health effects from once-in-a-lifetime, or rare, exposure to airborne chemicals, and are intended to protect most individuals in the general population, including those that might be particularly susceptible to the harmful effects of the chemicals

3.6

aerosol

relatively time-stable suspension of small solid or liquid particles in a gas with a diameter size range of aerosol particles about 0,001 to 100 µm ^[22] and for nano-aerosol within the range 0,001 to 0,1 µm in at least in one dimension for anisometric aerosol