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Fire safety engineering — Selection of design fire scenarios and design fires

Ingénierie de la sécurité contre l'incendie — Sélection de scénarios d'incendie et de feux de calcul

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Foreword

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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.

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:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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 16733 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

Introduction

Selection of the fire scenarios requiring analysis is critical in fire-safety engineering. The number of possible fire scenarios in any built environment (a building, structure or transportation vehicle) can be very large and it is not possible to quantify them all. It is necessary to reduce this large set of possibilities to a manageably small set of fire scenarios that is amenable to analysis. In a deterministic assessment, which is implicitly envisioned in this Technical Specification, a manageable number of design fire scenarios is selected. For a full risk assessment, as described in ISO 16732, the large number of fire scenarios is combined into a set of scenario clusters.

The characterization of a fire scenario involves a description of fire initiation, the growth phase, the fully developed phase and extinction together with likely smoke and fire spread routes. This includes the interaction with the proposed fire-protection features for the built environment. It is necessary to consider the possible consequences of each fire scenario.

This Technical Specification introduces a methodology for the selection of design fire scenarios that is tailored to the fire-safety design objectives and accounts for the likelihood and consequences of potential scenarios.

There can be several fire safety objectives being addressed including life safety, property protection, continuity of operations and environmental protection. A different set of design fire scenarios can be required to assess the adequacy of a proposed design for each objective.

Following selection of the design fire scenarios, it is necessary to describe the assumed characteristics of the fire on which the scenario quantification are based. These assumed fire characteristics are referred to as “the design fire”. It is important that the design fire be appropriate to the objectives of the fire-safety engineering analysis and that they result in a design solution that is conservative.

Design fires are usually characterized in terms of time-dependent variables, such as the heat-release rate and effluent production rate. Fire can grow from ignition through to a fully developed stage and finally decay and eventually burnout. The design fire is described by the above variables over the life of the fire.

Fire safety engineering — Selection of design fire scenarios and design fires

1 Scope

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

The selection of design fire scenarios is tailored to the fire-safety design objectives, and accounts for the likelihood and consequences of potential scenarios.

The selection of design fires is also tailored to the fire-safety objectives and to ensuring credible but severe fire exposure conditions.

While this Technical Specification provides more operational information on the selection of design fire scenarios and design fires than ISO/TR 13387-2[20], it is not intended to replace ISO/TR 13387-2 within the self-consistent set of parts making up ISO/TR 13387.

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/TR 13387-1, *Fire safety engineering — Part 1: Application of fire performance concepts to design objectives*

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO/TR 13387-1 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.

3.1
built environment
building, structure or transportation vehicle

EXAMPLE Examples of structures other than buildings include tunnels, bridges, off-shore platforms and mines.

3.2
design fire
quantitative description of assumed fire characteristics within a design fire scenario

NOTE Typically, an idealized description of the variation with time of important fire variables, such as heat release rate and toxic species yields, along with other important input data for modelling such as the fire load density.

3.3
design fire scenario
specific fire scenario on which a deterministic fire safety engineering analysis will be conducted

NOTE 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.

3.4
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

NOTE It typically defines the ignition and fire growth process, the fully developed stage, and decay stage as well as systems that impact the course of the fire and the nature of the local environment. Identification of potential fire scenarios is an important step whether a deterministic analysis or a risk assessment is envisioned.

4 Symbols

A area of an opening, expressed in square metres

h height of an opening, expressed in metres

$\dot{m}_\mathrm{f}$ rate of mass loss of fuel, expressed in kilograms per second

$\dot{m}_\mathrm{air}$ rate of entry of air into the enclosure, expressed in kilograms per second

$\dot{Q}$ rate of heat release, expressed in kilowatts

$\dot{Q}_\mathrm{o}$ reference rate of heat release, expressed in kilowatts

r stoichiometric air requirement for complete combustion of fuel, expressed as the ratio kilograms of air to kilograms of fuel

t time, expressed in seconds

t_g time required to reach the reference rate of heat release $\dot{Q}_\mathrm{o}$, expressed in seconds

5 Fire safety engineering applications

5.1 The role of design fire scenarios in fire safety design

Design-fire scenarios are the foundation of deterministic fire safety engineering assessments. Such assessments entail analysing design fire scenarios and drawing inferences from the results with regard to the adequacy of the proposed design to meet the performance criteria that have been set. Identification of the appropriate scenarios requiring analysis is crucial to the attainment of a built environment that fulfils the fire safety objectives.

It should be noted that there may be several fire safety objectives, including life safety, property protection, continuity of operations, and environmental protection, and that a different set of design fire scenarios can be required to assess the adequacy of the proposed design for each objective.

In reality, the number of possible fire scenarios in most built environments approaches infinity. It is impossible to analyse all scenarios even with the aid of the most sophisticated computing resources. It is necessary to reduce this infinite set of possibilities to a manageably small set of design fire scenarios that is amenable to analysis and that represents the range of fires that can challenge the engineering design that is the subject of the analysis.

Each design fire scenario is selected to represent a high-risk cluster of fire scenarios. The risk associated with a cluster is characterized in terms of the probability (or likelihood) of occurrence of the cluster and the resultant consequence: most typically, in terms of the product of the probability and consequence. For the purposes of this Technical Specification, where a deterministic assessment is envisioned, a qualitative estimation of the probability and consequence suffices. For a full risk assessment, such as that outlined in ISO/TS 16732[19], a more quantitative estimation is undertaken.

Once design fire scenarios are selected, 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 relevant fire safety objective(s).

It is important to demonstrate that the fire scenarios and associated scenario clusters NOT selected for direct analysis would not change the conclusions if they were included. First, a comparison is made between the total risk collectively represented by the selected scenarios and clusters vs. the total risk collectively represented by the scenarios and clusters not selected. If the latter is much lower than the former, that is evidence that the selected scenarios dominate the total risk and can be validly used to represent that risk. If the latter is lower but not much lower, then it is necessary that the combined risk for the selected scenarios be not only lower than an appropriate threshold for acceptable risk but also lower than a fraction of that threshold, where the fraction reflects the fraction of total risk that the selected scenarios constitute. A very rough calculation suffices to establish this point, and it is usually sufficient to concentrate on the size of the consequences, while allowing for the possibility that the probabilities are not low. Second, there can be unselected scenarios with significant consequences that can be shown to have acceptably low risk by virtue of acceptably low probability. It is necessary to take special care with these scenarios because the typically high consequences, if they occur despite the low probability, will be borne by society. Third, there can be unselected scenarios with significant risk that cannot be reduced by any choices available to the engineer. These scenarios can be mitigated by strategies outside the scope of the analysis, or it can be necessary to assure that the total risk, combining the selected scenarios with these unselected scenarios, is still acceptable.

It is necessary to identify important design-fire scenarios during the qualitative design review (QDR) stage. During this process, it is possible to eliminate scenarios that are of such low risk that they cannot, individually or collectively, affect the overall evaluation of the design. It is important to remember that low consequence combined with high probability or high consequence combined with low probability can be high or low risk, depending on whether consequence or probability dominates. Neither probability nor consequence can be used completely in isolation for risk screening (see 6.3).

The characterization of a design fire scenario for analysis purposes involves a description of such things as the initiation, growth and extinction of fire, together with likely smoke and fire spread routes under a defined set of conditions. The impacts of smoke and fire on people, property, structure and environment are all part of potentially relevant consequences of a design fire scenario and are part of the characterization of that scenario when those consequences are relevant to the specified fire safety objectives. The characterization of fire growth, fire and smoke spread, fire extinction and fire and smoke impact involving temporal sequences of events belong to the “design fire”. Some later events are predictable from earlier events through the use of fire safety science and it is important that the characterization of the event sequence in the scenario be consistent with such science.

5.2 The role of design fires in fire safety design

Following identification of the design fire scenarios, it is necessary to describe the assumed characteristics of the fire on which the scenario quantification is based. These assumed fire characteristics and the further associated fire development are referred to as the “design fire”.

As with the design-fire scenario, it is important that the design fire be appropriate to the relevant fire-safety objectives. For example, if the objective is to evaluate the smoke-control system, a design fire should be selected that challenges that system. If the severity of the design fire is underestimated, then the application of engineering methods to predict the effects of the fire elsewhere can produce results that do not accurately reflect the true impact of fires and can underestimate the hazard. Conversely, if the severity is overestimated, unnecessary expense can result.

5.3 Selection of design fire scenarios and design fires

The methodology for selecting design fire scenarios and design fires described in this Technical Specification is summarized in Figure 1.

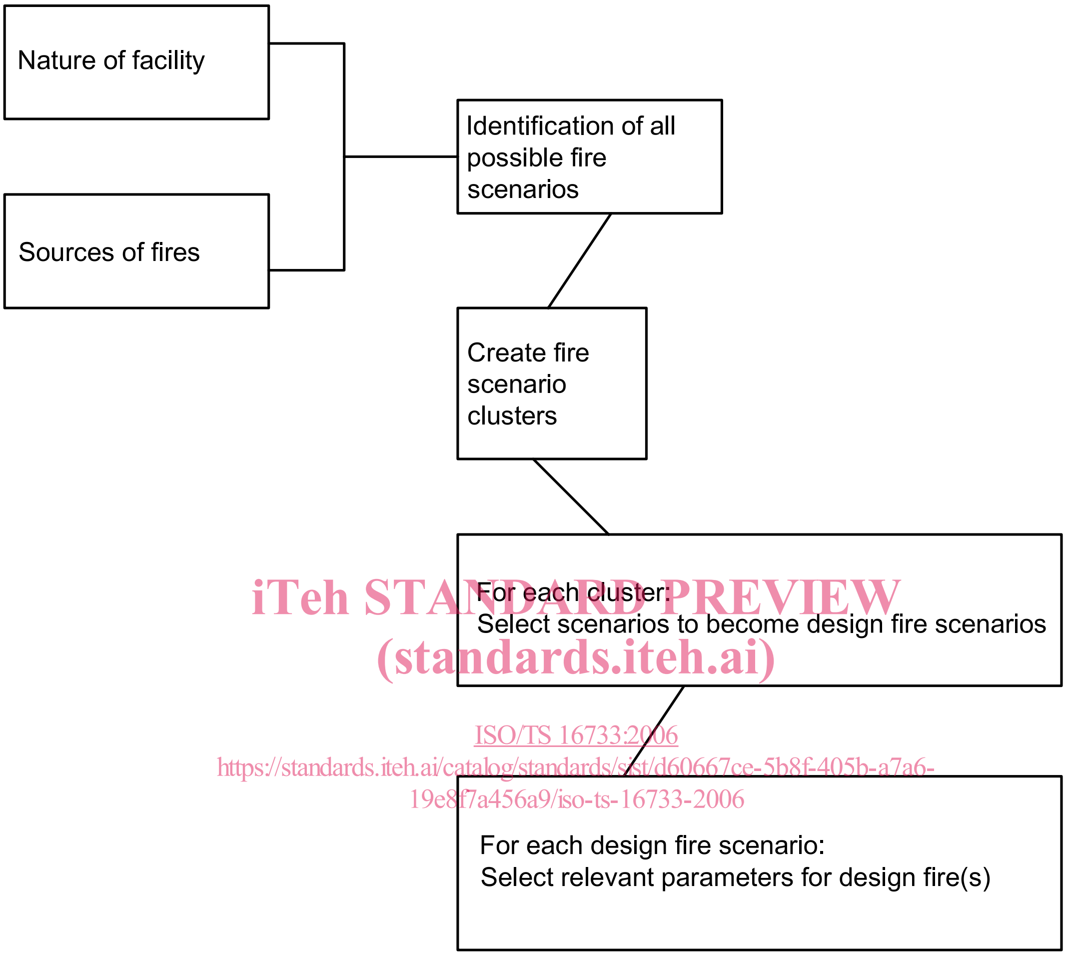

Figure 1 — Selection of design fire scenarios and design fires

6 Design fire scenarios

6.1 Characteristics of fire scenarios

Each fire scenario is represented by a unique occurrence of events and circumstances as well as a particular set of circumstances associated with the fire-safety measures. The latter are defined by the fire safety design, while the former is what is required to be specified to characterize the scenario. Accordingly, a fire scenario represents a particular combination of events and circumstances associated with non-design factors such as the following:

— type of fire (smouldering, localized, post-flashover…);

— internal ventilation conditions;

— external environmental conditions;

- status of each of the fire safety measures, including active systems and passive features;
- type, size and location of ignition source;
- distribution and type of combustible materials;
- fire-load density;
- detection, alarm, and suppression of fire by non-automatic, human means;
- status of doors;
- breakage of windows, if not taken into account by the fire design calculation method.

Other factors that can be elements of some designs are treated as non-design factors if they are not considered choices for the design, such as the following:

- choices of contents and furnishings, structural materials and methods and interior and exterior finishes, affecting distribution and type of fuel or fire load density;
- automatic fire detection and alarm;
- fire suppression;
- self-closing doors or other discretionary elements of compartmentalization;
- building air-handling system or smoke-management system.

Other factors are always treated as elements of design, such as the following:

- performance of each of the fire-safety measures;
- reliability of each of the fire-safety measures.

6.2 Identification of fire scenarios

6.2.1 General

A systematic approach to the identification of fire scenarios for analysis is desirable in order to identify important scenarios and to provide a consistent approach by different analysts. The number of possible fire scenarios in any built environment can be very large and it is not possible to quantify them all. It is necessary to reduce this large set of possibilities to a manageable set of fire scenarios that is amenable to analysis. In a deterministic assessment, a manageable set of design fire scenarios is selected. For a full risk assessment, as described in ISO 16732, the large number of design fires is combined into a set of scenario clusters.

It is important that the design fire scenarios be appropriate to the objectives of the fire-safety engineering task.

A risk-ranking process provides a helpful basis for the selection of design-fire scenarios. Such a process takes into account both the consequence and likelihood of the scenario. This implies that fire-risk assessment techniques can be applied to the selection of design-fire scenarios for a deterministic analysis. Key aspects of the risk-ranking process, explained in the detailed steps below, are the following:

- identification of a comprehensive set of possible fire scenarios;
- estimation of probability of occurrence of the scenario;
- estimation of the consequence of the scenario;

- estimation of the risk of the scenarios (reflecting consequence and probability of occurrence);
- ranking of the fire scenarios according to their risk.

The ten steps outlined below provide a systematic approach towards identifying design-fire scenarios.

6.2.2 Step 1 — Location of fire

Step 1 typically involves characterization of the space in which fire begins, as well as characterization of the specific location within the space.

Identification of most likely locations can be done using fire statistics. Alternatively, if statistics are not available, one can make an assessment based on the presence of heat sources, fuel packages and occupants.

Identification of most adverse or challenging locations involves engineering judgment. Challenging locations are those where special circumstances can adversely affect the performance of fire safety measures. Examples include the following:

- fires in assembly areas, clean rooms or other spaces with a high density of vulnerable people or highly vulnerable property close to the fire's point of origin or with access to exposed structural members, in each case such that there could be insufficient time and space for fire safety measures to act effectively;
- fires within or blocking entry to the egress system, which can delay or prevent safe evacuation; and
- fires in rooms or spaces, including concealed spaces and exterior surfaces, that are outside the coverage areas of fire-safety systems.

Other examples of locations for which design fire scenarios may be needed include the following:

a) internal:

  - fire in construction products (sandwich panels, …),
  - room fire (corner, ceiling, floor, wall),
  - fire in stairwells,
  - cable tray or duct fire,
  - roof fires (under roof),
  - cavity fire (wall cavity, facade, plenum).

b) external:

  - fire in neighbouring building or vegetation,
  - fires on roofs.

Other design fire scenarios may be agreed upon during the QDR for special situations.

6.2.3 Step 2 — Type of fire

The type of fire refers to the initial intensity and rate of growth of the fire, which can be associated with some combination of the initial heat source, the first item ignited, the first large item ignited and any other items ignited prior to ignition of the first large item. This means Step 2 typically involves two substeps: characterization of the initial ignition and characterization of the early-stage fire when it is well established. If the first item ignited is also a large item, these two substeps can be treated as the same. However, many fires begin with very small initial fuel items, such as spilled food on a stove, trash in a trash can, deposited soot in a chimney or accumulated lint in a clothes-dryer. For these fires, the initial ignition does not occur at the same time or closely resemble the early-stage well established fire.

Fire incident statistics provide an appropriate basis for identification of the initial ignition conditions for design fire scenarios, together with probabilities for alternative initial ignition conditions. The goal of this systematic approach is to screen possible design fire scenarios by relative risk. A practical way to do this using fire incident statistics and engineering judgment is to identify one set of fire scenarios with high probability and minimal consequence and another set of fire scenarios with high consequence and minimal probability. From fire incident statistics appropriate for the building and occupancy under consideration, rank combinations of the initial heat sources and the initial fuel items by some frequency and consequence-related criteria, such as the following:

a) types of fires accounting for the largest shares of fire injuries or fire fatalities;

b) types of fires accounting for the largest share of property damage, measured in monetary terms;

c) most likely fires of those with fire extent of a certain minimum size, such as flame extent beyond room of origin, fire size greater than a specific area, consequences of five or more deaths or consequences of more than a defined monetary threshold indicating a large loss, such as the minimum loss associated with the costliest 1 % of fires.

Other examples of types of fires for which design-fire scenarios can be necessary include the following:

a) internal:

- single burning item fire (furniture, wastepaper basket, fittings),
- developing fire (smoke extraction);

b) external:

- fires in external fuel packages,
- fires on facades.

Other design fire scenarios may be agreed upon during the QDR for special situations.

Appropriate statistics can be available on a national basis, a state or provincial basis, or for like properties sharing ownership with the structure being designed. If appropriate national statistics are not available, then information from other countries with similar fire experience may be utilized. It is necessary to exercise care in applying fire incident statistics to ensure that the data are appropriate for the built environment under consideration.

If any fire types involving very small initial fuel items ignited rank high on a consequence-weighted ranking, It is necessary that these fires have involved at least one additional fuel item of substantial size. Engineering judgement is usually sufficient to estimate what large fuel item(s) are close enough to a small fire of the defined type to be the subsequent item ignited that creates a well established fire.

