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Fire safety engineering — Selection of design occupant behavioural scenarios

Ingénierie de la sécurité incendie — Sélection de scénarios de dimensionnement du comportement des occupants

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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

Introduction

In a fire safety engineering assessment, the ability of occupants to escape safely or find a designated place of refuge is evaluated for each design fire scenario, taking account of the occupants expected to be present in the building or other structure.

The purpose of this Technical Specification is to outline a general methodology for selecting design fire scenarios for the specific fire safety objective of life safety of the occupants, and then developing the occupant behavioural scenarios for which those design fire scenarios will be tested. ISO 16733-1 provides general guidance on the selection of design fire scenarios.

Since each design fire scenario might require several different occupant behavioural scenarios, the number of possible design occupant behavioural scenarios in any built environment (a building, structure or transportation vehicle) can be very large, and it is not possible to quantify them all. This large set of possibilities needs to be reduced to a manageably small set of occupant behavioural scenarios that are amenable to analysis. In a deterministic assessment, which is implicitly envisioned in this Technical Specification, a manageable number of design occupant behavioural scenarios is selected. For a full quantitative risk assessment, see ISO 16732-1.

The characterization of an occupant behavioural scenario involves a description of the initial occupant distribution and the number and other characteristics of the population, including their reaction and response capabilities. The occupant behavioural scenarios will be specifically determined for each design fire scenario, which itself includes the interaction with the proposed fire protection features for the built environment. The possible consequences of each fire scenario for each occupant behavioural scenario need to be considered.

Following selection of the design occupant behavioural scenarios, it is necessary to describe the assumed characteristics of the occupant behaviour on which the scenario quantification will be based. These assumed occupant behaviour characteristics are referred to as “the design occupant behaviour”. Design occupant behaviours are usually characterised in terms of pre-travel activity delay times (response and reaction times) and occupant movement speeds. The design occupant behaviour needs to be appropriate to the life safety objective of the fire safety engineering analysis and has to result in a design solution that is conservative.

Fire safety engineering — Selection of design occupant behavioural scenarios

1 Scope

This Technical Specification describes a methodology for the selection of design occupant behavioural scenarios that are severe but credible for use in deterministic fire safety engineering analyses of any built environment including buildings, structures, or transportation vehicles.

Occupant behavioural scenarios are linked to design fire scenarios. Guidance on the selection of design fire scenarios and design fires is covered in ISO 16733-1. The steps in ISO 16733-1 are followed in this Technical Specification with life safety of the occupants as the single fire safety objective under consideration.

ISO/TR 16738 provides information on methods for the quantification of the different aspects of human evacuation behaviour in a design context. One part of that process involves the selection of occupant behavioural scenarios. This Technical Specification provides guidance for that aspect of the evaluation of an egress design.

This Technical Specification addresses behaviours that occur after fire ignition and does not deal with behaviours that influence fire ignition.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13571:2012, *Life-threatening components of fire — Guidelines for the estimation of time to compromised tenability in fires*

ISO 13943, *Fire safety — Vocabulary*

ISO 16733-1:2015, *Fire safety engineering — Selection of design fire scenarios and design fires — Part 1: Selection of design fire scenarios*

ISO/TR 16738, *Fire-safety engineering — Technical information on methods for evaluating behaviour and movement of people.*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO/TR 16738 and the following apply.

NOTE Some of the definitions have been updated to reflect the current understanding of the terms as employed in fire safety engineering. Some are duplicated here for the convenience of users of this document.

3.1
ASET
available safe escape time
for an individual occupant, the calculated time interval between the time of ignition and the time at which conditions become such that the occupant is estimated to be incapacitated, i.e. unable to take effective action to escape to a safe refuge or place of safety

Note 1 to entry: The time of ignition may be known, e.g. in the case of a fire model or a fire test, or it may be assumed, e.g. it may be based upon an estimate working back from the time of detection. The basis on which the time of ignition is determined needs to be stated.

Note 2 to entry: This definition equates incapacitation with failure to escape. Other criteria for ASET are possible. If an alternate criterion is selected, it needs to be stated.

Note 3 to entry: Each occupant can have a different value of ASET, depending on that occupant's personal characteristics.

[SOURCE: ISO 13943:2008, 4.20, modified]

3.2
built environment
building or other structure

EXAMPLE Off-shore platforms; civil engineering works, such as tunnels, bridges, and mines; and means of transportation, such as motor vehicles and marine vessels.

Note 1 to entry: ISO 6707-1 contains a number of terms and definitions for concepts related to the built environment.

[SOURCE: ISO 13943:2008, 4.26]

3.3
design fire
quantitative description of assumed fire characteristics within the *design fire scenario* (3.4)

Note 1 to entry: It is, typically, an idealized description of the variation with time of important fire variables, such as heat release rate, flame spread rate, smoke production rate, toxic gas yields, and temperature.

[SOURCE: ISO 13943:2008, 4.64]

3.4
design fire scenario
specific *fire scenario* (3.7) on which a deterministic fire safety engineering analysis is conducted

Note 1 to entry: As the number of possible fire scenarios can be very large, it is necessary to select the most important scenarios (the design fire scenarios) for analysis. The selection of design fire scenarios is tailored to the fire-safety design objectives and accounts for the likelihood and consequences of potential scenarios.

[SOURCE: ISO 13943:2008, 4.65]

3.5
design occupant behaviour
quantitative description of occupant behavioural characteristics within the *design occupant behavioural scenario* (3.6)

Note 1 to entry: It is, typically, an idealized description of the time needed for evacuation or refuge, comprising components for recognition, response, and travel. The actual variables include delay time, travel distance, and travel speed.

EXAMPLE Young, intoxicated people in a stadium might delay longer before beginning to evacuate than those who are not intoxicated; older people in a nursing home may travel more slowly than other mobile adults would; intoxicated people may have more difficulty with decision-making and, as a result, might take more time to make exit choices.

3.6
design occupant behavioural scenario
specific occupant behavioural scenario on which a deterministic fire safety engineering analysis will be conducted

3.7
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 1 to entry: 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.

[SOURCE: ISO 13943:2008, 4.129]

3.8
occupant behavioural scenario
qualitative description of occupant behaviour and response over time, including the number of occupants and the physical and cognitive characteristics that affect their decision-making and actions in response to fire cues, identifying key characteristics that differentiate members from other occupants

Note 1 to entry: It typically describes the number and other characteristics and capabilities of group members that would impact the decision-making and behavioural processes (i.e. elderly occupants might be less likely to hear an alarm and may move more slowly than younger occupants; staff may recognize and react to an alarm more quickly and engage in rescue activities before evacuating themselves).

3.9
pre-travel activity time
PTAT
for an individual occupant, the interval between the time at which a warning of a fire is given and the time at which the first move is made by that occupant towards an exit

Note 1 to entry: This consists of two components: *recognition time* (3.10) and *response time* (3.11).

Note 2 to entry: For groups of occupants, the following two phases can be recognized:

— pre-travel activity time of the first occupants to move;

— pre-travel activity time distribution between the first and last occupants to move.

[SOURCE: ISO/TR 16738:2009, 3.9]

3.10
recognition time
interval between the time at which a warning of a fire is given and the first response to the warning

[SOURCE: ISO/TR 16738:2009, 3.10]

Note 1 to entry: This concept is thoroughly discussed in ISO/TR 16738:2009, Annex B.

3.11
response time
interval between the time at which the first response to the event occurs and the time at which travel begins to a *safe location* (3.13)

[SOURCE: ISO/TR 16738:2009, 3.11]

Note 1 to entry: This concept is thoroughly discussed ISO/TR 16738:2009, Annex B.

3.12
RSET
required safe escape time
calculated time period required for an individual occupant to travel from their location at the time of ignition to a safe refuge or place of safety

[SOURCE: ISO 13943:2008, 4.277]

3.13
safe location
location remote or separated from the effects of a fire so that such effects no longer pose a threat

Note 1 to entry: The safe location may be inside or outside the building depending upon the evacuation strategy.

[SOURCE: ISO/TR 16738:2009, 3.12]

3.14
travel time
time needed, once movement towards an exit has begun, for an occupant of a specified part of a building to reach a *safe location* (3.13)

[SOURCE: ISO/TR 16738:2009, 3.14]

4 Fire safety engineering applications

4.1 The role of occupant behaviour scenarios in fire safety design

When a built environment is designed, it has expected (planned) uses and users. In order to complete an evaluation of an engineered design, design fire scenarios are developed to demonstrate that the design will meet its fire safety design objectives. This process is outlined in ISO 16733-1.

When life safety is one of the design objectives, the evaluation demonstrates the extent to which occupants are protected from the fire and its effects. The evaluation should include: the users and/or occupants of the building, their roles, needs, and anticipated abilities, and, if and how the occupants will react and respond to a fire. These factors enable determining the degree of life safety provided by the design.

Just as the fire safety evaluation requires fire scenarios appropriate to the building's design and intended use, the evaluation also requires scenarios of occupant behaviour that reflect the expected population and their characteristics, as described in this Technical Specification.

4.2 The role of design occupant behavioural scenarios in fire safety design

The evaluation of the life safety provided by an engineered design requires an assessment as to whether occupants are protected for the period of time, after fire ignition, until they reach a designated place of safety.

The location of occupants within a building, at any one time, and the way occupant location changes with time during normal use and emergency situations depends on the interaction of a variety of parameters related to the characteristics of the building and the occupants, the fire safety management system proposed for the building and the developing fire scenario. There are essentially five categories of information required to determine the location (and condition) of occupants during a fire:

a) the building characteristics;

b) fire safety management strategy/procedure;

c) the occupant characteristics;

d) the fire dynamics, including smoke transport;

e) intervention effects;

f) the acute effects of the fire effluent on the individual occupants to the extent that there is quantitative knowledge on which to base the evaluation.

Long-term effects of exposure to the fire effluent should also be considered, to the extent that there is quantitative knowledge on which to base the evaluation.

Changes in occupant location during an incident depend on pre-travel activity processes (including recognition and response) and movement processes. Each of these processes occurs over a period of time: recognition time, response time, and movement or travel time. These times can be estimated for each individual, for groups of people in the same location, or a distribution of times can be estimated for the building population. The calculation of these times is an essential task in evaluating an engineered design.

In evaluating a design option, one would:

— take a building, as designed, including its evacuation plan and fire safety management plan;

— determine the various types of potential occupants to consider (e.g. staff vs. visitors, disabled vs. able-bodied, etc.);

— determine the relevant design fire scenarios given the identified occupant population;

— for each design fire scenario, evaluate the predicted outcome for each type of occupant;

— compare the available and required escape times for relevant parts of the building (i.e. estimate the harm done to people by the range of fires that can occur in the building if it is designed as proposed, and compare that harm to levels of acceptable harm as set by the stakeholders for the project);

— at each step of the calculations, provide for estimation of uncertainty, as that will be important in the final evaluation.

In order to do this, one would:

1) determine design occupant behavioural scenarios, including initial input, as well as response data (if necessary);

2) choose an appropriate evacuation calculation method;

3) model the fire and apply the evacuation calculation method;

4) compare the results to the guidance on estimating time available for escape, given in ISO 13571.

There may be several fire safety objectives to be evaluated for a particular design. When life safety is the objective being considered, occupant behavioural scenarios are constructed. They may be relevant for other fire safety objectives.

It would be impossible to analyse all scenarios even with the aid of the most sophisticated computing resources. This infinite set of possibilities needs to be reduced to a smaller, manageable set of groupings or clusters of scenarios that are amenable to analysis and that collectively represent the range of combinations of occupant numbers and other characteristics that could be present.

Once occupant behavioural scenarios are selected and evaluated, the design of the built environment is modified until analysis demonstrates that the estimated fire risk associated with the design is acceptably low and meets the performance criteria associated with the specified fire safety objective(s).

The characterisation of a design occupant behavioural scenario for analysis purposes involves a description of such things as the number of occupants, their locations throughout the built environment, and their ability or inability to recognize and respond to fire cues, and their ability or inability to move through the available escape routes. The impacts of smoke and fire on people are part of potentially relevant consequences of a design occupant behavioural scenario and are part of the characterisation of that scenario when those consequences are relevant to the life safety objective. The characterisation or quantification of occupant recognition and response and movement belong to the “design occupant behaviour". Some later events will be predictable from earlier events through the use of fire safety science, and the characterisation of the event sequence in the scenario shall be consistent with such science.

5 Focusing the steps of ISO 16733-1 for a life safety objective

5.1 Overview of the procedure

In the first part of this three-part procedure, follow the first six steps described in ISO 16733-1 for design fire scenario selection as they would be followed for the fire safety objective of life safety of the occupants. The remainder of this Clause provides guidance for these steps.

Second, select the relevant scenarios following ISO 16733-1, steps 7 to 9.

Third, evaluate the design using occupant behavioural scenarios created and selected as outlined in Clauses 6 and 7.

5.2 Step 1 — Identify the specific safety challenges

At this step, the expected uses of the building are considered, and for every expected use, the variation in potential users shall be considered. This step informs the process that determines which characteristics of the structure, the fire, and any safety systems are relevant for evaluating life safety.

The building users will ultimately be specified in terms of the following:

— number of users;

— permanent/transitory;

— trained in evacuation procedures/untrained;

— potential age ranges;

— potential vulnerabilities;

— awake/asleep/unconscious/impaired;

— social groupings or not;

— variability in composition of occupant groups (e.g. will it always be the same kinds of users?).

It is not necessary at this stage to specify the different occupant groups that would be expected, but rather to be cognizant of the variations that could exist and will have to be considered while going through steps 2 to 6.

Because the aim of the deterministic analysis is to test the fire safety design using a selection of severe but credible scenarios, it is imperative to identify issues or conflicts that, in combination with fire, could potentially lead to the failure of the design. These issues and conflicts are referred to here as *life safety challenges*. Issues can be occupant characteristics that lead to non-optimal response or movement in emergency situations. Conflicts can involve a mismatch between building uses and users or between users and building layout.

5.3 Step 2 — Location of fire

This step focuses on locations most likely to threaten occupants, based on the challenge they present to the objective of life safety. The challenge could be related to the fire's proximity to occupied spaces or escape routes, or its potential for spreading smoke and toxic products into occupied areas or escape routes. The challenge could be related to difficulties in decision making that would face some occupants if a fire impacted their escape routes. Fires that will not spread flames into, spread effluent into, or otherwise damage areas where occupants will be located can be ignored.

