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Fire safety engineering — Guidance on fire risk assessment

Ingénierie de la sécurité contre l'incendie — Lignes directrices pour l'évaluation du risque d'incendie

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Foreword

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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

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An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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/TS 16732 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

Introduction

This Technical Specification is for use by fire safety practitioners who employ risk assessment based methods. Examples include fire safety engineers; authorities having jurisdiction, such as territorial authority officials; fire service personnel; code enforcers; code developers; insurers; fire safety managers; and risk managers. Users of this Technical Specification are to be appropriately qualified and competent in the fields of fire safety engineering and risk assessment. It is particularly important that the user understand the limitations of application of any methodology that is used.

Risk assessment is preceded by two steps: establishment of a context, including the fire safety objectives to be met, the subjects of the fire risk assessment to be performed and related facts or assumptions; and identification of the various hazards to be assessed.

The subjects of fire risk assessment include the design and control of any part of the built environment, such as buildings or other structures. Fire risk assessment of a design consists of analysis of the risks, e.g. frequency and severity of harm, that are predicted to result if the design is implemented, combined with an evaluation of the acceptability of those risks.

Fire risk assessment can be used to support any decisions about fire prevention or fire protection of new or existing built environments, such as buildings, where probabilistic aspects, such as fire ignition or the reliability of fire precautions, are important. Fire risk assessment also can be used to establish safety equivalent to a code, to assess the balance between cost and risk, or to examine acceptable risk specifically for severe events. Fire risk assessment also can be used to provide general guidance or to support choices in the selection of scenarios and other elements of a deterministic analysis.

Fire safety engineering — Guidance on fire risk assessment

1 Scope

This Technical Specification provides the conceptual basis for fire risk assessment by stating the principles underlying the quantification and interpretation of fire-related risk. These fire risk principles apply to all fire-related phenomena and all end-use configurations, which means these principles can be applied to all types of fire scenarios.

This Technical Specification is designed as a guide for future documents that provide formal procedures for the implementation of the risk assessment principles for specific applications, e.g. situations in which only certain types of fire scenarios are possible. Those future documents will complete the process of full standardization begun by this Technical Specification, which not only specifies the steps to be followed in fire risk assessment but also provides guidance for use in determining whether the specific approach used for quantification falls within an acceptable range.

Principles underlying the quantification of risk are presented in this Technical Specification in terms of the steps to be taken in conducting a fire risk assessment. These quantification steps are initially placed in the context of the overall management of fire risk and then explained within the context of fire safety engineering, as discussed in ISO/TR 13387. The use of scenarios and the characterization of probability and consequence are then described as steps in fire risk estimation, leading to the quantification of combined fire risk. Guidance is also provided on the use of the information generated, i.e. on the interpretation of fire risk. Finally, there is an examination of uncertainty in the quantification and interpretation of the fire risk estimates obtained, following the procedures in this document.

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 921:1997, *Nuclear energy — Vocabulary*

ISO 2394:1998, *General principles on reliability for structures*

ISO/TR 13387 (all parts), *Fire safety engineering*

ISO 13943:2000, *Fire safety — Vocabulary*

3 Terms and definitions

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

NOTE Shown below are a number of definitions of terms and concepts that are relevant to fire risk assessment. Shown in Annex A are additional definitions of terms and concepts that either describe specific fire risk analysis methods or can be relevant to fire risk assessment but are not used in this Technical Specification.

3.1
acceptance criteria
in the risk evaluation phase of a risk assessment, the threshold values, specified before risk estimation is undertaken, that separate acceptable from unacceptable on particular fire risk measurement scales

NOTE 1 See also “fire risk, acceptable”.

NOTE 2 “Acceptance criteria” can also be used non-quantitatively to refer to characteristics of outcomes that are necessary for fire risk acceptance, e.g. that any risk above a stated threshold must be voluntary to be acceptable.

3.2
behavioural scenario
description of the sequence of behaviours by occupants in the course of a fire

NOTE See also ISO/ 16738 [6].

3.3
built environment
any building, structure or transportation vehicle

EXAMPLES Structures other than buildings include tunnels, bridges, offshore platforms and mines.

3.4
consequence
outcome or outcomes of an event, expressed positively or negatively, quantitatively or qualitatively

3.5
design fire scenario
specific fire scenario on which a deterministic fire safety engineering analysis will be conducted

3.6
engineering judgement
process exercised by a professional who is qualified by way of education, experience and recognized skills to complement, supplement, accept or reject elements of a quantitative analysis

3.7
event tree
depiction of temporal, causal sequences of events, built around a single initiating condition

NOTE A fire scenario in an event tree is given by a time-sequence path from the initiating condition through a succession of intervening events to an end-event. For an introduction to decision tree analysis, see, for example, Howard Raiffa [11].

3.8
fault tree
depiction of the logical dependencies of events on one another, built around a critical resulting event, which usually has an unacceptable level of consequence and may be described as a “failure.”

NOTE 1 See ISO/TR 13387-1:1999, 8.2.

NOTE 2 A fire scenario in a fault tree is given by that critical resulting event and one of the alternative, fully specified logical sequences by which that critical resulting event can occur. For an introduction to decision tree analysis, see, for example, Howard Raiffa [11].

3.9
fire hazard
potential for injury and/or damage from fire

[ISO 13943:2000]

NOTE In the context of fire risk assessment, "fire hazard" can be understood either as a measure of consequence, using the term "potential" in a quantitative sense, or as a physical object or condition with the potential to affect the probability or consequences of certain fire scenarios.

3.10
fire risk
(a) when defined as risk of an event or scenario, the combination of the probability of that event or scenario and its consequence, often the product of probability and consequence, or (b) when defined as risk of a design, the combination of the probabilities and consequences of events or scenarios associated with the design, often the sum of the risks of those events or scenarios

3.11
fire risk, acceptable
in the risk evaluation phase of a risk assessment, risks that satisfy defined acceptance criteria and so do not form a basis for required change to a design proposal

NOTE See also "acceptance criteria".

3.12
fire risk assessment
well-defined procedure for estimation of the fire risk associated with a building design, other design, or other subject of study, and for evaluation of the estimated fire risk in terms of a well-defined criterion of acceptable risk

3.13
fire risk curve
representation of fire risk, expressed graphically as cumulative probability versus consequence and normally in logarithm/logarithm format

3.14
fire risk evaluation
comparison of estimated risk, based on fire risk analysis, to acceptable risk, based on defined acceptance criteria

3.15
fire risk matrix
matrix display in which fire scenario clusters are described by ranges of scenario probabilities, used to define the rows or columns, and ranges of design load (i.e. fire size or intensity), used to define the columns or rows, with the result that the matrix cell entries are acceptable consequences for each scenario cluster

NOTE This approach implicitly assumes that the design itself has no influence on the size or intensity of the fire challenging the building, but rather treats the design fire scenario as an externally imposed load.

3.16
fire scenario
qualitative description of the course of a fire with time identifying key events that characterize the fire and differentiate it from other possible fires

[ISO/TS 16733 [5]]

NOTE The fire scenario typically defines the ignition and fire growth process, the fully developed stage and the decay stage, together with the building environment and systems that will impact on the course of the fire. A fire scenario can be used for deterministic fire analysis (see "design fire scenario") or fire risk assessment.

3.17
fire scenario, representative
specific fire scenario selected from a fire scenario cluster, under the assumption that the consequences of the representative fire scenario provide a reasonable estimate of the average consequences of scenarios in the fire scenario cluster

NOTE See also “fire scenario”; “fire scenario cluster”; and the step procedure in ISO/TR 13387-1:1999, 8.2.1, a) to f).

3.18
fire scenario cluster
subset of fire scenarios, usually defined as part of a complete partitioning of the universe of possible fire scenarios so that estimation of scenario probability is done at the fire scenario cluster level

NOTE See also “fire scenario”; “representative fire scenario”; and the step procedure in ISO/TR 13387-1:1999, 8.2.1, a) to f).

3.19
hazard
condition with a potential for an undesirable consequence

3.20
limit state
state beyond which the structure no longer satisfies the design performance requirements

[ISO 2394:1998]

NOTE In the context of fire risk assessment, a “limit state” defines a threshold or limiting value on a consequence scale, usually in the context of a time-sequence state description of the fire scenario. This means the structure can return to a state that does not exceed the limit state.

3.21
reliability
probability that a unit will perform a required function for given conditions and for a given period of time

[ISO 921:1997]

NOTE Reliability applies to the performance of any building or product design feature whose performance can influence the course of fire development, thereby contributing to the specification of the fire scenario that occurs and the risk consequences associated with that scenario. It is also possible that the design feature performance is better described by a range of partial successes or partial failures. This requires a more general and flexible definition than the one given above.

3.22
risk, individual
measure of fire risk limited to consequences experienced by an individual and based on the individual’s pattern of life

EXAMPLE If the fire risk measure is the probability of an unwanted consequence, such as death, then individual risk would be an estimate, typically expressed as events per unit time, of the probability of that unwanted consequence for a specific individual. The risk measure can be expressed as conditional on exposure to the hazard, such as being at a hazardous location. Individual risk is independent of the number of persons affected. Contrast with “societal risk”.

3.23
risk, societal
measure of fire risk combining consequences experienced by every affected person and group

NOTE 1 Combining consequences to all affected parties also affects the overall probability of an incident. It equals the sum of the individual risks of all affected individuals but can be expressed as a rate relative to the number of affected or exposed people, in which case it is in a form directly comparable to the component individual risk measures.

NOTE 2 In societal risk, some consequences experienced by one individual can cancel consequences experienced by another individual. For example, business interruption losses experienced by one company can be exactly offset by increased business income for a competitor not affected by fire.

3.24
risk acceptance
decision to accept an estimated level of risk, based on either compliance with acceptance criteria or an explicit decision to modify those criteria

3.25
risk communication
exchange or sharing of information about risk between the decision-maker and other stakeholders

EXAMPLE Individuals, groups or organizations who can affect, be affected by, or perceive themselves to be affected by the risk).

3.26
risk management
processes, procedures and supporting culture for ongoing achievement of desired risk criteria

NOTE Risk management is a combination of risk assessment, risk treatment, risk acceptance and risk communication.

3.27
risk treatment
process of selection and implementation of measures to modify risk, normally used to refer to changes other than changes to design (e.g. in fire safety management of facility)

NOTE Risk treatment may also refer to the risk modification measures themselves.

3.28
sensitivity
measure of the degree to which a small perturbation of a system will create a large change in system status

NOTE In a fire risk assessment, analysis of "sensitivity" of the calculation to small variations in each of the variables, parameters, and relationships provides information useful in setting priorities for a subsequent analysis of "uncertainty," by focusing attention on those variables and parameters having greatest impact on the results and so on those variations most likely to change the conclusion of the analysis.

3.29
uncertainty
quantification of the systematic and random error in data, variables, parameters, or mathematical relationships; or of failure to include a relevant element

NOTE See also "uncertainty, propagation of".

3.30
uncertainty, propagation of
mathematical analysis of the uncertainty of final risk values as a function of the uncertainty in variables, parameters, data, and mathematical relationships, in the calculation that produces the final risk value

NOTE See also "uncertainty".

3.31
variability
quantification of the probability distribution function for a variable, parameter, or condition

4 Applicability of fire risk assessment

4.1 Circumstances where fire risk assessment is useful

Fire risk assessment is useful in circumstances where it is important to give due consideration to scenarios with low probability but high consequence, such as the following:

a) large numbers of vulnerable people, whose vulnerability results from sleeping, disability, age, impairment, or unfamiliarity;

b) initiating fires with very high fire growth rates;

c) transitory high fuel loads, particularly in vulnerable areas such as escape paths.

Fire risk assessment is also useful in circumstances where spatial measures of fire size, commonly used in deterministic fire hazard assessments, are insufficient as measures of event severity, such as the following:

a) properties involving very high value in small spaces;

b) vulnerable property, such as the contents of clean rooms;

c) contents whose importance is not reflected by its physical size or direct cost, such as the cables controlling safety equipment in a nuclear power facility;

d) properties where the principal form of harm to property is not direct damage, such as properties with high potential for environmental damage, high costs for business interruption, or high potential for lost image and goodwill if a major fire were to occur;

e) properties that have undergone changes in use, alterations, or renovations.

4.2 Circumstances where fire risk assessment is essential

Fire risk assessment is essential where deterministic fire safety engineering cannot adequately address the fire scenarios of concern. This tends to occur when deterministic treatment of a small number of fire scenarios cannot adequately capture the total fire risk of the property.

Fire risk assessment is essential where reliability is critical, because reliability is inherently probabilistic. For example, fire risk assessment is required if it is necessary to assess the defence in depth of a design that relies heavily on a single fire safety system.

Fire risk assessment is essential where the variability of input parameters has a significant impact on the results. Fire risk assessment is needed where there are significant variations in variables like the number of people, their characteristics, or fire growth rates, and deterministic analysis shows that credible combinations of the variables are not acceptably safe.

Fire risk assessment is essential where a wide range of fire scenarios is deemed to be necessary. Fire risk assessment is needed when a large number of distinct fire scenarios pose sufficiently different challenges to the property and its fire safety goals as to preclude the use of any one scenario to represent others.

5 Overview of fire risk management

Risk management includes risk assessment but also typically includes risk treatment, risk acceptance, and risk communication, which all occur after risk assessment. Risk treatment may precede a second fire risk assessment. (See Figure 1.) Fire risk assessment can also be used to assess alternative designs, prior to selecting a specific design or making changes to that design to achieve compliance with the acceptance criteria.

