INTERNATIONAL STANDARD

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Fire safety engineering — Procedures and requirements for verification and validation of calculation methods —

Part 1: General

Ingénierie de la sécurité incendie — Procédures et exigences pour la vérification et la validation des méthodes de calcul —

Partie 1: Généralités

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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*.

This document cancels and replaces ISO 16730:2008, which has been technically revised. The original title *Fire safety engineering — Assessment, verification and validation of calculation methods* has been replaced by *Fire safety engineering — Procedures and requirements for verification and validation of calculation methods — Part 1: General*.

Introduction

The objective of fire safety engineering is to assist in the achievement of an acceptable predicted level of fire safety. Part of this work involves the use of calculation methods to

— predict the course of events potentially occurring in case of a fire or as a consequence of a fire, and

— evaluate the ability of fire protection measures to mitigate the adverse effects of a fire on people, property, the environment and other objectives.

The main principles necessary for establishing credibility of these calculation methods are verification and validation. This International Standard addresses the procedures for verification and validation of calculation methods for fire safety engineering in general.

Potential users of calculation methods and those who are asked to accept the results need to be assured that the calculation methods provide sufficiently accurate predictions of the course and consequences of the fire for the specific application planned. To provide this assurance, the calculation methods chosen need to be verified for mathematical accuracy and validated for capability to reproduce the phenomena. A rigorous verification and validation process is a key element of quality assurance.

There is no fixed requirement of accuracy that is applicable to all calculation methods. The accuracy level depends on the purposes for which a calculation method is to be used. Not all calculation methods need to demonstrate high accuracy as long as the error, uncertainty and limits of applicability of the calculation methods are known.

This International Standard focuses on the predictive accuracy of calculation methods. However, other factors such as ease of use, relevance, completeness and status of development play an important role in assessing the most appropriate method to use for a particular application. The assessment of the suitability of a calculation method for a special purpose within the field of fire safety engineering is supported by the use of quality assurance methodology for the proof of the requirements being fulfilled. Guidance for establishing metrics for measuring the attributes of the relevant quality characteristics is outlined in brief in this International Standard.

This International Standard contains elements that are intended, in part or in whole, to be used by

a) developers of calculation methods (individuals or organizations who perform development activities, including requirement analysis, design and testing of components) – to document the usefulness of a particular calculation method, perhaps for specific applications. Part of the calculation method development includes identification of precision and limits of applicability, and independent testing,

b) developers of calculation methods (individuals or organizations who maintain computer models, supply computer models and for those who evaluate computer model quality as part of quality assurance and quality control) – to document the software development process to assure users that appropriate development techniques are followed to ensure quality of the application tools,

c) users of calculation methods (individuals or organizations who use calculation methods to perform an analysis) - to assure themselves that they are using an appropriate method for a particular application and that it provides adequate accuracy,

d) developers of performance codes and standards - to determine whether a calculation method is appropriate for a given application,

e) approving bodies/officials (individuals or organizations who review or approve the use of assessment methods and tools) - to ensure that the calculation methods submitted show clearly that the calculation method is used within its applicability limits and has an acceptable level of accuracy, and

f) educators - to demonstrate the application and acceptability of calculation methods being taught.

Users of this International Standard should be appropriately qualified and competent in the fields of fire safety engineering and risk assessment. It is important that users understand the parameters within which specific methodologies may be used.

General principles are described in ISO 23932, which provides a performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is evaluated through an engineered approach based on the quantification of the behaviour of fire and based on knowledge of the consequences of such behaviour on life safety, property and the environment. ISO 23932 provides the process (necessary steps) and essential elements to design a robust performance-based fire safety programme.

ISO 23932 is supported by a set of fire safety engineering International Standards available on the methods and data needed for the steps in a fire safety engineering design summarized in ISO 23932:2009, Clause 4 and shown in Figure 1 (taken from ISO 23932:2009, Clause 4). This set of International Standards is referred to as the *Global fire safety engineering analysis and information system*. This global approach and system of standards provides an awareness of the interrelationships between fire evaluations when using the set of fire safety engineering International Standards. The set includes ISO 16733-1[1)], ISO 16732-1, ISO 16734, ISO 16735, ISO 16736, ISO 16737, ISO/TS 24679, ISO 16730-1, ISO 29761[2)], ISO/TS 13447, and other supporting technical reports that provide examples of and guidance on the application of these standards.

Each International Standard supporting the global fire safety engineering analysis and information system includes language in the introduction to tie the standard to the steps in the fire safety engineering design process outlined in ISO 23932. ISO 23932 requires that calculation methods used in scenario-based evaluations of trial designs (ISO 23932:2009, Clause 11) be verified and validated. Pursuant to the requirements of ISO 23932, this International Standard provides the procedures and requirements for the verification and validation of fire calculation methods. This step in the fire safety engineering process is shown as a highlighted box in Figure 1 below and described in ISO 23932.

1) To be published.

2) To be published.

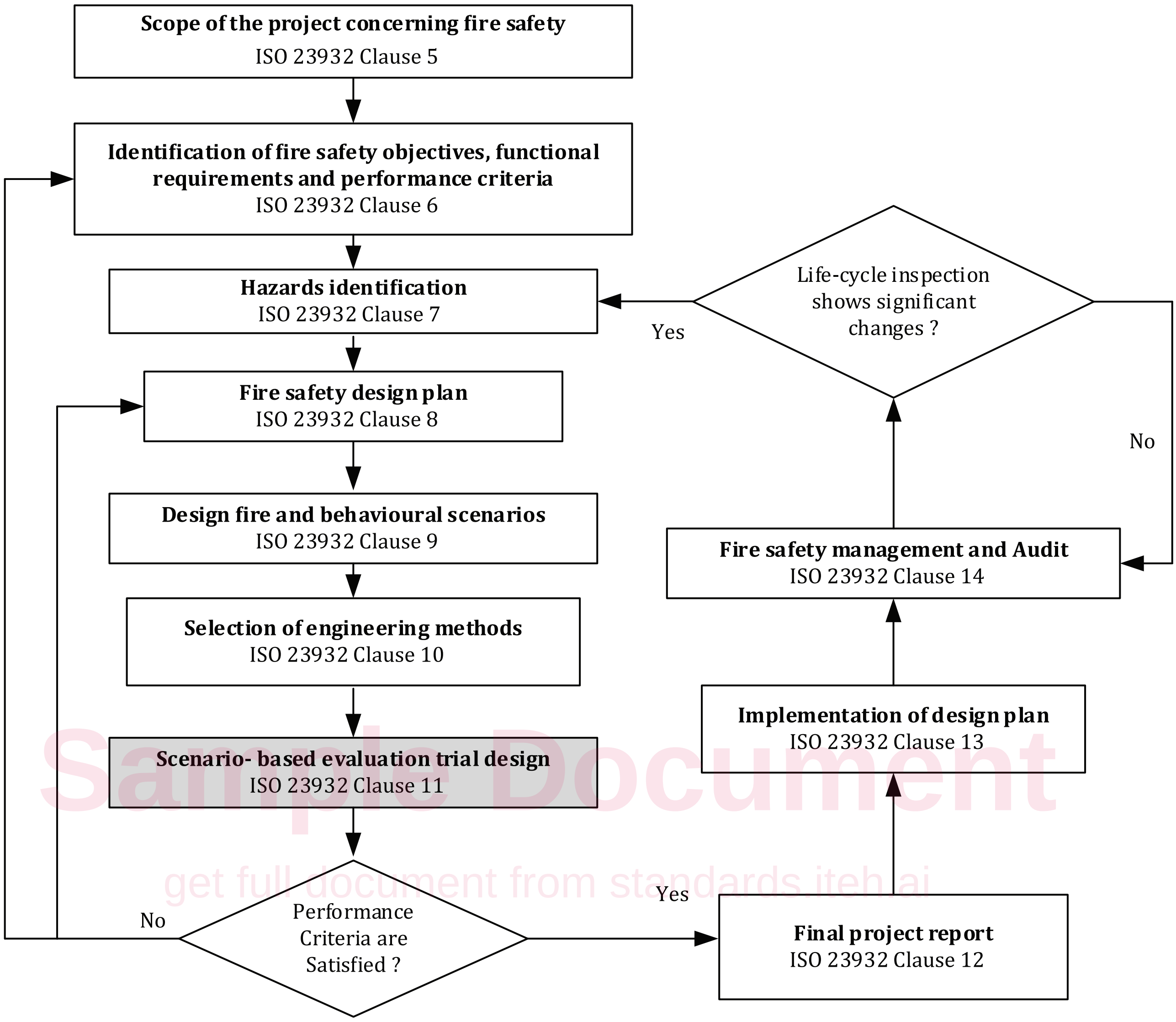

Figure 1 — Flow chart illustrating the fire safety engineering design process (from ISO 23932:2009)

Fire safety engineering — Procedures and requirements for verification and validation of calculation methods —

Part 1: General

1 Scope

This International Standard establishes a framework for the verification and validation of all types of calculation methods used as tools for fire safety engineering by specifying specific procedures and requirements for the purpose. It does not address specific fire models, but it is applicable to analytical models, algebraic correlations and complex numerical models, which are addressed as calculation methods in the context of this International Standard.

This International Standard includes

— a process to determine that the relevant equations and calculation methods are implemented correctly (verification) and that the calculation method being considered is an accurate representation of the real world (validation),

— requirements for documentation to demonstrate the adequacy of the scientific and technical basis of a calculation method,

— requirements for data against which a calculation method's predicted results are checked, and

— guidance on use of this International Standard by developers and/or users of calculation methods, and by those assessing the results obtained by using calculation methods.

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 23932, *Fire safety engineering — General principles*

ISO 13943, *Fire safety — Vocabulary*

ISO/IEC 25000, *Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Guide to SQuaRE*

ISO/IEC 25010:2011, *Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models*

ISO/IEC 25040:2011, *Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Evaluation process*

3 Terms and definitions

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

3.1
accuracy
degree of exactness actually possessed by an approximation, measurement, etc.

Note 1 to entry: Accuracy includes *error* (3.9) and *uncertainty* (3.23).

3.2
calculation method
mathematical procedure used to predict fire-related phenomena

Note 1 to entry: Calculation methods may address the behaviour of people as well as objects or fire; may be probabilistic as well as deterministic; and may be algebraic formulae as well as complex computer models.

3.3
calibration
⟨of a model⟩ process of adjusting modelling parameters in a computational model for the purpose of improving agreement with experimental data

3.4
computer model
computerized model
operational computer program that implements a conceptual model

3.5
conceptual model
description composed of all the information, mathematical modelling data and mathematical equations that describe the (physical) system or process of interest

3.6
default value
standard setting or state to be taken by the program if no alternate setting or state is initiated by the system or the user

3.7
deterministic model
calculation method that uses science-based mathematical expressions to produce the same result each time the method is exercised with the same set of input data values

3.8
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

3.9
error
recognizable deficiency in any phase or activity of calculation that is not due to lack of knowledge

3.10
fire model
representation of a system or process related to fire development, including fire dynamics and fire impacts

3.11
mathematical model
sets of equations that describe the behaviour of a physical system

3.12
measure
variable to which a value is assigned as the result of measurement

3.13
measurement
set of operations having the object of determining a value of a measure

3.14
metric
measure, quantitative or qualitative, of relative achievement of a desired quality characteristic

3.15
modelling
process of construction or modification of a model

3.16
numerical model
numerical representation of a physical (fire) model

3.17
physical model
model that attempts to reproduce fire phenomena in a simplified physical situation. (e.g. scale models)

3.18
probabilistic model
model that treats phenomena as a series of sequential events or states, with mathematical rules to govern the transition from one event to another (e.g. from ignition to established burning) and probabilities assigned to each transfer point

3.19
precision
error in the implementation and solution of calculation method to accurately represents the developer's conceptual description of the calculation method

3.20
sensitivity analysis
<calculation method> study of how changes in specific parameters affect the results generated by the calculation method

3.21
simulation
exercise or use of a calculation method

3.22
simulation model
model that treats the dynamic relationships that are assumed to exist in the real situation as a series of elementary operations on the appropriate variables

3.23
uncertainty
potential deficiency in any phase or activity of the modelling process that is due to lack of knowledge

3.24
validation
process of determining the degree to which a calculation method is an accurate representation of the real world from the perspective of the intended uses of the calculation method

3.25
verification
process of determining that a calculation method implementation accurately represents the developer's conceptual description of the calculation method and the solution to the calculation method

Note 1 to entry: The fundamental strategy of verification of computational models is the identification and quantification of error in the computational model and its solution.

4 Documentation

4.1 General

The technical documentation should be sufficiently detailed so that all calculation results can be reproduced within the stated accuracy by an appropriately qualified independent individual or group. Sufficient documentation of calculation methods, including computer software, is essential to assess the adequacy of the scientific and technical basis of the calculation methods, and the accuracy of computational procedures. In addition, adequate documentation can assist to prevent the unintentional misuse of calculation methods. Reports on any verification and validation of a specific calculation method should become part of the documentation. The validity of a calculation method includes comparing results to data from real fire incidents, or from statistical surveys, tests and experiments, and shall be stated by applying quality assurance methodology. These methodology give a measure or a set of measures that shall be compared to previously defined criteria to demonstrate whether agreed quality requirements have been met.

Documentation shall include

— technical documentation that explains the scientific basis of the calculation method, see 4.2, and

— a user's manual, in the case of a computer program, see 4.3.

The necessary requirements for technical documentation and a user's manual are described in 4.2 and 4.3. The list is quite lengthy, but is not intended to exclude other forms of information that can assist the user in assessing the applicability and usability of the calculation method.

4.2 Technical documentation

4.2.1 General

Technical documentation is needed to assess the scientific basis of the calculation method. The provision of technical documentation of a calculation method is a task to be done by model developers. Technical documentation must describe thoroughly the calculation method and its basis, demonstrate its ability to perform adequately and provide users with the information they need to apply the calculation method correctly. In cases where calculations make use of algebraic formulae derived from experimental results by regression or when analytical solutions are applied, the user shall rely on relevant documentation from standards or similar material like scientific literature. When standards are developed that contain calculation methods to be used for fire safety engineering, the source(s) for the calculation methods to be used together with technical documentation as described in 4.2.2 to 4.2.4 shall be given, where applicable.

4.2.2 Description of the calculation method

The description of the calculation method shall include complete details on

a) purpose:

   1) define the problem solved or function performed;

   2) describe the results of the calculation method;

   3) include any feasibility studies and justification statements,

b) theory:

   1) describe the underlying conceptual model (governing phenomena), if applicable;

2) describe the theoretical basis of the phenomena and physical laws on which the calculation method is based, if applicable,

c) implementation of theory, if applicable:

1) present the governing equations;

2) describe the mathematical techniques, procedures, and computational algorithms employed and provide references to them;

3) identify all the assumptions embedded in the logic; take into account limitations on the input parameters that are caused by the range of applicability of the calculation method;

4) discuss the precision (error) of the results obtained by important algorithms, and, in the case of computer models, any dependence on particular computer capabilities;

5) describe results of the sensitivity analyses, and

d) input:

1) describe the input required;

2) provide information on the source of the data required;

3) for computer models, list any auxiliary programs or external data files required;

4) provide information on the source, contents and use of data libraries for computer models.

4.2.3 Description of the verification and validation of the calculation method

The verification and validation of the calculation method must be completely described, with details on

a) the results of any efforts to evaluate the predictive capabilities of the calculation method in accordance with Clause 5; this should be presented in a quantitative manner,

b) references to reviews, analytical tests, comparison tests, experimental validation, and code checking already performed; if, in case of computer models, the verification of the calculation method is based on beta testing, the documentation should include a profile of those involved in the testing (e.g. whether they were involved to any degree in the development of the calculation method or whether they were naive users; whether they were given any extra instruction that would not be available to the intended users of the final product, etc.), and

c) the extent to which the calculation method meets this International Standard.

The technical documents shall be collected in one document, such as a manual, as far as computer models are concerned. Whenever explicit algebraic formulae are used to solve a fire safety engineering problem, relevant technical documentation may be cited from sources as indicated above.

Quality assurance methods shall be used to determine the suitability of the software for its intended purposes. This process is further defined in 5.6. It is supported by definition and use of relevant quality assurance methods to arrive at a measure or a set of (derived) measures that allow scaling of the quality of a calculation method and consider whether a calculation method is accurate enough to meet the requirements of the intended user. [See, for example, the concept on internal and external metrics and on quality in use from the ISO/IEC series of Software Quality Requirements and Evaluation (SquaRE)]. For further information see the ISO/IEC 25000-series (and following) documents. The purpose of a calculation method's evaluation, in general, is to compare the quality of a calculation method against quality requirements that express user needs, or even to select a calculation method by comparing different calculation methods.

4.2.4 Worked examples

The technical documentation shall include at least one (or more) worked example(s). Worked examples may be required both for explicit algebraic formulae and for mathematical models. The latter is addressed in 4.3.9. The purpose of a worked example is to demonstrate what the required input data are and their limitations, and the range of applicability of the result(s) of the calculation method being considered. Examples for required input data and their intended range or limitations within which the calculation has been validated are, for example, geometry, material properties and boundary conditions. The range of applicability and accuracy of the calculation method shall be clearly stated in the documentation.

NOTE Significant errors in safety decisions and fire protection measures implemented will result from the use of the calculation method outside the range of stated scenarios determined through the validation process (see 5.3 for requirements to identify the range of applicability established by a validation process).

Standards on calculation methods shall include worked example(s) in an informative annex. By specifying the required components of a worked example in a standard on calculation methods (e.g. ISO 16734 to ISO 16737) guidance is therefore given on how to apply the standard correctly, together with the information given in the standard itself about requirements on limitations and input parameters. Examples taken from real world problems may be: (development of) temperature of a steel member; a fire insult to a cable in a nuclear power plant. As there are examples available in the open literature, the requirement of worked examples in an informative annex to a standard on calculation methods may also be met by reference to, for example, textbooks that include such examples.

4.3 User's manual

4.3.1 General

A user's manual is required only in cases where computer models are used. The user's manual for a computer model should enable users to understand the model application and methodology, reproduce the computer operating environment and the results of sample problems included in the manual, modify data inputs, and run the program for specified ranges of parameters and extreme cases. The manual should be concise enough to serve as a reference document for the preparation of input data and the interpretation of results. Installation, maintenance and programming documentation should be included in the user's manual or be provided separately. There should be sufficient information to install the program on a computer. All forms of documentation should include the name and sufficient information to define the specific version of the calculation method and identify the organization responsible for maintenance of the calculation method and for providing further assistance.

For computer models, the user's manual must provide all the information necessary for a user to apply a computer model correctly. The items it should include are listed in 4.3.2 to 4.3.10.

4.3.2 Program description

The program description is

a) a self-contained description of the model,

b) a description of the basic processing tasks performed, and the calculation methods and procedures employed (a flow chart can be useful), and

c) a description of the types of skills required to execute typical runs.

4.3.3 Installation and operating instructions

The installation and operating instructions

a) identify the minimum hardware configuration required,

b) identify the computer(s) on which the program has been executed successfully,

c) identify the programming languages and software operating systems and version in use,

d) provide instructions for installing the program,

e) provide the typical personnel time and setup time to perform a typical run, and

f) provide information necessary to estimate the computer execution time on applicable computer systems for typical applications.

4.3.4 Program considerations

The program considerations

a) describe the functions of each major option available for solving various problems with guidance for choosing these options,

b) identify the limits of applicability (e.g. the range of scenarios over which the underlying theory is known or believed to be valid or the range of input data over which the calculation method was tested), and

c) list the restrictions and/or limitations of the software, including appropriate data ranges and the program's behaviour when the ranges are exceeded, where this information should be derived from and be consistent with that contained in the technical documentation.

4.3.5 Input data description

The input data description

a) name and describe each input variable, its dimensional units, the default value (if any) and the source (if not widely available),

b) describe any special input techniques,

c) identify limits on input based on stability, accuracy and practicality of the data and the applicability of the model, as well as their resulting limitations to output,

d) describe any default variables and the process for setting those variables to user-defined values, and,

e) if handling of consecutive cases is possible, explain the conditions of data retention or reinitialization from case to case.

4.3.6 External data files

The external data files

a) describe the contents and organization of any external data files, and

b) provide references to any auxiliary programs that create, modify or edit these files.

4.3.7 System control requirements

The system control requirements

a) detail the procedure required to set up and run the program,

b) list the operating system control commands,

c) list the program's prompts, with the ranges of appropriate responses, and,

d) if possible to do so, describe how to halt the program during execution, how to resume or exit, and the status of the files and data after the interruption.