TECHNICAL REPORT

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Fire safety engineering —

Part 1:
Application of fire performance concepts to design objectives

Ingénierie de la sécurité contre l'incendie —

Partie 1: Application des concepts de performance aux objectifs de conception

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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 main task of ISO technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art“, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 13387-1, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 92*, Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

It is one of eight parts which outlines important aspects which need to be considered in making a fundamental approach to the provision of fire safety in buildings. The approach ignores any constraints which might apply as a consequence of regulations or codes; following the approach will not, therefore, necessarily mean compliance with national regulations.

ISO/TR 13387 consists of the following parts, under the general title *Fire safety engineering:*

— *Part 1: Application of fire performance concepts to design objectives*

— *Part 2: Design fire scenarios and design fires*

— *Part 3: Assessment and verification of mathematical fire models*

— *Part 4: Initiation and development of fire and generation of fire effluents*

— *Part 5: Movement of fire effluents*

— *Part 6: Structural response and fire spread beyond the enclosure of origin*

— *Part 7: Detection, activation and suppression*

— *Part 8: Life safety — Occupant behaviour, location and condition*

Annex D forms a normative part of this part of ISO/TR 13387. Annexes A to C and annexes E and F are for information only.

Introduction

A fire safety engineering approach may have many benefits over prescriptive approaches (see annex A). It takes into account the totality of the fire safety package and provides a more fundamental and economic solution than traditional approaches to fire safety. It may be the only viable means of achieving a satisfactory level of fire safety in some large and complex buildings. For most buildings prescriptive recommendations may be found to be adequate but the use of a fire safety engineering approach enables the more precise design necessary for the assessment of new and complex projects.

This part of ISO/TR 13387 is intended to be applicable to both new and existing buildings and can be used either to justify minor deviations from traditional/prescriptive codes or to evaluate the building design as a whole.

The interaction of fire, buildings and people gives rise to a large number of possible scenarios. Together with the wide range of building designs and uses, this makes it impractical to establish a single set of calculations and procedures that can be applied directly to all buildings. There are still many gaps in the available knowledge and it is, therefore, not possible to set down simple step-by-step procedures that can be applied to all buildings. This part of ISO/TR 13387 is, therefore, intended to provide a framework for a flexible but formalised approach to fire safety design that can be readily assessed by the statutory authorities.

The current knowledge and ability to model fire processes and the response of people requires the use of engineering judgement to compensate for gaps in, or supplement, knowledge. The approaches and procedures detailed in this part of ISO/TR 13387 should, therefore, only be used by suitably qualified and experienced fire safety professionals. It is also important that account should be taken of statutory requirements, and the appropriate approvals bodies should, where necessary, be consulted before final decisions are made about the fire safety design.

Fire safety engineering —

Part 1:
Application of fire performance concepts to design objectives

1 Scope

This part of ISO/TR 13387 describes one framework for the provision of an engineered approach to the achievement of fire safety in buildings, based on the quantification of the behaviour of fire and people. The Technical Report is not intended as a detailed technical design guide, but could be used as the basis for development of such a guide. It indicates the interdependence and interactions between various components of the fire safety system and provides an indication of the totality of fire safety design. It is appropriate for various alternative single or multiple design objectives.

The basic principles given in this part of ISO/TR 13387, together with the guidance on detailed aspects of fire safety design given in other parts, may be applied to all types of building and their use. Principally this Part applies to common types of building such as dwellings, office buildings, department stores, schools, hotels, and public-assembly and industrial buildings, new and existing.

The principles, the methodology and many of the calculation tools may be applied to the safe design of many other structures, which may or may not accommodate people, such as tunnels, petrochemical plants, offshore oil/gas installations and transportation systems (railway carriages, aircraft cabins and passenger ships).

This part of ISO/TR 13387 takes into account many factors including building construction, means of escape, human factors, smoke management, detection, alarm and fire suppression and their contribution to the attainment of the fire safety objectives. It provides some alternative approaches to existing codes for fire safety and allows the effect of departures from more prescriptive codes and regulations to be evaluated.

Although the emphasis in this document is on safety of life, the fire safety engineering approach can also be used to assess property loss, business interruption, contamination of the environment and destruction of heritage. It is anticipated that, in the future, this part of ISO/TR 13387 will be broadened to cover, for example, property loss, business interruption, contamination of the environment and destruction of heritage.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO/TR 13387. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/TR 13387 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 31-0:1992, *Quantities and units — Part 0: General principles.*

ISO 31-4 1992, *Quantities and units — Part 4: Heat.*

ISO/TR 13387-2, *Fire safety engineering — Part 2: Design fire scenarios and design fires.*

ISO/TR 13387-3, *Fire safety engineering — Part 3: Assessment and verification of mathematical fire models.*

ISO/TR 13387-4, *Fire safety engineering — Part 4: Initiation and development of fire and generation of fire effluents.*

ISO/TR 13387-5, *Fire safety engineering — Part 5: Movement of fire effluents.*

ISO/TR 13387-6, *Fire safety engineering — Part 6: Structural response and fire spread beyond the enclosure of origin.*

ISO/TR 13387-7, *Fire safety engineering — Part 7: Detection, activation and suppression.*

ISO/TR 13387-8, *Fire safety engineering — Part 8: Life safety — Occupant behaviour, location and condition.*

ISO 13943, *Fire safety — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO/TR 13387, the terms and definitions given in ISO 13943 and the following apply.

3.1
acceptance criteria
qualitative and quantitative criteria which have been agreed with the building approval authority and hence form an acceptable basis for assessing the safety of a building design

3.2
alarm time
the time between ignition and alarm

3.3
characterisation
the process of determining design data which are in a form suitable for input to a subsystem

3.4
critical fire load
the fire load required in a compartment to produce a fire of sufficient severity to cause failure of fire-resisting barriers or structural elements

3.5
detection time
the time between ignition of a fire and its detection by an automatic or manual system

3.6
deterministic study
a methodology, based on physical relationships derived from scientific theories and empirical results, that for a given set of initial conditions will always produce the same outcome

3.7
engineering judgement
the process exercised by a professional who is qualified by way of education, experience and recognised skills to complement, supplement, accept or reject elements of a quantitative analysis

3.8
escape/evacuation time
the interval between the time of a warning of fire being transmitted to the occupants and the time at which the occupants of a specified part of a building or all of the building are able to enter a place of safety

3.9
estimated design parameter
a design parameter which involves a process of estimation (or characterisation)

It may describe the building, contents, occupants and environment. This is usually decided by the fire safety engineer.

3.10
exit
a doorway or other suitable opening giving direct access to a place of safety

Exits include exterior exit doors, exit passageways, horizontal exits, separated exit stairs and separated exit ramps.

3.11
fire safety engineering
the application of engineering principles, rules and expert judgement based on a scientific appreciation of the fire phenomena, of the effects of fire, and of the reaction and behaviour of people, in order to:

- save life, protect property and preserve the environment and heritage;
- quantify the hazards and risk of fire and its effects;
- evaluate analytically the optimum protective and preventative measures necessary to limit, within prescribed levels, the consequences of fire

3.12
fire safety manual
a document detailing the fire safety management procedures that should be implemented on a continuing basis

3.13
hazard
the potential for loss of life (or injury) and/or damage to property by fire

3.14
movement time
the time needed for all of the occupants of a specified part of a building to move to an exit and pass through it and into a place of safety

3.15
management or manager
the persons or person in overall control of the premises whilst people are present, exercising this responsibility either in their own right, e.g. as the owner, or by delegation

3.16
means of escape
structural means whereby safe routes are provided for persons to travel from any point in a building to a place of safety

3.17
phased evacuation
a process by which a limited number of floors (usually the fire floor and the level above and below) are evacuated initially and the remaining floors are evacuated as and when necessary

3.18
place of safety
a place in which persons are in no immediate danger from the effects of fire

3.19
prescribed design parameter
a design parameter which can be directly measured and requires no estimation or conversion of data

It may describe the building, contents, occupants and environment, and is usually decided by the fire safety engineer.

3.20
pre-movement time
the time interval between the warning of fire being given (by an alarm or by direct sight of smoke or fire) and the first move being made towards an exit

3.21
risk
the potential for realisation of an unwanted event, which is a function of the hazard, its probability and its consequences

3.22
system variables
those parameters which are functions of time and which are used in a fire safety engineering evaluation

They are listed under the category Simulation Dynamics in the global information.

3.23
travel distance
the actual distance that needs to be travelled by a person from any point within a building to the nearest exit, having regard to the layout of walls, partitions and fittings

3.24
trial design parameters
design parameters (prescribed and estimated) chosen for the purpose of making a fire safety engineering analysis on one (trial) design

3.25
validation (as applied to fire calculation models)
process of determining the correctness of the assumptions and governing equations implemented in a model when applied to the entire class of problems addressed by the model

3.26
verification (as applied to mathematical fire models)
process of checking a mathematical fire model for correct physical representation and mathematical accuracy for a specific application or range of applications

The process involves checking the theoretical basis, the appropriateness of the assumptions used in the model, and that the model contains no unacceptable mathematical errors and has been shown, by comparison with experimental data, to provide predictions of the course of events in similar fire situations with a known accuracy.

4 The global approach

4.1 General

Traditional approaches to achieving fire safety in buildings have involved the adoption of a number of complex and often disjointed requirements for different components of the fire safety system. The value of each to the overall design objective is unknown and the complementary or compensating nature of these provisions cannot be quantified.

As a result of the large and rapid increase in innovative and diversified building design, traditional regulations based on "prescription" rather than "performance" have proved to be restrictive and inflexible. Consequently, more fundamental approaches to the provision of fire safety in buildings have had to be pursued. A more detailed discussion of the background to the application of fire safety engineering and its benefits is given in annex A.

This part of ISO/TR 13387 looks at the provision of fire safety in buildings from a fundamental viewpoint, and it ignores the constraints that may be applied to building design as a consequence of various national regulations or codes. The fact that a building has been designed adopting the approach given in this document does not, therefore, mean that it will satisfy the requirements of national regulations. The document may help to discipline engineered approaches to fire safety design and to ensure that all the essential requirements and aspects of design have been properly considered and addressed, and that, having established the objectives of design, these are demonstrated as being satisfied in an acceptable and quantified manner.

The approach adopted in this part of ISO/TR 13387 is to consider the global objective of fire safety design and to give guidance on the nature of criteria which may be appropriate to demonstrating compliance with these objectives. The global design is sub-divided into what are called "subsystems" of the total design, and the document ensures that the inter-relationship and interdependence of the various subsystems are appreciated, and that the consequences of all the events in any one subsystem on all other subsystems are identified and addressed.

In addition to life safety, the principles and methodology in this document can also be used to determine property loss, business interruption, contamination of the environment and destruction of heritage. The Technical Report can be used, for instance, to predict a contents response-time profile which enables the amount of fire loss (direct, consequential, etc.) to be determined from a knowledge of the location, value, damageability and salvageability of the individual items of building contents and spatial distribution of smoke, heat, water and corrosive products.

4.2 Summary of the fire safety engineering assessment process

Fire safety engineering assessment involves the following steps (the basic process is illustrated in Figure 1):

a) Qualitative design review (QDR):

The review is qualitative because not all the values of the design parameters will be known and engineering judgement will need to be applied to obtain them. It is also qualitative because judgement will need to be used to decide on a limited number of important fire scenarios for later quantified analysis.

For a large project, it is preferable for the QDR to be undertaken by a team which includes the design team and the approval authorities.

More information on the QDR is given in annex B.

It is necessary to:

- define fire safety objectives and acceptance criteria — possibly in consultation with the approval authorities;
- establish the prescribed design parameters by reviewing the architectural design and the proposed fire safety features;
- characterise the building and its occupants, i.e. estimate design parameters not given by the architect;
- identify potential fire hazards and their possible consequences;
- select those fire scenarios which should form part of the quantified analysis;
- establish trial fire safety designs;
- indicate appropriate methods of analysis.

b) Quantitative analysis of design:

- carry out a time-based quantified analysis using the appropriate subsystems — or use another appropriate method of analysis as indicated in the QDR, making sure that, wherever possible, mathematical models are verified (see ISO/TR13387-3).

c) Assess the outcome of the analysis against the safety criteria:

- Repeat the analysis if the acceptance criteria not satisfied (e.g. in a life safety assessment) by controlling the fire process to increase the time available for safe escape (where appropriate) and/or reducing the time required to escape.

d) Report and present the results.

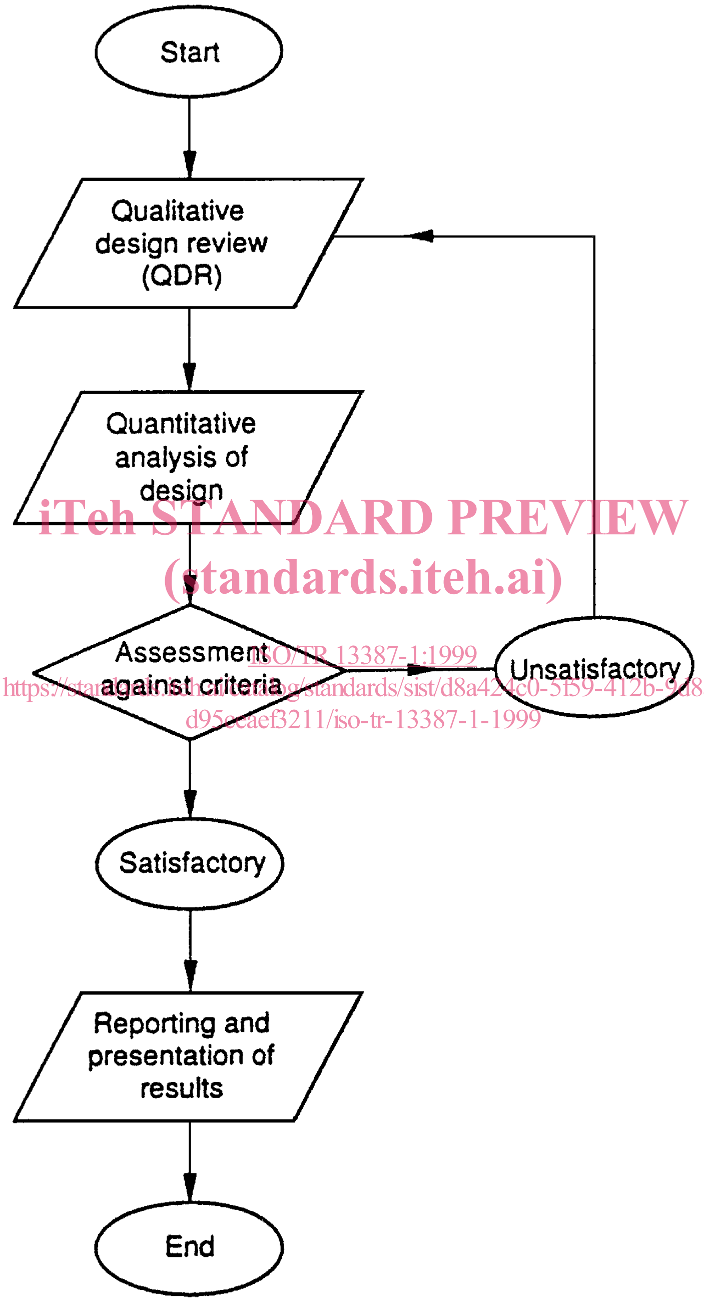

Figure 1 — Basic fire safety design process

4.3 The subsystems of the design

4.3.1 General

The evaluation of the fire safety design of a building is broken down, to simplify the process, into five separate components of the system (subsystems denoted by SS1 to SS5) as follows:

4.3.2 SS1 — Initiation and development of fire and generation of fire effluents

This subsystem provides a framework for critically reviewing the suitability of an engineering method for assessing the potential for the initiation and development of fire and generation of fire effluents. The subsystem may also provide means to assess the effectiveness of fire safety measures meant to reduce the probability of ignition, to control fire development, and to reduce accumulation of heat, smoke, and toxic products or products causing non-thermal damage. Methods for calculating the effects of the design fires for use in the design and assessment of fire safety of a building are also addressed.

4.3.3 SS2 — Movement of fire effluents

This subsystem provides a framework for critically reviewing the suitability of an engineering method for assessing the potential for movement of fire effluents during the course of a fire. The subsystem may also provide means to assess the effectiveness of fire safety measures meant to reduce the adverse effects of the movement of fire effluents. Methods for calculating the effects of the design fires for use in the design and assessment of fire safety of a building are also addressed.

The subsystem draws on other subsystems for a prescription or characterisation of the fire. The predictions of the fire development and the production of fire effluents is provided by subsystem 1. The prediction of the spread of smoke and flames through openings is addressed by subsystem 2 while the spread of fire through barriers is provided by subsystem 3.

4.3.4 SS3 — Structural response and fire spread beyond the enclosure of origin

This subsystem provides a framework for critically reviewing the suitability of an engineering method (hand calculation, computer method or fire test) for assessing the structural response and the potential for fire spread in a given situation (application). This entails an analysis of the unit physical and chemical processes involved in each of the modes of fire spread (e.g. room to room, building to building, room to external items). The availability (and reliability) of the relevant input data for each unit process is also addressed.

The subsystem draws on other subsystems for a prescription or characterisation of the fire. Subsystem 1, for example, provides predictions of the time to flashover and the temperature history in the room of fire origin. These data, along with the description of the building assemblies (trial design parameters) are employed by the subsystem to predict the likelihood (and time) of fire spread, and the likelihood (and time) of structural collapse.

Should fire spread from the room (compartment) of fire origin or should local structural collapse occur, not only will additional property damage be incurred, but the safety of building occupants and firefighters outside the room (compartment) of fire origin can be compromised. Hence data generated by subsystem 3 become inputs to subsystem 5.

Finally, guidance on interpreting the results of an analysis of the potential of fire spread is also provided. This includes guidance on the selection of criteria for assessing the effectiveness of fire safety measures meant to reduce the potential of fire spread. The latter is only possible if the objectives of fire safety design have been clearly specified.

4.3.5 SS4 — Detection, activation and suppression

This subsystem provides guidance on the use of engineering methods for the prediction of the time to detect smoke or flames by a wide range of commercial devices, including the time required for heat-sensitive elements in suppression or other control devices to respond to the gas flow generated by an incipient or growing fire. The subsystem also provides guidance on how to predict, once detection has occurred, the time required to activate the desired response to a fire, such as an alarm, a smoke damper or a specified flow of extinguishing agent from typical distribution devices. Methods of estimating the effectiveness of many common fire-suppression and control strategies are also addressed.

Subsystem 4 draws on subsystems 1 to 3 for characterising the size of the fire as well as the temperature, species concentration and gas velocity fields generated by the fire at any time after ignition/initiation of the design fire event. This information, along with a description of sensor locations from the building design parameters, is employed by subsystem 4 to predict detection times and the operation of elements, such as those in automatic sprinklers, that allow release of pressurised extinguishing agent (e.g. water) at a nozzle.

The effect of various suppression strategies on the fire heat release rate is estimated in subsystem 4 currently by reference to national codes and installation guidelines and the use of engineering judgement in the application of these guidelines to the design fire scenarios. Once an assumed suppression strategy (usually in terms of a required agent flow rate) takes effect, there is considerable feedback required between subsystem 4 and subsystem 2 so that the resultant fire environment (e.g. gas temperatures and species concentrations) can be determined. If the fire environment is unacceptable, alternative suppression strategies may have to be considered.

Activation times are also determined in subsystem 4, most often from a wealth of input information available from the vendors and manufacturers of the various detection and suppression systems to be installed in a building. The hydraulic design of sprinkler piping systems is considered to be part of this activation process since such piping design ensures that the required flow rate of water or other agent will be available when distribution nozzles are activated by the detection elements.

4.3.6 SS5 — Life safety: occupant behaviour, location and condition

This subsystem provides guidance to designers, regulators and fire safety professionals on the use of engineering methods of evaluating the condition and location of the occupants of a building exposed to fire with respect to time.

It covers assumptions that underlie the basic principles of designing for life safety and provides guidance on the processes, assessments and calculations necessary to determine the location and condition of occupants of the building, with respect to time. The subsystem also draws on other subsystems for matters that impact on the occupants. Temperature, smoke and toxicity profiles from SS2 are of particular importance.

This subsystem also provides a framework for reviewing the suitability of an engineering method for assessing the life safety potential of building occupants.

4.4 Design parameters

4.4.1 Prescribed design parameters

These represent all the parameters and data which are known and provided by the architect to the fire safety engineer. Prescribed design parameters fall into the following categories:

a) aspects of the building design, its contents and its use;

b) the fire safety system installations and facilities for fire brigade intervention;

c) the occupants;

d) the environment.

4.4.2 Estimated design parameters

These represent all the parameters and data needed to supplement the prescribed design parameters before a fire safety engineering assessment can begin. Here the fire safety engineer, based on engineering analysis, needs to make assumptions or estimates in the absence of data from the architect, hence the term estimated design parameters. Fire load density is an example of an estimated design parameter since it is unlikely that the architect will know the value (e.g. kg timber/m^2 or MJ/m^2) corresponding to the actual combustible contents of the building or room, and will therefore not be able to give this data as a prescribed design parameter.

The process of deriving the estimated design data is called "characterisation" in this Technical Report and concerns four main areas:

a) fire load;

b) design fire scenario/design fires;

c) occupant characteristics and number;

d) environmental effects.

Further information on how to derive characteristic data for design fires is given in ISO/TR 13387-2.

4.5 The global information, evaluation and process concept

The relationships and inter-dependence of the two kinds of design parameters and subsystems is illustrated in a simplified form in Figure 2 in which evaluations and processes are omitted for clarity.

Values of the prescribed design parameters (which are fixed for a particular trial design) are input to the global information, indicated in Figure 2 by an inward-pointing arrow. Some of the values of the estimated design parameters (which are also fixed for a particular trial design) require input from the prescribed design parameters and this is done via the global information; other values of the estimated design parameters come direct from other sources. The engineering analysis is done to convert the inputs to the estimated design parameters to outputs which are placed in the global information. All the values of the design parameters are now included in the global information ready for input to the various subsystems.

Each subsystem takes the values of design parameters it needs, makes the calculation and places the output in the global information. For example, subsystem 2 (SS2) takes information such as rate of heat release at the appropriate time (obtained as an output of SS1), time to activate smoke extract system and environmental effects, makes its calculations and outputs information such as smoke temperature and layer depth versus time at the target location(s) to the global information for possible use by another subsystem.

If a calculation is complex, the subsystem is more complex and subsystem evaluations and processes are then established in addition to the global information.

The relationship of these three (global information, evaluations and processes) and the activities involved is as follows. The global information contains only numbers representing information about each item in the information. The information can be a single number (e.g. room height in the building) or an array of numbers (such as temperature distribution at a particular location in a room). The evaluations represent a series of sub-routines executed in such a way that the overall job of a particular subsystem is accomplished. The evaluation sub-routines will accept all the information it or its processes need from the global information. Process algorithms accomplish specific jobs for an evaluation sub-routine (e.g. calculating radiative heat transfer from one object to another). When an evaluation sub-routine has finished its execution, it now contains updated information for output to the global information related to its specific tasks. When all the sub-routines in a given subsystem's evaluations have been executed, the whole subsystem's tasks are finished for a given time from ignition. When all the subsystems have executed all their sub-routines in logical order and looped through time in small increments, a fire safety engineering assessment for a defined scenario will have been made.

In a life safety assessment, the occupant location and condition data are returned to the global information system and these are compared against the life safety strategy to establish if the safety objective has been met.

The above-mentioned procedure is used in a deterministic design. A probabilistic risk assessment would require an overlay of the anticipated frequency that the events or sequence of events will occur in the way assumed.