TECHNICAL REPORT

ISO/TR 13387-8

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Fire safety engineering —

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

Ingénierie de la sécurité contre l'incendie —

Partie 8: Sécurité des personnes — Comportement des occupants, emplacement et état physique

Reference number
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Contents

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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 Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.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 13387-8, 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 may 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*

Annexes A and B of this part of ISO 13387 are for information only.

Introduction

This part of ISO 13387 provides guidance on engineering methods currently available for the evaluation of occupant behaviour, particularly escape behaviour, during a fire emergency and for the evaluation of occupant condition, particularly in relation to exposure to fire effluent and heat. These are reported as two major evaluation outputs: occupant location and condition.

In order to achieve these evaluations, detailed input information is required in four main areas:

a) the building design and emergency life safety management strategy;

b) the occupant characteristics;

c) the fire simulation dynamics;

d) the intervention effects.

The response of occupants to a fire condition is influenced by a whole range of variables in these four categories, related to the characterization of the occupants in terms of their number, distribution within the building at different times, their familiarity with the building, their abilities, behaviours and other attributes; the characterization of the building including its use, layout and services; the provision for warnings, means of escape and emergency management strategy; the interaction of all these features with the developing fire scenario and provisions for emergency intervention (fire brigade and rescue facilities). Key aspects on theses inputs are described in annexes A and B.

This part of ISO 13387 is intended for use together with the other parts of ISO 13387. These latter provide the input information for this part of ISO 13387 but take up the output from this document.

Clause 4 of this document outlines the information flow system for subsystem 5 (SS5), i.e. life safety, the life safety engineering flow chart, and the interactions between this part and the other parts of ISO 13387.

Clause 5 describes the processes involved in the evaluation of parameters relating to location and condition of building occupants exposed to a fire with respect to time. Occupant location and condition are outputs necessary for the global information bus to enable a determination of whether the life safety objectives of the design have been achieved. Life safety objectives and their evaluation is described in ISO/TR 13387-1.

Clause 6 is a discussion of the engineering methods available for the evaluation.

Further bibliography can be found in the other parts of ISO 13387.

Fire safety engineering —

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

1 Scope

Should a fire occur in which occupants are exposed to fire effluent and/or heat, the objective of the fire safety engineering strategy is to ensure that such exposure does not significantly impede or prevent the safe escape (if required) of essentially all occupants, without their experiencing or developing serious health effects.

This part of ISO 13387 is intended to provide guidance to designers, regulators and fire safety professionals on the engineering methods available to evaluate the location and condition of the occupants of a building exposed to a fire.

This part of ISO 13387 addresses the 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 the occupants of the building, with respect to time.

This part of ISO 13387 also provides a framework for reviewing the suitability of an engineering method for assessing the life safety potential of a building for its occupants.

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

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 13571:—[1)], *Fire hazard analysis — Life-threatening components of fire*.

ISO 13943, *Fire safety — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO 13387, the definitions given in ISO 13943, ISO/TR 13387-1 and the following apply:

3.1
asphyxiant
toxicant causing hypoxia, resulting in central nervous system depression with loss of consciousness and ultimately death

3.2
defend in place
life safety strategy in which occupants are encouraged to remain in their current location rather than to attempt escape during a fire

3.3
evacuation process
process which enables occupants of a building to reach a place of safety (where appropriate), consisting of pre-movement and movement processes

3.4
fractional effective concentration
FEC
ratio of the concentration of an irritant to that expected to produce a given effect on an exposed subject; when not used with reference to a specific irritant, this term represents the summation of FECs for all irritants in a combustion atmosphere

3.5
fractional effective dose
FED
ratio of the concentration of the asphyxiant toxicant to that concentration of the asphyxiant expected to produce a given effect on an exposed subject; when not used with reference to a specific asphyxiant, this term represents the summation of FEDs for all asphyxiants in a combustion atmosphere

3.6
incapacitation
state of physical inability to accomplish a specific task, for example safe escape from a fire

3.7
irritation,
<sensory or upper respiratory> the stimulation of nerve receptors in the eyes, nose, mouth throat and respiratory tract, causing varying degrees of discomfort and pain along with the initiation of a range of physiological responses (including reflex eye closure, tear production, coughing, bronchoconstriction)

3.8
movement processes
process which enables occupants of a building to reach a place of safety once they have begun to evacuate, where appropriate

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[1)] To be published.

3.9
pre-movement process
process occurring during which the occupants recognize and respond to the alarm or cue of fire, where appropriate, before they begin to evacuate

NOTE This process can be divided into two components, “recognition” and “response” [see also **defend in place** (3.2) and **movement processes** (3.8)].

3.10
recognition
process occurring during the period after an alarm or cue has been given but before occupants of a building begin to respond

NOTE The recognition time ends when the occupants realize that there is a need to respond.

3.11
response
process occurring after occupants recognize the alarms or cues and begin to respond to them, but where appropriate, before they begin to evacuate

3.12
impaired escape capability
effects on willingness and efficiency of escape actions, which may delay, slow or prevent evacuation

4 Design subsystem 5 of the total fire safety design system

4.1 General

An ideal fire safety design would ensure that building occupants are able to reach a place of safety without ever coming into contact with or even being aware of fire effluent and/or heat. This should be the main design criterion for the safety of the majority of occupants in multi-compartment buildings. However, there will inevitably be some potential scenarios when some occupants will become aware of or be exposed to fire effluent, particularly when the occupants are in the enclosure of fire origin. This may vary between slight smoke contamination, common in many accidental fires, to life threatening exposures such as in major fire disasters. For all of these types of scenarios, it is important to be able to assess the likely effects of such exposures, either as part of the main design or as part of a risk assessment.

In most systems of fire safety regulation measures are taken to ensure the life safety of the occupants by prevention of ignition, prevention of fire spread, provision of facilities and access for fire brigades, provision of detection and warning systems and adequate means of escape. These are often applied through prescriptive means covered by documents and codes relating to national legislative requirements.

The fire safety engineering approach adopted in the work of ISO/TC 92/SC 4 considers a performance-based approach to achieve a global objective of fire safe design. The global design, described in more detail in the framework document, ISO/TR 13387-1, is subdivided into a series of subsystems. One principle is that inter-relationships and inter-dependencies of the various subsystems are appreciated, and that the consequence of all the considerations taking place in any one subsystem are identified and realized. Another principle is that the evaluation is time based to reflect the fact that real fires vary in growth rate and spread with time. Despite this performance based approach it has to be recognized that some prescriptive parameters may need to be observed in any assessment of the life safety provisions within a building.

4.2 Information system

In the framework document the total fire safety design is illustrated by a global information bus which has three layers: global information, subsystem evaluations and subsystem processes. The information system for this subsystem is illustrated in Figure 1.

4.3 Function of subsystem 5

The function of subsystem 5 is to determine the location and condition of the occupants with respect to time. The analysis necessary is illustrated in the flow chart, Figure 2.

The upper part of the flow chart shows the input data from the relevant sections of the global information system and the framework document ISO/TR 13387-1.

The next part identifies the processes necessary for the evaluations.

The next part shows the evaluation of occupant condition and location, which are output to the global information system at the bottom for further processing.

ISO TC 92/SC 4 FIRE SAFETY ENGINEERING BUS SYSTEM

Subsystem 5 (SS5) — Life safety — Occupant behaviour, location and condition

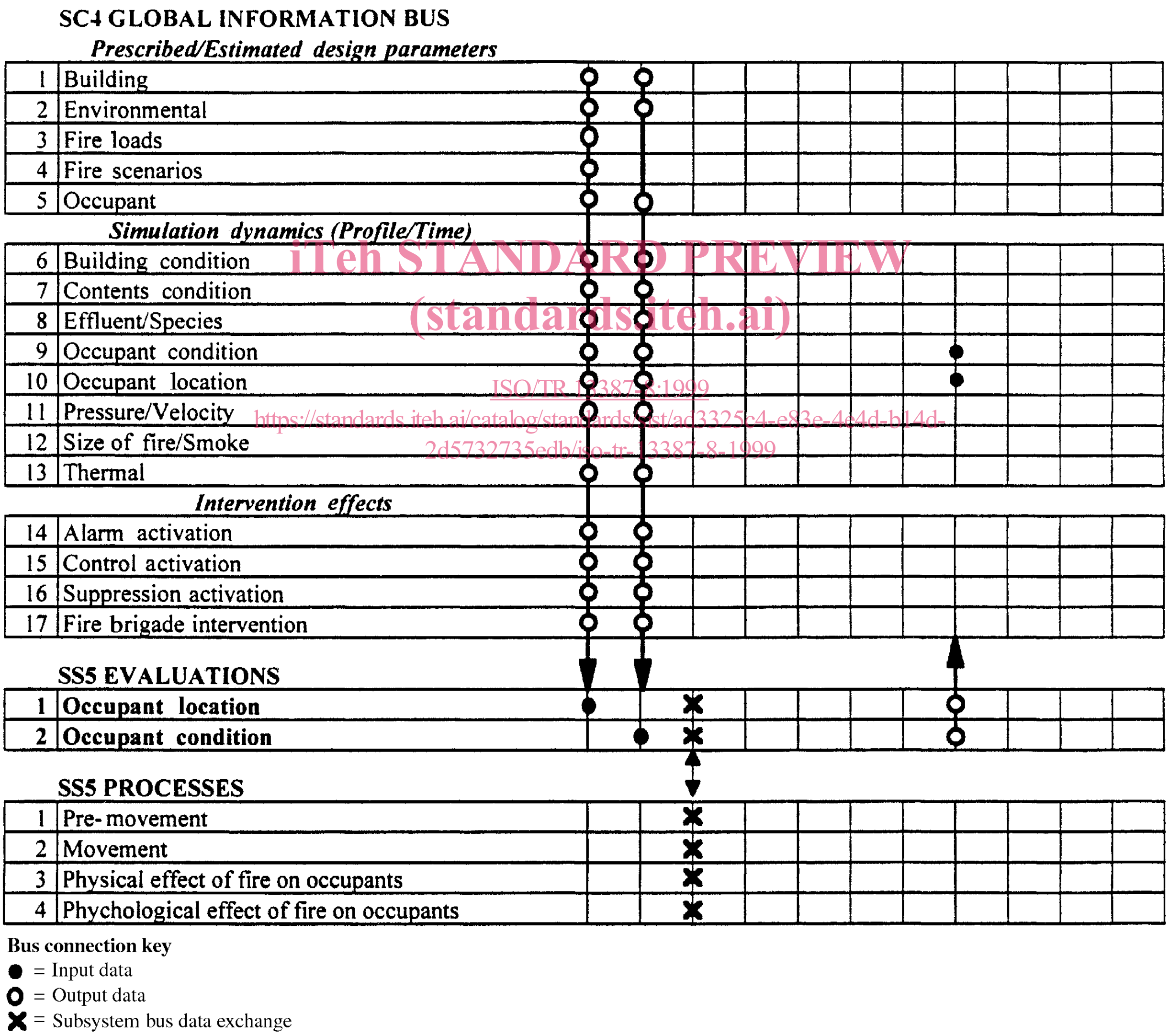

Figure 1 — Illustration of the global information, evaluation and process buses for SS5

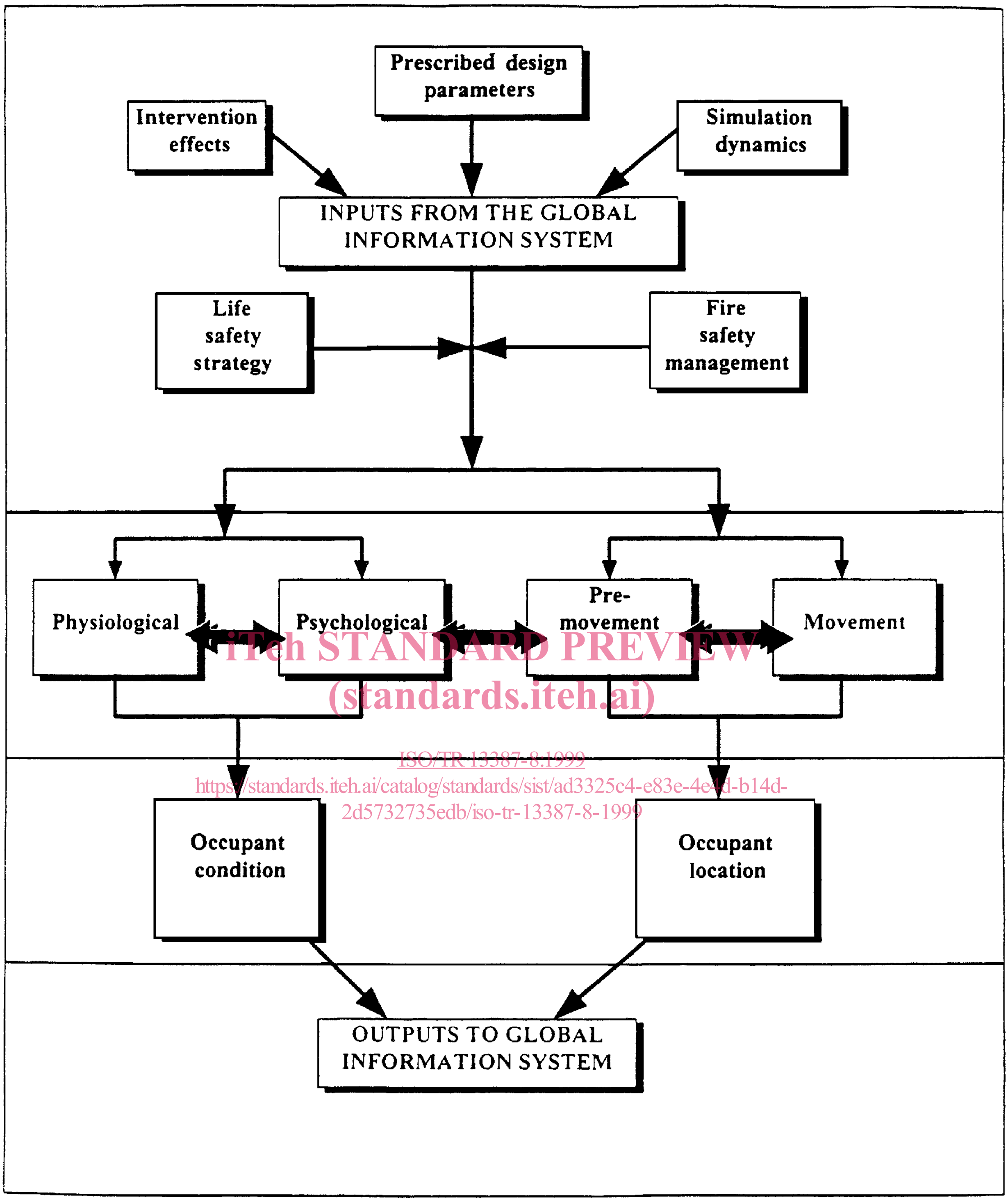

Figure 2 — Life safety engineering flow chart

5 Subsystem 5 (SS5) life safety: evaluations

5.1 General

The purpose of any life safety strategy is to ensure that, in the event of a fire the occupants will be able to leave the building, evacuate to a designated space within a building, or remain *in situ* (as appropriate), without being exposed to untenable conditions. An ideal fire safety design would ensure that building occupants are able to reach a place of safety without ever coming into contact with or even being aware of fire effluent and/or heat. This should be the main design criterion for multi-compartment buildings. However, there will inevitably be some potential scenarios when some occupants will become aware of or be exposed to fire effluent, particularly when the occupants are in the enclosure of fire origin. This may vary between slight smoke contamination, common in many accidental fires, to life threatening exposures such as in major fire disasters. For all of these types of scenarios, it is important to be able to assess the likely effects of such exposures, either as part of the main design or as part of a risk assessment. A single acceptable criterion of no permitted exposure could impose serious constraints on the design. This part of ISO 13387 allows for a more flexible approach to fire safety engineering by providing a basis for estimating levels of exposure that would not be expected to seriously impair escape or impair health.

Whilst the processes for determining the occupant location and the occupant condition can be dealt with as discreet issues, there is in reality significant interaction between them. Guidance is given in this clause on the processes involved and on these potential interactions. The life safety strategy developed for a building is an integral element of the design philosophy detailed in the framework document ISO/TR 13387-1.

The strategy may require evacuation of the occupants, by either simultaneous or phased procedures, evacuation to a place of safety within a building or that occupants remain in a place of safety. The strategy should not normally rely on direct assistance to the occupants, except for special cases such as evacuation of people with disabilities.

In order to determine the adequacy of fire engineering design of buildings in terms of life safety, it is necessary to evaluate over time, the impact of the design fire scenario on the occupants in terms of their:

a) location;

b) condition.

The location of occupants within a building, at any one time, and the way occupant location changes with time during normal use and emergency situations depends upon the interaction of a variety of parameters related to the characteristics of the building and the occupants, the fire safety management system adopted and the developing fire scenario. The condition of the occupants depends upon their psychological and physiological state before the fire and the subsequent effects of the developing emergency including any exposure to fire effluent and heat.

As a result of the very large number of variables involved, difficulties in their identification and quantification and difficulties in predicting interactions between them, not even the most complex and sophisticated behavioural and physiological model can hope to provide a full representation of all the possible processes and outcomes of any scenario. Some methods are designed to address only one or a few of these processes, while others claim to provide a more global approach. It is therefore important when evaluating any particular building design to take account of all the parameters which may affect the life safety of occupants and chose appropriate evaluation methodology. The different methods available are reviewed in clause 6. It is essential that a design review is first undertaken before the application of any of the engineering methods discussed. The following subclauses introduce the various inputs and parameters to be considered and discuss aspects that are essential to the evaluation process.

5.2 Inputs required from the global information bus

As shown in Figure 2 there are essentially four categories of information required to determine the condition and location of occupants:

a) the building characteristics and fire safety management strategy;

b) the occupant characteristics;

c) the fire simulation dynamics;

d) intervention effects.

5.2.1 The building characteristics and fire safety management strategy

The first major input to the life safety evaluation processes comprises details of the building characteristics, its management in relation to fire safety and the emergency life safety strategy. These comprise the basic building dimensions, internal arrangement and services relevant to fire safety, as follows:

— layout and geometry (including size, building height, ceiling height, layout, complexity, compartment, subdivision into internal spaces, interconnection of spaces; travel distances; door and stair corridor widths, normal circulation routes, opening/closing forces of fire doors; door furniture);

— escape routes [including: visual access, complexity, protection (passive/active), lengths, horizontal, vertical (escape upwards or downwards), accessibility (for example by break-glass and key only, by crash bar), use during normal flows in building, final exits (number distribution related to characterization data), etc.];

— building use [including general building/occupancy type (for example office, department store, theatre, etc.), layout and functions/uses in particular locations within the building which may impact on likely behavioural responses and escape route usage (some functions may tend to provide easy access and escape while others may not)];

— fire safety management system (including management of the building; management and maintenance of essential equipment; management of staff and occupants of the building; fire prevention management; management flexibility; training of staff and occupants, security and fire surveillance, emergency procedures);

— life safety strategy (including life safety design philosophy, evacuation strategies; passive/active fire control systems, fire detection, alarm and communication systems, facilities for fire brigade, emergency lighting, wayfinding system, fire safety management);

— application of active systems (including sprinkler/spray systems, sprinklers for life safety, gas suppression systems, smoke management or extraction and ventilation systems);

— signs and lighting (including emergency lighting);

— refuge areas (form, degrees of protection and tolerability, communication systems and connection to escape routes, staging areas, access for assisted escape or rescue);

— environmental considerations (for example wind and internal air pressurization on door opening force, evacuations in wet, hot or cold conditions, dress requirements, effect of snow on exits).

Guidance on these parameters is given in A.1.

5.2.2 The occupant characteristics

The second major input to the life safety evaluation process is the occupant characteristics. The main considerations are the likely nature and timing of occupant response to cues or alarms and likely subsequent pattern and timing of occupant movements, particularly in carrying out an evacuation if required. Also important is the likely susceptibility of the occupants to sight of or exposure to fire effluent or heat.

Occupant characteristics to be considered include:

a) population numbers and density: expected numbers in each occupied space including seasonal variations;

b) familiarity with the building: depends on factors such as occupancy type, frequency of visits and participation in emergency evacuations;

c) distribution and activities;

d) alertness: depends on factors such as activities, time of day, sleeping or awake;

e) mobility: depends on factors such as age and any disabilities;

f) physical and mental ability;

g) social affiliation: extent to which occupants present as individuals or in groups such as family groups, groups of friends, etc.;

h) role and responsibility: includes categories such as member of the public, manager, floor warden, etc.;

i) location: location in building relative to escape routes, etc.;

j) commitment: extent of commitment to activities engaged in before the fire;

k) focal point: point where occupant attention is directed, such as the stage in a theatre or a counter in a shop;

l) responsiveness: extent to which occupant is likely to respond to alarms, etc.;

m) occupant condition: as determined by the analysis of occupant condition.

Guidance on these parameters is given in A.2.

5.2.3 The fire simulation dynamics

The third major input to the life safety evaluation process is the fire simulation dynamics. The object of the life safety design is to protect occupants from exposure to fire effluents or heat (or physical trauma from structural failure). This is achieved by a combination of the provision of adequate means of escape and protection of occupied spaces. In order to evaluate life safety during a fire it is necessary to obtain continuous information on the extent of the fire and fire effluent and their effect on the building.

The following specific factors need to be considered:

a) Fire alarms and cues available to occupants.

   When the fire originates in an occupied enclosure it is necessary to determine the visibility of the flames and smoke, so that an estimate can be made of the time when occupants would become aware of the situation, and how they would respond to it. For both occupied and unoccupied fire enclosures it is necessary to know when an automatic alarm system would be triggered, and when information on fire spread would be available from analogue addressable systems. The main requirement is to be able to determine what information is available to building occupants throughout the fire incident.

b) Fire size and extent, smoke density, toxic gas concentrations, temperature and heat flux in all building enclosures, activation of suppression and smoke control systems.

   For all enclosures in the building it is necessary to know the size of the fire, the extent to which it is contained or has spread through adjacent enclosures, any structural failures and the temperature and heat fluxes in affected enclosures. It is also necessary to known the optical density and concentrations of irritant gases in the smoke, and the concentrations of asphyxiant gases present. For occupied enclosures this information is required to assess the tenability of the enclosure to occupants, and the extent to which their escape out of each enclosure is affected. For unoccupied enclosures the information is required particularly if they form part of potential escape routes or refuges. Where the fire effluent is in well defined layers, the height of the hot layer and downward radiant flux need to be reported.

5.2.4 Intervention effects

Circumstances may arise in a building where the intervention of the fire brigade is necessary to secure the safety of the occupants. To assist the fire brigade in the execution of intervention strategies, it is necessary to include appropriate facilities in the design of the building. Further guidance in given in annex B.

5.3 Occupant location

At the moment the fire starts, the building will contain a certain number of occupants dispersed in a particular pattern depending principally upon the season of the year and time of day or upon any particular planned events taking place as well as the variety of activities in which the occupants are engaged. The subsequent behaviour of the occupants and the time required for them to react will depend upon the interactions of the various input parameters described and the occupant response processes.

When the first cues to the occurrence of a fire become available to the occupants of different parts of a building or when an alarm is given, the occupants engage in a variety of behaviours (see references (see references [1], [2] and [3]). These behaviours require certain times for their execution so that the location of occupants can be assessed on a time basis. The behaviours involved in the evacuation process have been classified into two broad processes in this document, the pre-movement process occurring before the physical evacuation begins and the movement process during which occupant evacuate to a place of safety (if appropriate). Each of these have sub-categories which need to be identified and addressed in a design review and incorporated into a performance assessment. Occupant response behaviours and movements will vary according to a number of variables. The pattern and timing of the overlapping phases of behaviour and movement also vary with the type of occupancy, architectural setting, fire growth scenario and other factors. Different assessment methods and models handle these variables to different extents.

5.3.1 Pre-movement processes

During an evacuation, the pre-movement processes take place after an alarm of cue has become evident, but before the occupants of the building begin to evacuate (where evacuation is appropriate). These processes may be sub-divided into two components, “recognition” and “response”.

There is a lack of reliable data upon which to base accurate predictions of pre-movement time, although it may comprise a significant part of the total time required for escape (see references [3], [4] and [5]). Pre-movement time varies between individuals within an enclosure and between groups in different enclosures within a building. The following procedure has been developed which may assist in assessing the pre-movement time of occupants.

The two components of pre-movement time have the following characteristics.

a) Recognition

This consists of a period after an alarm of cue is evident but before occupants of a building begin to respond.

During the recognition period occupants continue with the activities engaged in before the alarm of cue, such as working, shopping or sitting. The length of the recognition period can be extremely variable, depending upon factors such as the types of building, the nature of the occupants and the building alarm and management system (see references [1], [2], [3], [4] and [5]).

In single enclosure buildings that are well managed the recognition period is likely to be short. In multi-enclosure buildings where occupants may be remote from the fire, especially those with a sleeping risk such as hotels, residential homes and hostels, the recognition times may vary considerably (see references [1], [2], [3], [4] and [5]). The recognition time ends when the occupants have accepted that there is a need to respond.

b) Response

This consists of a period after occupants recognize the alarms or cues, and begin to respond to them, but before they begin to evacuate (where necessary). As with the recognition period this may range from a few seconds to many minutes, depending upon the circumstances (see references [1], [2], [3], [4] and [5]).

Examples of activities undertaken during the response time include:

1) investigative behaviour, including action to determine the source, reality or importance of a fire alarm or cue;

2) stopping machinery/production processes or securing money and other risks;