A Guide to Fire Safety Engineering

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The Construction (Design and Management) Regulations 1994. The Stationery Office.
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Part 7: Detection, activation and suppression.
Part 8: Life safety – Occupant behaviour, location and condition.

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Part 4: Non-combustibility test for materials.
Part 6: Method of test for fire propagation for products.
Part 7: Method of test to determine the classification of the surface spread of flame of products.
Part 10: Guide to the principles and application of fire testing.
Part 11: Method for assessing the heat emission from building materials.
Part 12: Method of test for ignitability of products by direct flame impingement.

BS 5588, *Fire precautions in the design, construction and use of buildings.*
Part 0: Guide to fire safety codes of practice for particular premises/applications.
Part 4: Code of practice for smoke control using pressure differentials.
Part 5: Code of practice for firefighting stairs and lifts.
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Part 9: Code of practice for ventilation and air conditioning ductwork.
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BS 7974:2001, *Application of fire safety engineering principles to the design of buildings – Code of practice.*

PD 7974, Application of fire safety engineering principles to the design of buildings.
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Part 5: Fire service intervention (Sub-system 5).
Part 6: Evacuation.[1]
Part 7: Probabilistic fire risk assessment.

DD 240, *Fire safety engineering in buildings.*[2]
Part 1: Guide to the application of fire safety engineering principles.
Part 2: Commentary on the equations given in Part 1.

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[1] In preparation.
[2] DD 240 has been superseded by BS 7974 and is withdrawn.

Foreword

This document aims to provide an introduction and initial understanding of the principles of fire safety engineering and its relationship to fire precautions. It also suggests why such engineered solutions might be offered in achieving the objective of satisfactory safety levels in case of fire.

This document does not aim to provide a detailed understanding of fire safety engineering. It is a basic guide for those who are new to the subject and also provides a guide to where further, more detailed information can be found. Such detailed guidance is available from many different sources, some of which are listed in the bibliography.

1

What are fire precautions?

The term 'fire precautions' is generally accepted to include matters that are the subject of legal requirements under specific fire precautions legislation. These include The Building Regulations 2000, The Fire Precautions (Workplace) Regulations 1997 (as amended) and The Fire Precautions Act 1971 (as amended). In Northern Ireland the Fire Services (Northern Ireland) Order 1984 (as amended) is in use. More generally, there exists health and safety legislation including the Health and Safety at Work etc. Act 1974 and regulations made under that Act.

Fire precautions legislation deals with general fire precautions. These include:

- means of detection and giving warning in case of fire;
- provision of means of escape;
- means of fighting fire;
- training of staff in fire safety;
- linings that inhibit the spread of fire;
- means to provide structural stability; and
- means to resist the spread of fire within and between buildings.

The Fire Precautions (Workplace) Regulations 1997 also include a requirement for employers to undertake an assessment of the fire risks. The term 'fire risk' is generally accepted to collectively describe both the risk of fire occurring and the risk to people in the event of fire.

The 'risk assessment' is an organized assessment of the work activities and associated hazards in the workplace that could cause harm to people. It is intended to assess whether adequate precautions to avoid or reduce the risk of harm have been taken or whether more action is necessary.

In this context, 'hazard' and 'risk' are defined in ISO/TR 13387-1 as follows.

- A 'hazard' is the potential for loss of life (or injury) and/or damage to property by fire.
- A 'risk' is the potential for realization of an unwanted event, which is a function of the hazard, its probability and its consequences.

The present statutory duty imposed upon employers requires that the employer carry out a fire risk assessment of the workplace. Consideration must be given, amongst other things, to the needs of all employees and all other people who may be affected by a fire in the workplace. Adequate provision must also be made for any people with disabilities or with special needs who may use or be present on the premises.

The Fire Precautions (Workplace) Regulations 1997 require that the assessment is kept under review and is revised as necessary. The Regulations place a statutory duty on the employer, which will be related to the provisions of any fire safety engineered solution provided in his building.

Approved Document B – European Supplement

Approved Document B, Fire safety, 2000 edition, refers to and utilizes within its guidance a large number of British Standards – typically the BS 476 series of documents. In order to facilitate harmonization and the adoption and use of new European technical specifications and supporting standards under the auspices of the Construction Products Directive (see above), it has been necessary to amend the 2000 edition of Approved Document B.

The amendment to Approved Document B ensures that construction products tested by the European harmonized fire test methods can be used in England and Wales as required under the Construction Products Directive. In practical terms this will tend to require increased performance for products tested to BS 476.

The Construction Products Directive, through the use of harmonized technical specifications and supporting standards, aims to break down the technical barriers to trade, associated with the movement of construction products between Member States.

At the present time, CEN TC/127 has now published all the necessary technical specifications to enable the Commission Services to publish their formal Commission Decision on the classification of construction products according to their reaction to fire and fire resisting properties. The Technical Committee is still addressing the need for further harmonized technical standards under a direct standardization mandate from the Commission. These technical standards now provide the means of implementing the Essential Requirements of the Directive in respect of reaction to fire and fire resistance testing of construction materials, thereby providing the harmonized European Standards that are needed to make possible the implementation of national laws, regulations and administrative procedures.

Any formal European position would take into consideration all published documents on the subject. These would include ISO/TR 13387, BS 7974 and PD 7974. They would also include consideration of any other documents published by any other Member State. It is probable therefore that once the Fire Regulators Group, with the approval of the Standing Committee, have established a 'European' position, CEN TC/127 may be asked to prepare the European version of ISO/TR 13387 under the existing mandates.

Essential Requirement 'Safety in case of fire'

In a document (Interpretative Document 2) describing the provisions of the Essential Requirement, 'Safety in case of fire' published in 1991, the question of an engineering approach in the field of fire safety was addressed. According to this document, fire safety engineering covered the way in which fire safety in a construction works is evaluated by the means of calculation methods, taking account of the performance and effect of products, i.e. passive and active fire protection measures.

It was also made clear that fire safety engineering included a number of activities of wide scope, which influenced fire safety in use of construction products. This included the use of calculation methods for determining the development and spread of fire and smoke, the time for untenable conditions to be reached and evacuation time.

In a fully integrated approach, fire safety engineering was also judged to include the complex interaction between the performance of passive and active fire protection measures and the construction works. For example, the development of life-threatening atmosphere and human behaviour to achieve safety in the most flexible and cost-effective way must be considered. This engineered approach required that the relevant characteristics of products are provided and calculation and design procedures are validated on an agreed and harmonized basis.

2

What is fire safety engineering?

Fire safety engineering is the provision of adequate fire safety precautions in a complex building or structure that accommodates a departure from the prescribed performances in any specific area by taking other higher or compensatory measures in another area. There could be trade-offs between passive and active fire protection measures that either allow the designer to use materials in a novel application or allow the building user to make optimum use of the space available.

Fire safety engineering can be considered under several headings.

- The *process* of fire safety engineering is about measurements and relationships, backed by scientific study, for engineering application to the required problems, but where experience and judgement can contribute, as in other engineering disciplines.
- The *context* of fire safety engineering is the need to evaluate fire hazard and risk and to offer fire safety strategies and designs based on performance not prescription.
- The *tools* supporting fire safety engineering are the calculation methods (sometimes called models) that describe the measurements, relationships and interactions and any necessary test results.
- The *inputs* are the physical data for the calculation methods, derived from measurement methods (tests, etc.).
- The *framework* of fire safety engineering comprises the essential core, and transfer, of knowledge, which permits an engineering approach, the education and training of users and the professional recognition of the discipline.

As a result of the substantial increase in fire research during the last decades, many components and systems are becoming more amenable to analytical and computer modelling. Consequently, many national building regulators, particularly in the UK, have moved from a prescriptive approach to a performance-based approach.

The fire safety engineering approach may have benefits over the prescriptive approach. It takes into account the entire fire safety package and provides a more fundamental and sometimes 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 systems.

For most buildings the prescriptive recommendations on design in existing codes and guides, as given in BS 5588-0, may be found to be adequate. However, BS 7974 is intended for use to develop and assess fire safety engineering proposals. The use of a fire safety engineering approach enables a more precise design necessary for the assessment of new and complex projects. In addition, although prescriptive regulations have served us well in the past, it is widely recognized that they are inflexible in certain circumstances and therefore unable to evolve quickly enough to meet the modern challenges of new materials and innovative design.

BS 7974 defines fire safety engineering as 'the application of scientific and engineering principles to the protection of people, property and the environment from fire'. In practice, fire safety engineering involves the use of scientifically based or statistically based calculations to demonstrate an adequate level of fire safety for a specific building, structure or installation. Often, it will be applied to a specific part of a project while other parts follow standard guidance or codes.

BS 7974 is derived from DD 240 (now withdrawn) prepared by BSI Technical Committee FSH/24. The Draft for Development was prepared with the support of the government departments concerned with fire safety (Department of the Environment and the Home Office – now the Office of the Deputy Prime Minister). BS 7974 therefore provides a framework for an engineering approach to fire safety, which may be applied to both the design of new buildings and the appraisal of existing buildings, and to show that regulatory requirements can be, or are, satisfied. BS 7974 is also intended to provide a framework for a flexible but formalized approach to fire safety design that can also be readily assessed by the approvals bodies.

BS 7974 is supported by a series of Published Documents (PDs) that contain guidance and information on how to undertake detailed analysis of specific aspects of fire safety engineering. This does not, however, preclude the use of appropriate methods and data from other sources.

PD 7974, Application of fire safety engineering principles to the design of buildings, is structured as follows:

- *Part 0: Guide design framework and fire safety engineering procedures;*
- *Part 1: Initiation and development of fire within the enclosure of origin (Sub-system 1);*
- *Part 2: Spread of smoke and toxic gases within and beyond the enclosure of origin (Sub-system 2);*
- *Part 3: Structural response and fire spread beyond the enclosure of origin (Sub-system 3);*
- *Part 4: Detection of fire and activation of fire protection systems (Sub-system 4);*
- *Part 5: Fire service intervention (Sub-system 5);*
- *Part 6: Evacuation (Sub-system 6)* (in preparation);
- *Part 7: Probabilistic fire risk assessment (Sub-system 7)* (in preparation).

BS 7974 can be used to identify and define one or more fire safety designs to be addressed using fire safety engineering. The appropriate part(s) of PD 7974 can then be used to set specific acceptance criteria and undertake detailed analysis.

Within the international and European arena, there has been detailed consideration of the need for guidance and standardization. The International Organization for Standardization (ISO) has produced a comprehensive Technical Report that has now been published by BSI as BS ISO/TR 13387, *Fire safety engineering*. In eight parts, the Technical Reports were prepared by ISO Technical Committee TC/92, Fire safety. This series of ISO documents offers a slightly different approach to that of BS 7974 and the PDs that accompany it. Neither approach can be regarded as the 'definitive' view. As each separate approach offers an alternative and given the consideration now required of both the BS Published Documents and the ISO Technical Reports, it is hard to say which approach will be formally adopted. While it could be one or the other, the more likely outcome would be an amalgamation of both.

Specifically within the European arena, the European Commission has recently funded a feasibility study on the benefits of fire safety engineering within the European Union.

NOTE: Further information is given on both international and European activities in Appendix B.

Appendix B – International and European standardization activities for fire safety engineering

International Standards (ISO)

With no action at the European level, work started at the international level to produce a series of documents covering the subject. BS 7974 was used as the basis of the early work, but was substantially extended. It quickly became clear, that considerable work was needed to make this document useable. The work was undertaken by ISO TC/92, Fire safety and ISO published a multi-sectioned ISO/TR 13387: Parts 1 to 8 and the documents have generated considerable interest.

European Standards (CEN)

Since the publication of the British and international documents, interest has been generated at the European level. While all the early preparation for the subsequent documents was underway, CEN and the European Commission were content to await the outcome.

Given that the Construction Products Directive (89/106/EEC) and the Essential Requirements both make direct reference to fire safety engineering, the Commission Services funded a feasibility study on the application of fire safety engineering principles in all of the Member States.

Also, in preparation for beginning work at the European level, CEN TC/127, Fire safety in buildings, has formed a new Working Group to cover the issue.

The present position is brought into sharper focus as the European Commission have recently funded extensive Research on the Benefits of Fire Safety Engineering in the European Union (BeneFEU). It is clear from the conclusions of this study that a European position will have to be formalized and adopted.

Once the decision has been made by the EU Fire Regulators Group as to what form the European interest will take, CEN will decide who will undertake the work. Given the basic remit of CEN TC/127, it will probably be included in its work programme.

Construction Products Directive (89/106/EEC)

Council Directive 89/106/EEC on the approximation of laws, regulations and administrative procedures of the Member States relating to Construction Products was published in 1989. This Directive contained a number of Essential Requirements; one of which was 'Safety in case of fire'.

Under the Construction Products Directive (89/106/EEC), the Commission Services have established a Standing Committee on Construction. Reporting to this Standing Committee, the Group of EU Fire Regulators has discussed the issue of fire safety engineering several times. Once a full consideration has been given to the BeneFEU Report, the Fire Regulators Group will need to consider their future options.

Appendix A – Terms and definitions

available safe egress time (ASET) calculated time available between ignition of a fire and the time at which tenability criteria are exceeded in a specified space in a building

complex analysis consideration of a design proposal and the application of the statistical data in order to come to an agreed position

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

escape time calculated time from ignition until the time at which all of the occupants of a specified part of the building are able to reach a place of safety

equivalence provision by other means of a level of safety providing the same level of performance as that referred to in guidance relevant to that requirement

evacuation time interval between the time of warning of fire being transmitted to the occupants and the time at which all of the occupants are able to reach a place of safety

fire hazard source of possible injury or damage from fire

fire risk product of probability of occurrence of a fire to be expected in a given technical operation or state in a defined time and the consequence or extent of damage to be expected on the occurrence of a fire

fire safety engineer person suitably qualified and experienced in fire safety engineering

fire safety engineering application of scientific and engineering principles to the protection of people, property and the environment from fire

functional requirement expression of a safety requirement in terms of the required level of performance of the fire safety system referred to

prescriptive requirement expression of a safety requirement by the means of a detailed description of the provisions required which should not be varied

probabilistic risk assessment methodology to determine statistically the probability and outcome of events

qualitative identification of constituents of an evaluation of a proposal

science observation, identification, description, experimental investigation and theoretical explanation of phenomena

simple calculation first or initial consideration of data in order to come to a first impression on the validity of the proposal

trial fire safety design package of fire safety measures, which in the context of the building may meet the specified fire safety objectives

3

Benefits of fire safety engineering

Fire safety engineering can have many benefits; the use of a code of practice such as BS 7974 will facilitate the practice of fire safety engineering and in particular will:

- provide the designer with a disciplined approach to fire safety design;
- allow the safety levels for alternative designs to be compared;
- provide a basis for selection of appropriate fire protection systems;
- provide opportunities for innovative design;
- provide information on the management of fire safety for a building.

The structure of the BS 7974 is given below. This code of practice:

- provides a means of establishing acceptable levels of fire safety economically and without imposing unnecessary constraints on aspects of building design;
- provides guidance on the design and assessment of fire safety measures in buildings;
- gives a structured approach to assessing the effectiveness of the total fire safety system in achieving the design objectives;
- provides a framework for, and describes the philosophy of, fire safety engineering;
- outlines the principles involved in the application of the philosophy to the fire safety engineering of particular buildings;
- can be used to identify and define one or more fire safety design issues to be addressed using fire safety engineering;
- provides some alternative approaches to existing codes and guides for fire safety and also allows the effect of departures from more prescriptive codes to be evaluated;
- recognizes that a range of alternative and complementary fire protection strategies may achieve the design objectives.

In PD 7974: Parts 0 to 7 the following steps in the fire safety design process are identified:

- definition of the safety objectives and the scope of the study;
- setting of the acceptance criteria;
- characterization of the building, occupants and environment;
- undertaking a qualitative design review; and
- conducting quantified analysis.

The evaluation of the fire safety design of a building is broken down, to simplify the process, into the separate components of the overall system (the sub-systems, see below) belonging to either the tools for fire safety engineering evaluation or the fire safety objectives.

A brief extract and description of the scope of each of the sub-systems is given below. These include the scopes of those sections yet to be published. There are slight differences in these individual scopes with those of Parts of BS ISO/TR 13387.

Sub-system 1 (PD 7974-1:2003) Initiation and development of fire within the enclosure of origin

Sub-system 1 provides guidance on evaluating fire growth and/or size within the enclosure of origin, as well as enclosures to which the fire has subsequently spread. Guidance is also provided for 'special cases', which include malicious fires, racked/stacked storage of goods and fires external to the building.

The characteristics of the design fire for any particular scenario are influenced by a number of factors, including building design, environmental influences, potential ignition sources and location, types of combustible materials, distribution and arrangement of combustible materials, ventilation conditions and other events occurring during the fire.

The determination of the characteristics of the design fire from the ignition phase through growth to the decay phase is used by other sub-systems as inputs into calculations of events such as time of fire spread from enclosure (Sub-system 3) and time to activation of fire suppression systems (Sub-system 4).

Sub-system 2 (PD 7974-2:2002) Spread of smoke and toxic gases within and beyond the enclosure of origin

Sub-system 2 provides guidance on the application of fire safety management principles for the treatment of smoke movement, control and management problems. The guidance is intended primarily for professional engineers with a responsibility for the design or assessment of fire safety in buildings.

Sub-system 1 provides information on the rate of production of heat and combustion products from the fire source. The aim of Sub-system 2 is to provide design approaches to estimate the spread of the combustion gases within and beyond the room of origin and to evaluate their properties, i.e. temperature, visibility and concentration of toxic products. This information may be used to calculate the time between the detection of a fire and to conditions developing which are dangerous to building occupants. This will enable the design of fire safety measures to ensure that sufficient time is available for escape. It also provides information that will allow property issues to be assessed.

While PD 7974-2 forms part of the series of Published Documents containing sub-systems 1 to 7, it may, in consultation with the appropriate references, be regarded as 'stand-alone' guidance.

8

Conclusion

Fire safety engineering is a very important and valuable engineering technique. Many building, infrastructure and other types of structure can only be safely designed and constructed using fire safety engineering techniques. In many cases the fire engineering process can deliver major cost savings and higher levels of safety than that provided by standard guidance. The capability of a fire safety engineer should be carefully considered and any design reviewed and approved following the procedures set out in the relevant British Standards and Published Documents.

7

Good questions for those dealing with a fire safety engineering design

Many individuals and organizations may come into contact with a fire engineering design as clients, regulators, users, designers, etc. These will include:

- building owners;
- building occupiers;
- Building Control Bodies;
- Fire Authorities;
- architects;
- non-fire safety engineers;
- surveyors;
- operators of infrastructure businesses, e.g. railways, tunnels, roads;
- owners and operators of ships.

When dealing with a proposal to apply fire engineering to a building, an infrastructure installation or a ship, etc. there are many useful questions that can be asked. The answers to such questions will enable the parties involved to form a view of the validity of the fire safety engineering proposal. It should be noted that the list below is not exhaustive.

Checklist for a fire safety engineering proposal

The fire safety engineer	What qualifications does the engineer have?	CEng, IEng, BEng, MEng, PhD
	What experience does the engineer have?	Previous projects
	Does the engineer's practice use a QA process?	Is BS ISO 9000 registration in place?
Models and methods used in the fire safety engineering process	Are they validated, published, referenced, widely used, from a respected source?	References, journals, peer review
What checks have been carried out?	What are the input data, results, judgements?	
What level of confidence/comfort is there?	What is the scope and type of design? Are conservative features built into the design?	

Sub-system 3 (PD 7974-3:2003) Structural response and fire spread beyond the enclosure of origin

Sub-system 3 provides guidance and information on how to undertake quantitative and detailed analysis of specific aspects of the design. It is a summary of the state of the art guidance and it is intended that it be updated as new theories, calculation methods and/or data become available. It does not preclude the use of appropriate methods and data from other sources.

Sub-system 4 (PD 7974-4:2003) Detection of fire and activation of fire protection systems

Sub-system 4 provides guidance on the development, design and application of fire detection systems and the activation of fire alarm and fire control systems to fulfil a role in the fire safety engineered design for a building. Scientific and engineering principles are used as part of a structured approach. The key elements covered are: detection, activation and control.

In the context of PD 7974-4, fire control includes fire suppression systems, fire barrier systems and smoke/heat control systems.

Sub-system 5 (PD 7974-5:2002) Fire service intervention

Sub-system 5 provides guidance on fire service intervention and evaluates the rate of build-up of fire fighting resources of the fire service. These activities may include in-house or private fire brigades and, in particular, the time interval between the call to the local authority fire service and the arrival of the fire service at its predetermined level of attendance. The time interval between the arrival of the fire service and the start of their attack on the fire relates to the build-up of any additional fire service resources and the extent of fire fighting resources and extinguishing capability available at various times.

This sub-system takes information on building characteristics and the design fire from the Qualitative Design Review (QDR), together with the time of fire service notification from Sub-system 4 and the time of evacuation from Sub-system 6. It provides information on the effect of fire service activities on the growth of the fire, which is used in Sub-system 1.

Sub-system 6 (in preparation) Evacuation

This sub-system will provide guidance on all aspects of evacuation procedures; the text is still in the course of preparation.

Sub-system 7 (in preparation) Risk assessment, uncertainty and safety factors

This sub-system provides guidance on probabilistic risk analysis. It sets out the general principles and techniques of risk analysis that can be used in fire safety engineering. This sub-system also outlines the circumstances where this approach is appropriate and gives examples illustrating the use of risk analysis techniques.

The sub-system also includes data for probabilistic risk assessment and criteria for assessment. The data included is based on fire statistics, building characteristics and reliability of fire protection systems. The criteria included cover life safety and property protection, both in absolute and comparative terms.

This sub-system does not contain guidance on techniques for hazard identification or qualitative risk analysis. Probabilistic risk assessment of fire in buildings (with the exception of nuclear, chemical process, offshore and transport) is not widely used and so a discussion of possible future developments is included.

BS ISO/TR 13387: Parts 1 to 8

When ISO/TR 13387 was being prepared by ISO TC/92/SC4, reference was made to all the documents available at the time. Prominent in this consideration was DD 240, *Fire safety engineering in buildings*. DD 240 was the only document available and the content had a major influence on the drafting of both BS 7974 and ISO/TR 13387. There are a limited number of fire safety experts and they participated in the preparation of both documents. While the British Standard was developed from DD 240 and was subjected to all the national considerations, ISO/TR 13387 was developed in recognition of other, international considerations, particularly from the United States of America and Japan.

While the two documents are different in a number of respects; the basic philosophy remains the same. The differences should not be regarded as corrections or errors in either document; there can be no definitive guidance document at this time. The national and international differences are intended to accommodate the different approaches now being discussed. It is for this reason that the ISO document has been published as a Technical Report. A considerable amount of detailed consideration is needed at the international level before these Technical Reports can be issued as international standards. To provide the outline basis for comparison with BS 7974, a brief synopsis of the ISO Technical Reports follows.

The Parts of ISO/TR 13387 are as follows:

- *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;* and
- *Part 8: Life safety: occupant behaviour, location and condition.*

options that have very different fire safety features and for identifying the most cost-effective improvements to fire safety systems.

Comparative approach

Here it is necessary to show that the proposed design provides a level of safety equivalent to that in a building which conforms to more prescriptive codes. If this approach is used, it is important to understand the intention of each recommendation of the prescriptive code as a particular provision may have more than one objective.

Functional building requirements introduce the concept of ‘equivalency’. The onus is upon the architect or developer to demonstrate that their scheme provides an equivalent level of safety, and if they can do so, then the necessary approvals should be forthcoming from the Approvals Authority.

Who can carry out fire engineering?

The definition of ‘fire safety engineer’ as ‘a person suitably qualified and experienced in fire safety engineering’ flows from the definition of fire safety engineering to be found in BS 7974 (see above). It would normally be expected that a fire engineer would be a member of the appropriate professional body specific to fire such as the Institution of Fire Engineers at either corporate, EngTech, IEng or CEng level, as appropriate, or be a chartered engineer with suitable fire experience.

The level of skills and experience required for fire engineering can vary widely according to the complexity of the project. It may be useful to set out a broad indication of the range of work and the appropriate level of qualification and experience for each type.

Table 1 provides an indication of the potential relationship between the complexity of the tasks and the level of training and experience required to carry out the particular level of task.

Table 6.1 Suggested level of competence to deal with variations

Fire safety solution	Minor variations to standard	Major variations to standard
Qualitative	1	2
Simple calculations	2	2
Complex analysis	3	3

Key to Table 1

The level of experience/qualification recommended for each fire safety solution is given as follows.

1 Competent construction professional with building code experience, e.g. Chartered Surveyor, Building Control Surveyor.
2 As for 1 but with appropriate additional training and experience, e.g. Member of Institution of Fire Engineers or other appropriate professional body.
3 CEng qualification with appropriate Continuing Professional Development.

The Qualitative Design Review defines the scope and objectives of the fire safety design and sets acceptance criteria for any proposed solutions to any fire risk which is to have a fire safety engineered solution.

Quantitative analysis is used to evaluate such items as fire size, quantity and temperature of smoke produced, smoke ventilation, the effect of fire alarm systems, sprinklers, fire service intervention, evacuation times for occupants, etc. Quantitative risk analysis can also be used to establish the risk of particular events occurring which can be compared with the acceptability of those events occurring.

The results of quantitative analysis are used to compare the performance of the design with the acceptance criteria. Where there are a number of possible solutions to be considered, the assessment should allow a comparison of each so that a determination as to the most appropriate can be made.

Code-based approach

The Building Regulations in England and Wales are accompanied by a series of Approved Documents. In the case of fire safety, it is Approved Document B. Approved Document B provides examples as to how the various functional requirements can be accommodated and so achieves an acceptable level of fire safety.

The majority of building control is achieved through the simple means of providing a design that meets all these design criteria. Such a code-based system would not, therefore, require the consideration of an engineered approach.

BS 7974 identifies what might be considered as suitable acceptance criteria. The acceptability or otherwise of the criteria is a matter for the regulatory body concerned or the client's requirements in the case of fire risks outside a regulatory context. Where buildings, railway stations, ships and other structures are concerned, regulatory bodies such as the Building Control Authority, the Fire Authority, the Health and Safety Executive, the International Maritime Organization, etc. must be satisfied.

In presenting the criteria to the Regulatory Authority, the approach by the architect or the developer should be along one of the following lines:

Deterministic approach

This involves showing that the initial assumptions (usually the reasonable worst case) do not produce an outcome that exceeds a set of predetermined conditions. Examples would be calculations of fire size, smoke volume and temperature, toxic potency of the combustion products, evacuation time, structural fire protection, etc. These would be considered in relation to each other to show that any outcomes would meet the design objectives of life safety, property protection, business continuity, etc.

Probabilistic approach

This involves calculating the probability of certain outcomes occurring and showing that these are acceptably low. This could include quantified risk assessments using statistical data to rate the likelihood of particular events taking place and the seriousness of the consequences. Examples of this approach would include comparing an innovative approach against a code-based system as contained in the series of Approved Documents that accompany the Buildings Regulations (see above), or to identify the most important risk factors for business continuity purposes, etc. It can be a powerful tool for comparing two

In the Parts of ISO/TR 13387, the following five important steps in the fire safety design process are identified. They are common to those identified in BS 7974 and the Published Documents that accompany it:

- definition of the safety objectives and scope of the study;
- setting acceptance criteria;
- characterization of the building, occupants and environment;
- undertaking a qualitative design review; and
- conducting quantified analysis.

The evaluation of the fire safety design of a building is broken down, to simplify the process, into eight separate components of the system (sub-systems denoted by the prefixes SS1 to SS8) belonging either to the tools for fire safety engineering evaluation (SS1 to SS5) or the fire safety objectives (SS6 to SS8).

SS1 Initiation and development of fire and fire effluents

This sub-system provides guidance on the use of engineering methods for the prediction of ignition of fire, the generation of fire effluents and the development of fire inside the room of origin.

The sub-system 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 sub-system may also provide the 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 on a building are also addressed.

SS2 Movement of fire effluents

This sub-system provides guidance on the use of engineering methods for the prediction of movement of fire effluents in buildings. The sub-system draws on other sub-systems for the prescription or characterization of the fire. The prediction of the fire development and the production of fire effluents are provided by Sub-system 1, the prediction of the spread of smoke and flames through openings is addressed by Sub-system 2, while the spread of fire through barriers is provided by Sub-system 3.

The sub-system 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 sub-system may also provide the means to assess the effectiveness of fire safety measures meant to reduce the adverse effects of the movement of fire effluents.

SS3 Structural response and fire spread beyond the enclosure of origin

This sub-system provides guidance on the use of engineering methods for the prediction of fire spread beyond the enclosure (e.g. room or compartment) of fire origin, to adjacent enclosures within the building, other buildings or external items. The exposure of a building to external fires is also addressed by this sub-system.

The sub-system draws on other sub-systems for a prescription or characterization of the fire. Sub-system 1, for example, provides prediction 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 sub-system to predict the likelihood (and time) of fire spread and the likelihood (and time) of structural collapse.

The sub-system provides a framework for critically reviewing the suitability of an engineering method (calculation worked out by hand, computer method or fire test) for assessing the potential for fire spread in a given situation or 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). The availability and reliability of the relevant input data for each unit process is also addressed.

Should fire spread from the room or 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 fire fighters outside the room or compartment of fire origin can be compromised. Hence data generated by Sub-system 3 become input to Sub-system 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.

SS4 Detection, activation and suppression

This sub-system provides guidance on the use of engineering methods for the prediction of the time taken to detect smoke or flames by a wide range of commercial devices. This includes 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 sub-system 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 to estimate the effectiveness of many common fire-suppression and control strategies are also addressed.

Sub-system 4 draws on Sub-systems 1 to 3 for characterizing 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 location from the building design parameters, is employed by Sub-system 4 to predict detection times and the operation of elements, such as those in automatic sprinklers, that allow release of pressurized extinguishing agent (e.g. water or foam) at a nozzle.

The effect of various suppression strategies on the fire-heat release rate is estimated in Sub-system 4. Currently this is carried out by reference to national codes and installation guidelines and the use of engineering judgement in the application of these guidelines to design fire scenarios. Once an assumed suppression strategy (usually in terms of a required

functional requirements are restrictive in a specific case and it will follow that some compromise will be offered. There is little point in presenting the regulator with a *fait accompli* and expecting acceptance. It is very much a joint effort and early discussion should lead to a solution where all the requirements of the regulatory authorities, the developer, the architect, the building user and the public in respect of a safe environment are met.

Who uses fire safety engineering?

Many individuals and organizations will have different interests as well as an involvement in fire safety engineering.

Building Control Authorities and Fire Authorities will have a regulatory interest, with an emphasis on life safety for occupants and fire fighters. They need to be sure that they can approve a fire safety engineered proposal in the knowledge that it provides an equivalent or better level of fire safety in a building or infrastructure project to that provided by a ‘standard’ code-based solution.

- Insurance companies and building owners and occupiers will be concerned about loss prevention.
- Businesses have a vital interest in business continuity.
- Environmental authorities seek the protection of the environment from air and water pollution from fire incidents.
- Heritage buildings are often priceless and cannot be replaced.
- Developers seek to reduce construction costs and improve functionality and flexibility.
- Designers will seek to provide efficient and innovative buildings with flexible spaces used in new ways.

The principle behind all such uses of fire safety engineering is to tailor the fire safety provision in a building to the actual risk. This is the basis on which the above objectives can be met. One advantage of a fire safety engineered design is that it may offer greater flexibility or significant cost savings as well as being a safer design than a building that meets standard guidance.

In the planning stages, the Building Control Authorities and Fire Authorities are faced with the task of consenting to the necessary building and planning approvals. Once the building is occupied as a place of work, the Fire Authority is charged with the enforcement of the Fire Precautions (Workplace) Regulations 1997 (as amended).

These Regulations are based upon the European Union Framework (89/391/EEC) and Workplace Directives (89/654/EEC), and these European documents ensure that equivalent legislation is in place throughout the European Union. The Regulations place a statutory duty on the employer to carry out an assessment of the risk from fire in his premises. Therefore, employers will be closely involved as the ongoing management of any fire safety engineered solution rests clearly with them.

How is fire safety engineering used?

BS 7974 identifies three main stages in the framework for engineering approach to fire safety.

Example 2

An airport terminal building is required to have very little compartmentation to facilitate ease of wayfinding and efficient movement of large numbers of people in a pleasant environment. To compensate for the omission of some of the compartmentation two techniques are used: limited areas of high fire load are sprinklered and local smoke extraction provided and areas of combustible seating are separated by distances large enough to ensure that fire cannot spread from one area to the next. The maximum fire size is limited to one seating area, allowing the smoke ventilation system to function adequately.

When is fire safety engineering used?

There are no rules as to when fire safety engineering can, or should, be used. In the majority of buildings, compliance with the functional requirements will not be contentious and little difficulty will be experienced.

The example given above (Example 1) of the extension of travel distances as a result of an improved alarm system shows a simple justification for a minor variation of the standard guidance. In the case of larger, complex buildings, the proposal may be for a package of interdependent proposals.

Example 3

In a large multi-storey shopping/leisure complex with a mixture of new and existing listed buildings, limited space for natural smoke ventilation can be shown to be adequate using:

- fast response sprinklers to limit maximum fire size;
- control over plume widths for smoke escaping from units in the development.

The expectations of today's society are continually more demanding and the designers and developers of major buildings or development schemes are fully aware of their obligations in this respect. The user will need a return on his/her capital and for this to happen the building user's needs must be met. For instance, in the case of a large shopping mall, the designers must work to create an atmosphere that attracts the public there in the first place. To provide an attractive environment, the architect may often resort to the provision of large, wide-open spaces. This is very attractive to the shopper, but difficult for the regulatory authorities where travel distances to a place of safety may become very long. This particular problem has become so common that standard fire safety engineering solutions have been developed for shopping malls, although these are outside ordinary building regulations guidance and need to be adapted in more complicated buildings that combine retail and leisure functions.

Example 4

CIBSE Guide Technical Memoranda TM19:1995, Relationships for smoke control calculations. Using this document, smoke ventilation requirements for single and two-storey shopping centres can be designed using calculations worked out by hand or simple spreadsheets.

NOTE: BR186, Design principles for smoke ventilation in enclosed shopping centres, may also be suitable depending on the nature of the circumstances under analysis.

The need for an engineered solution will usually emanate from the requirements of an architect or developer. Preliminary considerations will have revealed that the normal

agent flow rate) takes effect, there is considerable feedback required between Sub-system 4 and Sub-system 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 such as the use of inert gas discharge may have to be considered.

Activation times are also determined in Sub-system 4, most often from a wealth of input information available from the 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.

SS5 Fire service intervention

This sub-system provides guidance on the evaluation of the rate of build-up of fire extinguishing resources of the fire service, including the activities on any in-house or private fire brigades and in particular:

- the time interval between the call to the fire service and the arrival of the fire service predetermined attendance;
- the time interval between the arrival of the fire service and the initiation of attack on the fire by the fire service;
- the time intervals related to the build-up of any necessary additional fire service resources;
- the extent of fire fighting resources and extinguishing capability available at various times.

SS6 Life, health and safety of people

The occupants of a building and fire fighters who may have entered that building together with members of the public, and fire fighters who are in the vicinity of the building can, potentially, be put at risk by fire. The main life-safety objectives are therefore to ensure that:

- the occupants are able to remain in place, evacuate to another part of the building or totally evacuate the building without being subject to hazardous (e.g. causing injury or incapacitating) or untenable conditions;
- fire fighters are safely able to:
  – assist evacuation where necessary;
  – effect rescue where necessary;
  – prevent extensive spread of fire;
- collapse of elements of structure does not endanger people (including fire fighters) who are likely to be near the building.

Details of life-safety strategies and evaluation techniques are given in Annex D of ISO/TR 13387-1.

SS7 Property protection

The effects of fire on the continuing viability of a business/infrastructure may be of vital interest and can be substantial and therefore consideration should be given to the limitation of damage to:

- the structure and fabric of the system (building);
- the contents of the system;
- ongoing business/activity viability;
- public perception or image.

SS8 Environmental protection

A fire involving several buildings or the release of quantities of hazardous materials may have an environmental impact that is out of all proportion to the size of the original fire. A small fire involving some toxic products which is extinguished by water that goes into an adjacent river may lead to large or extensive environmental pollution. Consideration should, therefore, be given to the limitation of the effects of fire on adjacent buildings or facilities and the release of hazardous materials into the environment.

a. A fire safety engineering design is more dependent upon management controls. Whether designed in accordance with prescriptive codes or fire safety engineering principles, good fire safety management is essential to the safe operation of any building. The fire safety engineering approach presented in BS 7974-0 requires that management issues be taken into account and any specific management requirements are addressed explicitly.

b. Fire safety engineering cannot, or should not, be applied to just one aspect of the design. The most common use of fire safety engineering is to justify one or two specific departures from prescriptive codes. There may be little need to apply fire safety engineering principles to all aspects of a project if it is otherwise code-compliant.

c. A fire safety engineering design may provide less flexibility for future use. During the preparation of an engineered solution, the design team should identify potential future changes of use. They should, where practical, ensure that the design would accommodate these changes. If this is not feasible, any potential restriction should be highlighted. A lack of flexibility is a function of poor engineering design rather than an inherent function of fire safety engineering.

d. A fire safety engineering design is more dependent upon the correct performance of fire protection systems. There is no reason why a wedged-open fire door or poorly maintained sprinkler system should be any less of a problem in a code-compliant building than in a building designed on the basis of fire safety engineering principles. BS 7974 (see **6.4.6.1.2.1**) requires that the potential impact of systems failures be assessed. The input of such failures may often be less in a building designed on fire safety engineering principles.

e. The accuracy of many fire safety engineering calculations is unknown. The accuracy of all of the calculation procedures presented in BS 7974 will generally be sufficiently accurate for engineering design purposes if they are used within the limits of applicability.

f. A fire safety engineering solution always requires calculations and a numerical solution. BS 7974 provides a design framework and does not necessarily require a quantified analysis. Very often it will be possible to reach a solution without recourse to numerical calculations. During the design review process, it may be possible to establish simply by local deduction that a trial design is at least as safe as the code-compliant solution, without the need for any calculations.

Why is fire safety engineering used?

The principal objective of any application of fire safety engineering is to provide an environment that enjoys a level of safety that is demonstrably equal to, or better than, the level that would be developed by direct compliance with prescriptive requirements or standard guidance in respect of fire safety systems. The objective would be to design or develop measures, either singularly or in a package, to reduce the potential for injury, death, property loss or environmental damage to an acceptable level.

In some major projects, there may be no possible solution to identified fire safety problems other than to offer an engineered solution. In particular, large shopping malls, airport terminals and tall multi-storey commercial and residential buildings, often containing an atrium, present the designer and fire safety professional with problems that cannot be overcome using the available standard guidance.

6

Using fire safety engineering

What is fire safety engineering?

As mentioned above, BS 7974 defines fire safety engineering as 'the application of scientific and engineering principles to the protection of people, property and the environment from fire'.

The application of engineering principles therefore, is aimed at:

- saving life, protecting property and conservation of the environment including heritage buildings, protection of air and water resources;
- the identification and quantification of the hazards and risk of fire;
- the analytical evaluation of the optimum measures, both protective and preventative to limit the effects of fire.

The choice usually offered to the Building Control Authorities runs along the lines of 'If I can fulfil these provisions, can I carry out the proposed design?' The interlinking of such provisions may be an integral part of the proposed building design and may rely upon the effective and efficient management of the building. This applies also to many of the provisions of standard solutions such as fire doors intended to reduce the travel distances in particularly long corridors.

Example 1

Extended travel distances can sometimes be justified by the provision of an automatic smoke detection and alarm system.

With the introduction over the last ten years of the Construction (Design and Management) Regulations 1994 and the Fire Precautions (Workplace) Regulations 1997 it is possible to have more confidence in continuing management of risks and maintenance of life safety installations such as smoke vents, alarm systems, etc.

NOTE: Certain building types may have a higher level of effective and efficient management due to the nature of their use, e.g. airports.

Common misconceptions

In coming to understand and accept the concept of fire safety engineering, there are a number of common misconceptions that need to be addressed. The resolution of these will enable the acceptance of the basic principles of an engineered solution.

4

Background

Fire safety engineering is usually carried out in response to the requirements of regulations such as Building Regulations, Fire Regulations and the fire safety aspects of the International Maritime Organization for safety on ships, etc. Alternatively, it may be offered as a way of satisfying insurance conditions or to protect businesses, irreplaceable buildings or artefacts by providing an enhanced level of fire safety by active or passive fire protection measures. In order to discuss the most common uses of fire engineering, it is necessary to have a basic understanding of the system of Local Authority Building Control (LABC) in the UK and the role of functional as opposed to prescriptive regulations.

All building works in the UK are subject to regulations. The system of regulation has developed over the years to the point where the current Regulations (Building Regulations 2000, Approved Document B that accompanies them) in England and Wales and Northern Ireland acknowledge (Clause 0.11) that an agreed fire safety engineered solution may be the *only* means of achieving an acceptable level of fire safety.

However, in Scotland such engineered solutions are likely to be the subject of a formal relaxation process. Professional staff from building control bodies and fire authorities will need the skills and experience to check building designs, which involve fire engineering.

Where did building regulations come from?

Building regulations were originally introduced into the UK by larger cities passing by-laws to meet the problems of urbanization, starting with London after the Great Fire of 1666 and also developing both in the capital and in manufacturing centres during the Industrial Revolution – Manchester, Birmingham, Glasgow, the West Riding area of Yorkshire, etc. Regulations dealt with a wide range of public health and safety matters including plumbing, drainage and ventilation, heating appliances and, of course, fire safety. Limited local fire regulations are still in place today in some areas of the UK, although pressure is now growing within the industry for all such local provisions to be either repealed or incorporated within national regulations.

To this effect, The Office of the Deputy Prime Minister issued a consultation document on the reform of fire safety legislation in July 2002, which provides for a mechanism to simplify, rationalize and consolidate the law with respect to fire safety in buildings in use.

Building regulations dealing with fire safety and other fire safety legislation such as the Fire Precautions Act 1971 are a response to known fire risks and to fire disasters which revealed previously unexpected fire hazards in buildings.

Prescriptive regulations

Early regulation was prescriptive. The Building Regulations issued in 1965, 1972 and 1976 were of this type. Here the conditions and performance that were required of materials was prescribed in a series of 'deemed to satisfy' provisions or referenced technical standards published by BSI (usually the early versions of BS 476 in its many parts). Little by way of deviation was allowed or considered without time-consuming and expensive relaxation or dispensation procedures that had to be sanctioned by local council political committees or by central government.

The change to functional regulations

Over time, it became apparent that such prescriptive regulations were restrictive to both architects in their choice of materials and to the users of buildings in preventing them from utilizing the full potential of their building.

In England and Wales a major philosophical development took place with the implementation of the Building Act 1984 and The Building Regulations 1985. These items of legislation were accompanied by a series of Approved Documents, which provided guidance and suggested ways of complying with the regulations. Approved Document B covers fire safety. The most recent documents in England and Wales are the Building Regulations 2000 and the 2000 edition of Approved Document B. The equivalent documents in Northern Ireland and Scotland are Technical Booklet E and Technical Standard E respectively.

These developments brought about the use of functional regulations in parts of the UK. Such regulations are typically framed in such a way as to require a particular safety feature in a building to be 'adequate' or 'appropriate'. For example, England and Wales Regulation B1 contains the wording:

> 'The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire and the appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times.'

This type of expression allows a wide variety of interpretations of the word 'appropriate' and also allows the possibility of compensating for a deficiency in one element of the means of escape with extra provision in another element.

The functional nature of the requirements of the England and Wales and Northern Ireland regulations is emphasized in Approved Document B and Technical Booklet E in the following statements:

> 'The Approved Documents are intended to provide guidance for some of the more common building situations. However, there may well be alternative ways of achieving compliance with the requirements. Thus there is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way.' (Approved Document B)

With regard to the building control system in Northern Ireland, there is no parity at the moment between the Regulations in England and Wales and the Regulations in Northern Ireland, although it is hoped that this will be achieved in the future. Technical Booklet E has been prepared by the Department of the Environment for Northern Ireland and provides for certain methods and standards of buildings, which, if followed, will satisfy the requirements of the Building Regulations (Northern Ireland) 1994.

The building control system in Scotland is based on the administration, by local authorities, of the Buildings Standards (Scotland) Regulations 1990 (as amended). These Regulations apply to the construction, alteration, extension or demolition of a building or part of a building or to any change of use, which attracts additional or more onerous requirements.

5

Using standard guidance – code-based solutions

Example – England and Wales

Approved Document B to the England and Wales Building Regulations 2000 is widely regarded as a comprehensive document, which can be used by any competent design professional. It combines an easy-to-use index with step-by-step and cross-referenced content which allows an architect or engineer to work out the requirements for each part of the regulations from B1 to B5, covering:

- B1 Means of Escape;
- B2 Internal Fire Spread (Linings);
- B3 Internal Fire Spread (Structure);
- B4 External Fire Spread;
- B5 Access and Facilities for the Fire Service.

British Standards in the BS 5588 series provide similar guidance for a variety of building types and occupants. They include some information that is outside the scope of the content of Approved Document B.

For example, BS 5588-6 contains recommendations for plans for fire service use, audience/crowd control, pre-performance checks and staff training. Likewise, BS 5588-11 has information and recommendations about management issues such as management responsibilities, commissioning and hand over of fire safety installations, fire routines, emergency procedures, housekeeping, etc. Many of these items can form part of a fire safety engineering solution and are connected to the risk assessment process for the purpose of compliance with the Fire Precautions (Workplace) Regulations 1997 (as amended) referred to above.

Other UK standard guidance

Northern Ireland Technical Booklet E and Scottish Technical Standard E also contain guidance (which is specific to those areas), which is straightforward to follow.

It is often simpler, quicker and cheaper for a designer to follow the appropriate standard guidance where a 'code-compliant' building does not impose extra costs or unacceptable loss of functionality. However, there are many situations where there is an advantage in using fire engineering when designing a building.

> 'There is no obligation to follow the methods or comply with the standards set out in this Technical Booklet. If you prefer you may adopt another way of meeting the requirements of the Building Regulations but you will have to demonstrate that you have satisfied those requirements by other means.' (Northern Ireland Technical Booklet E).

The Scottish Regulations do not allow variations of the 'deemed to satisfy' provisions contained in Technical Standards but rely on a relaxation procedure where a design does not meet the standard guidance. They require the applicant for a building warrant to make a formal application to the local authority for a relaxation if they propose a solution not contained in the Technical Booklet. If the relaxation is refused, the applicant can appeal to the Scottish Executive.

Therefore, Building Control in the UK outside Scotland has introduced the concept of functional requirements. From 1985 the levels of safety to be achieved were given for the first time in functional terms, i.e. the levels to be achieved were given, but the actual method of achieving the level was not prescribed. This allowed architects, developers and other users a far greater freedom in their designs, applications and use of the building.

Paragraph 0.11 of Approved Document B goes further in acknowledging that a fire safety engineering approach may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings. Similarly, it also notes that fire safety engineering may also be suitable for solving a problem with an aspect of the building design which otherwise follows the provisions of Approved Document B or existing buildings of special architectural or historic interest.

From the above it can be concluded that current building regulations in the UK acknowledge the role of fire safety engineering as a useful tool which can provide alternative approaches to fire safety than those in published guidance. Consideration is presently being given to the possibility of amending the current Scottish Building Regulations to bring them into line with those building regulations currently in force in the rest of the UK.

Building Control Bodies

Until the 1980s building control approval for building plans and work on-site in England and Wales was carried out only by local authorities. The Building Act 1984 enabled the Secretary of State for the Department of the Environment (now The Office of the Deputy Prime Minister), to 'approve' building control inspectors other than local authorities. Due to insurance constraints this system was only available for use with domestic buildings until 1997 after which large numbers of individual and corporate building inspectors were approved by the government. Consequently building control is now carried out in England and Wales by both local authorities and private companies and individuals. In Scotland and Northern Ireland, building control is still carried out exclusively by local authorities.

The role of the fire authority

Section 16 of The Fire Precautions Act 1971 requires Building Control Bodies to consult the fire authority before approving a plan for any building which has a 'designated' use. This category includes all places of work (offices, shops and factory premises) and most hotel and boarding house buildings. The Building Control Body can make the final decision about approval and does not necessarily have to accept the fire authority's comments – although it would be unusual for it not to.

Fire authorities employ specialist fire safety officers to comment on building regulations proposals as well as dealing with enforcement under the Fire Precautions Act 1971 (as amended) and the Fire Precautions (Workplace) Regulations 1997 (as amended). Fire authorities also have a major role in the provision of liquor licensing and other licences issued by magistrates and local authorities.

How should the regulatory authorities deal with proposals for fire safety engineered buildings?

Just as only competent persons can carry out fire safety engineering design, in the same way regulatory authorities must have the resources to check the validity of a fire safety engineered design. Without this there is a danger of a valid design being rejected or an inadequate design being accepted with potentially dangerous consequences.

The document *Building Control Performance Standards* was published in 1999 by a consortium of government and professional bodies and contains the following statements.

> 'The principles of risk assessment, and experience, coupled with the responsibilities placed by the Standards will help the Building Control Body to determine the level of expertise and input into individual projects …'

> 'An approved inspector must not accept a project if it is unlikely to be adequately resourced. A local authority … cannot turn work away. Therefore, where a local authority finds itself regularly under resourced in respect of its building control function, it must take … all reasonable steps to rectify the situation.'

In the spirit of this guidance on performance standards, when a Building Control Body deals with a building design, which involves fire safety engineering, it should check whether it has adequate in-house skills and experience to form a proper judgement of the proposals. If not, it may have to consider employing a suitably qualified and experienced consultant. This process is well established among Building Control Bodies for the approval of complex structural designs.

The *Building Control Performance Standards* document does not apply to fire authorities; however, some authorities or fire safety offices within a particular fire authority may need to employ consultants if they do not have adequate fire engineering skills and experience within their staff.

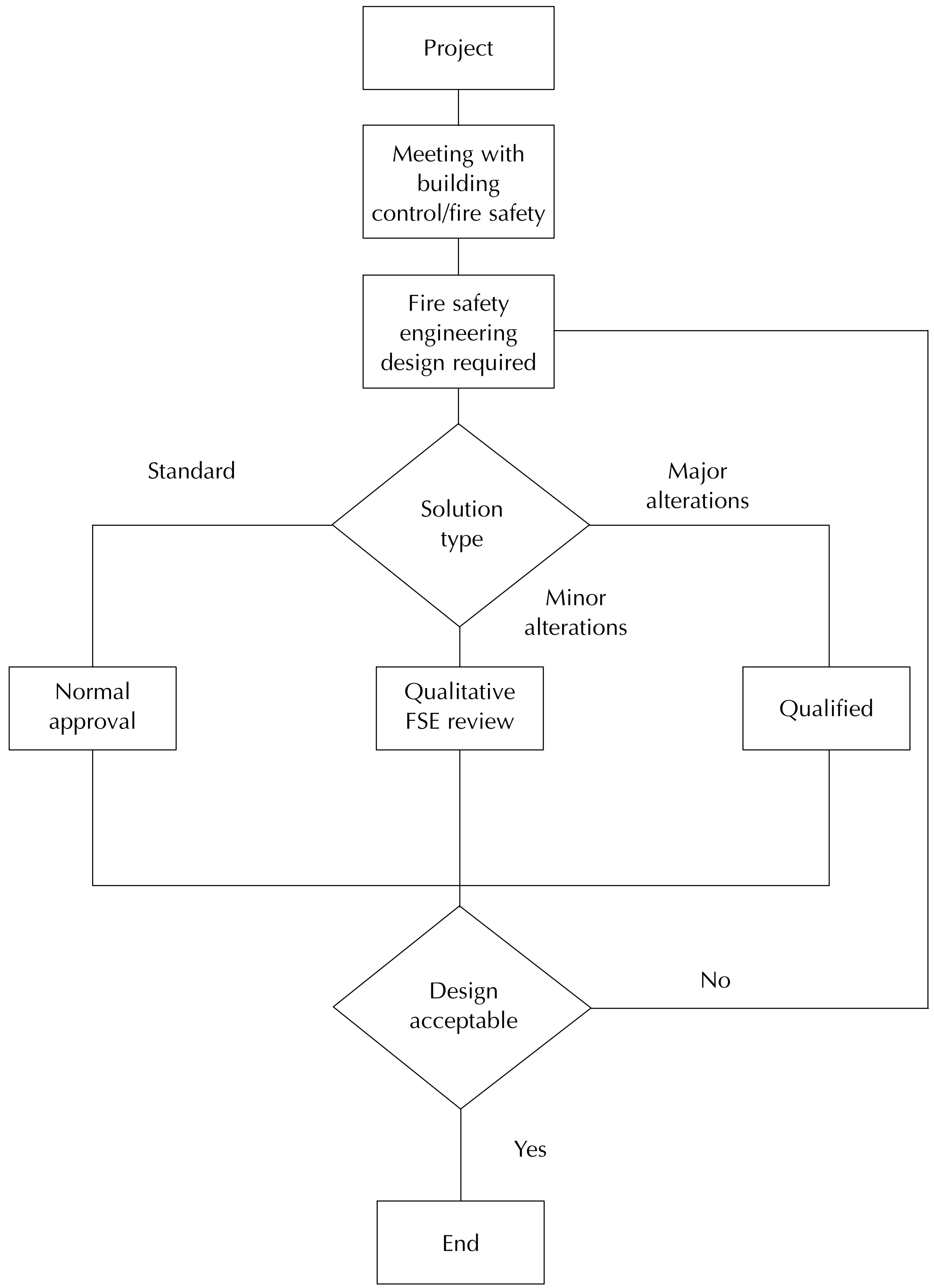

Figure 4.1 The fire safety engineering design process

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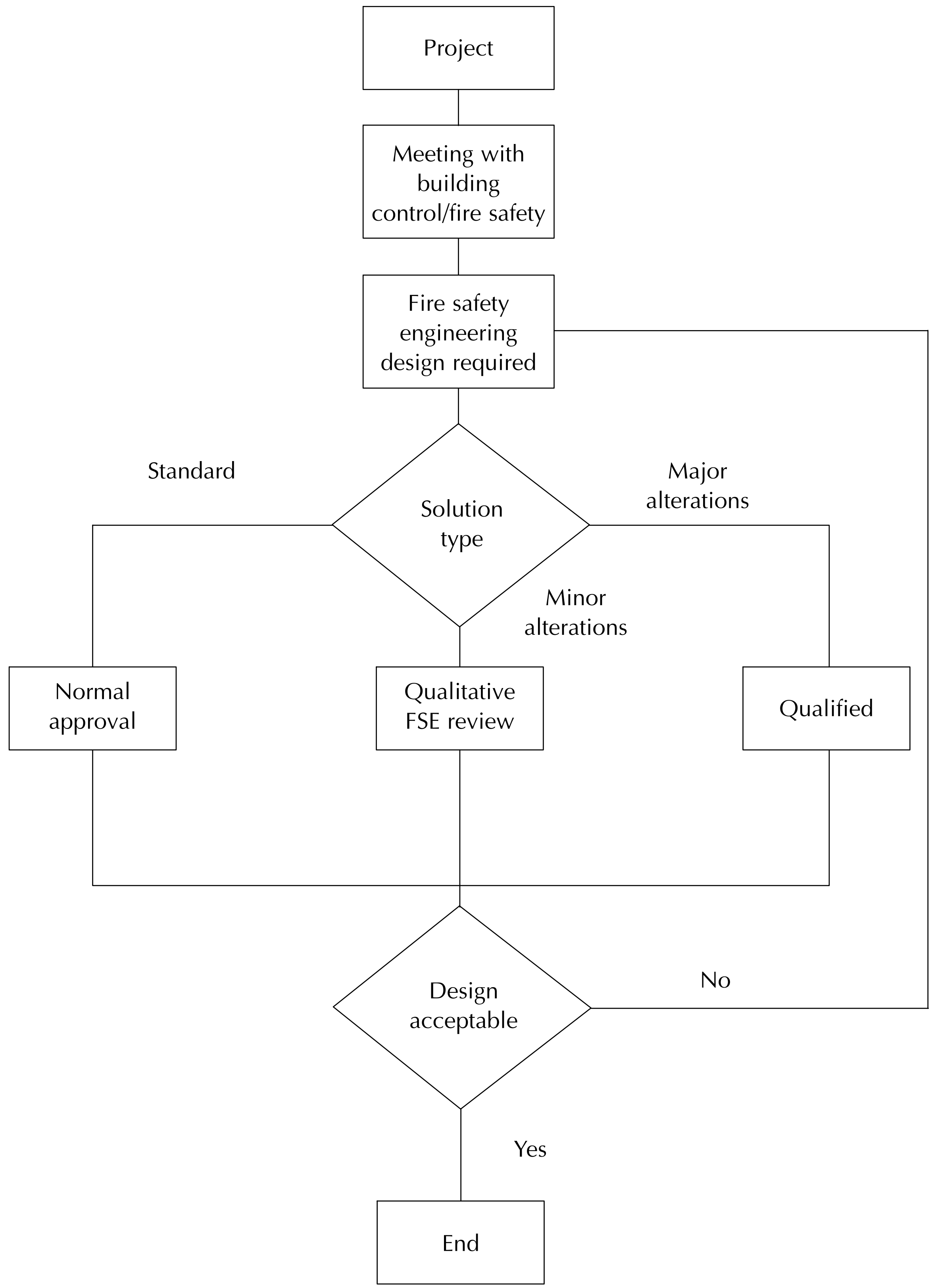

Figure 4.1 The fire safety engineering design process

5

Using standard guidance – code-based solutions

Example – England and Wales

Approved Document B to the England and Wales Building Regulations 2000 is widely regarded as a comprehensive document, which can be used by any competent design professional. It combines an easy-to-use index with step-by-step and cross-referenced content which allows an architect or engineer to work out the requirements for each part of the regulations from B1 to B5, covering:

- B1 Means of Escape;
- B2 Internal Fire Spread (Linings);
- B3 Internal Fire Spread (Structure);
- B4 External Fire Spread;
- B5 Access and Facilities for the Fire Service.

British Standards in the BS 5588 series provide similar guidance for a variety of building types and occupants. They include some information that is outside the scope of the content of Approved Document B.

For example, BS 5588-6 contains recommendations for plans for fire service use, audience/crowd control, pre-performance checks and staff training. Likewise, BS 5588-11 has information and recommendations about management issues such as management responsibilities, commissioning and hand over of fire safety installations, fire routines, emergency procedures, housekeeping, etc. Many of these items can form part of a fire safety engineering solution and are connected to the risk assessment process for the purpose of compliance with the Fire Precautions (Workplace) Regulations 1997 (as amended) referred to above.

Other UK standard guidance

Northern Ireland Technical Booklet E and Scottish Technical Standard E also contain guidance (which is specific to those areas), which is straightforward to follow.

It is often simpler, quicker and cheaper for a designer to follow the appropriate standard guidance where a 'code-compliant' building does not impose extra costs or unacceptable loss of functionality. However, there are many situations where there is an advantage in using fire engineering when designing a building.

> 'There is no obligation to follow the methods or comply with the standards set out in this Technical Booklet. If you prefer you may adopt another way of meeting the requirements of the Building Regulations but you will have to demonstrate that you have satisfied those requirements by other means.' (Northern Ireland Technical Booklet E).

The Scottish Regulations do not allow variations of the 'deemed to satisfy' provisions contained in Technical Standards but rely on a relaxation procedure where a design does not meet the standard guidance. They require the applicant for a building warrant to make a formal application to the local authority for a relaxation if they propose a solution not contained in the Technical Booklet. If the relaxation is refused, the applicant can appeal to the Scottish Executive.

Therefore, Building Control in the UK outside Scotland has introduced the concept of functional requirements. From 1985 the levels of safety to be achieved were given for the first time in functional terms, i.e. the levels to be achieved were given, but the actual method of achieving the level was not prescribed. This allowed architects, developers and other users a far greater freedom in their designs, applications and use of the building.

Paragraph 0.11 of Approved Document B goes further in acknowledging that a fire safety engineering approach may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings. Similarly, it also notes that fire safety engineering may also be suitable for solving a problem with an aspect of the building design which otherwise follows the provisions of Approved Document B or existing buildings of special architectural or historic interest.

From the above it can be concluded that current building regulations in the UK acknowledge the role of fire safety engineering as a useful tool which can provide alternative approaches to fire safety than those in published guidance. Consideration is presently being given to the possibility of amending the current Scottish Building Regulations to bring them into line with those building regulations currently in force in the rest of the UK.

Building Control Bodies

Until the 1980s building control approval for building plans and work on-site in England and Wales was carried out only by local authorities. The Building Act 1984 enabled the Secretary of State for the Department of the Environment (now The Office of the Deputy Prime Minister), to 'approve' building control inspectors other than local authorities. Due to insurance constraints this system was only available for use with domestic buildings until 1997 after which large numbers of individual and corporate building inspectors were approved by the government. Consequently building control is now carried out in England and Wales by both local authorities and private companies and individuals. In Scotland and Northern Ireland, building control is still carried out exclusively by local authorities.

Prescriptive regulations

Early regulation was prescriptive. The Building Regulations issued in 1965, 1972 and 1976 were of this type. Here the conditions and performance that were required of materials was prescribed in a series of 'deemed to satisfy' provisions or referenced technical standards published by BSI (usually the early versions of BS 476 in its many parts). Little by way of deviation was allowed or considered without time-consuming and expensive relaxation or dispensation procedures that had to be sanctioned by local council political committees or by central government.

The change to functional regulations

Over time, it became apparent that such prescriptive regulations were restrictive to both architects in their choice of materials and to the users of buildings in preventing them from utilizing the full potential of their building.

In England and Wales a major philosophical development took place with the implementation of the Building Act 1984 and The Building Regulations 1985. These items of legislation were accompanied by a series of Approved Documents, which provided guidance and suggested ways of complying with the regulations. Approved Document B covers fire safety. The most recent documents in England and Wales are the Building Regulations 2000 and the 2000 edition of Approved Document B. The equivalent documents in Northern Ireland and Scotland are Technical Booklet E and Technical Standard E respectively.

These developments brought about the use of functional regulations in parts of the UK. Such regulations are typically framed in such a way as to require a particular safety feature in a building to be 'adequate' or 'appropriate'. For example, England and Wales Regulation B1 contains the wording:

> 'The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire and the appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times.'

This type of expression allows a wide variety of interpretations of the word 'appropriate' and also allows the possibility of compensating for a deficiency in one element of the means of escape with extra provision in another element.

The functional nature of the requirements of the England and Wales and Northern Ireland regulations is emphasized in Approved Document B and Technical Booklet E in the following statements:

> 'The Approved Documents are intended to provide guidance for some of the more common building situations. However, there may well be alternative ways of achieving compliance with the requirements. Thus there is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way.' (Approved Document B)

With regard to the building control system in Northern Ireland, there is no parity at the moment between the Regulations in England and Wales and the Regulations in Northern Ireland, although it is hoped that this will be achieved in the future. Technical Booklet E has been prepared by the Department of the Environment for Northern Ireland and provides for certain methods and standards of buildings, which, if followed, will satisfy the requirements of the Building Regulations (Northern Ireland) 1994.

The building control system in Scotland is based on the administration, by local authorities, of the Buildings Standards (Scotland) Regulations 1990 (as amended). These Regulations apply to the construction, alteration, extension or demolition of a building or part of a building or to any change of use, which attracts additional or more onerous requirements.

6

Using fire safety engineering

What is fire safety engineering?

As mentioned above, BS 7974 defines fire safety engineering as 'the application of scientific and engineering principles to the protection of people, property and the environment from fire'.

The application of engineering principles therefore, is aimed at:

- saving life, protecting property and conservation of the environment including heritage buildings, protection of air and water resources;
- the identification and quantification of the hazards and risk of fire;
- the analytical evaluation of the optimum measures, both protective and preventative to limit the effects of fire.

The choice usually offered to the Building Control Authorities runs along the lines of 'If I can fulfil these provisions, can I carry out the proposed design?' The interlinking of such provisions may be an integral part of the proposed building design and may rely upon the effective and efficient management of the building. This applies also to many of the provisions of standard solutions such as fire doors intended to reduce the travel distances in particularly long corridors.

Example 1

Extended travel distances can sometimes be justified by the provision of an automatic smoke detection and alarm system.

With the introduction over the last ten years of the Construction (Design and Management) Regulations 1994 and the Fire Precautions (Workplace) Regulations 1997 it is possible to have more confidence in continuing management of risks and maintenance of life safety installations such as smoke vents, alarm systems, etc.

NOTE: Certain building types may have a higher level of effective and efficient management due to the nature of their use, e.g. airports.

Common misconceptions

In coming to understand and accept the concept of fire safety engineering, there are a number of common misconceptions that need to be addressed. The resolution of these will enable the acceptance of the basic principles of an engineered solution.

4

Background

Fire safety engineering is usually carried out in response to the requirements of regulations such as Building Regulations, Fire Regulations and the fire safety aspects of the International Maritime Organization for safety on ships, etc. Alternatively, it may be offered as a way of satisfying insurance conditions or to protect businesses, irreplaceable buildings or artefacts by providing an enhanced level of fire safety by active or passive fire protection measures. In order to discuss the most common uses of fire engineering, it is necessary to have a basic understanding of the system of Local Authority Building Control (LABC) in the UK and the role of functional as opposed to prescriptive regulations.

All building works in the UK are subject to regulations. The system of regulation has developed over the years to the point where the current Regulations (Building Regulations 2000, Approved Document B that accompanies them) in England and Wales and Northern Ireland acknowledge (Clause 0.11) that an agreed fire safety engineered solution may be the *only* means of achieving an acceptable level of fire safety.

However, in Scotland such engineered solutions are likely to be the subject of a formal relaxation process. Professional staff from building control bodies and fire authorities will need the skills and experience to check building designs, which involve fire engineering.

Where did building regulations come from?

Building regulations were originally introduced into the UK by larger cities passing by-laws to meet the problems of urbanization, starting with London after the Great Fire of 1666 and also developing both in the capital and in manufacturing centres during the Industrial Revolution – Manchester, Birmingham, Glasgow, the West Riding area of Yorkshire, etc. Regulations dealt with a wide range of public health and safety matters including plumbing, drainage and ventilation, heating appliances and, of course, fire safety. Limited local fire regulations are still in place today in some areas of the UK, although pressure is now growing within the industry for all such local provisions to be either repealed or incorporated within national regulations.

To this effect, The Office of the Deputy Prime Minister issued a consultation document on the reform of fire safety legislation in July 2002, which provides for a mechanism to simplify, rationalize and consolidate the law with respect to fire safety in buildings in use.

Building regulations dealing with fire safety and other fire safety legislation such as the Fire Precautions Act 1971 are a response to known fire risks and to fire disasters which revealed previously unexpected fire hazards in buildings.

SS7 Property protection

The effects of fire on the continuing viability of a business/infrastructure may be of vital interest and can be substantial and therefore consideration should be given to the limitation of damage to:

- the structure and fabric of the system (building);
- the contents of the system;
- ongoing business/activity viability;
- public perception or image.

SS8 Environmental protection

A fire involving several buildings or the release of quantities of hazardous materials may have an environmental impact that is out of all proportion to the size of the original fire. A small fire involving some toxic products which is extinguished by water that goes into an adjacent river may lead to large or extensive environmental pollution. Consideration should, therefore, be given to the limitation of the effects of fire on adjacent buildings or facilities and the release of hazardous materials into the environment.

a. **A fire safety engineering design is more dependent upon management controls.** Whether designed in accordance with prescriptive codes or fire safety engineering principles, good fire safety management is essential to the safe operation of any building. The fire safety engineering approach presented in BS 7974-0 requires that management issues be taken into account and any specific management requirements are addressed explicitly.

b. **Fire safety engineering cannot, or should not, be applied to just one aspect of the design.** The most common use of fire safety engineering is to justify one or two specific departures from prescriptive codes. There may be little need to apply fire safety engineering principles to all aspects of a project if it is otherwise code-compliant.

c. **A fire safety engineering design may provide less flexibility for future use.** During the preparation of an engineered solution, the design team should identify potential future changes of use. They should, where practical, ensure that the design would accommodate these changes. If this is not feasible, any potential restriction should be highlighted. A lack of flexibility is a function of poor engineering design rather than an inherent function of fire safety engineering.

d. **A fire safety engineering design is more dependent upon the correct performance of fire protection systems.** There is no reason why a wedged-open fire door or poorly maintained sprinkler system should be any less of a problem in a code-compliant building than in a building designed on the basis of fire safety engineering principles. BS 7974 (see **6.4.6.1.2.1**) requires that the potential impact of systems failures be assessed. The input of such failures may often be less in a building designed on fire safety engineering principles.

e. **The accuracy of many fire safety engineering calculations is unknown.** The accuracy of all of the calculation procedures presented in BS 7974 will generally be sufficiently accurate for engineering design purposes if they are used within the limits of applicability.

f. **A fire safety engineering solution always requires calculations and a numerical solution.** BS 7974 provides a design framework and does not necessarily require a quantified analysis. Very often it will be possible to reach a solution without recourse to numerical calculations. During the design review process, it may be possible to establish simply by local deduction that a trial design is at least as safe as the code-compliant solution, without the need for any calculations.

Why is fire safety engineering used?

The principal objective of any application of fire safety engineering is to provide an environment that enjoys a level of safety that is demonstrably equal to, or better than, the level that would be developed by direct compliance with prescriptive requirements or standard guidance in respect of fire safety systems. The objective would be to design or develop measures, either singularly or in a package, to reduce the potential for injury, death, property loss or environmental damage to an acceptable level.

In some major projects, there may be no possible solution to identified fire safety problems other than to offer an engineered solution. In particular, large shopping malls, airport terminals and tall multi-storey commercial and residential buildings, often containing an atrium, present the designer and fire safety professional with problems that cannot be overcome using the available standard guidance.

Example 2

An airport terminal building is required to have very little compartmentation to facilitate ease of wayfinding and efficient movement of large numbers of people in a pleasant environment. To compensate for the omission of some of the compartmentation two techniques are used: limited areas of high fire load are sprinklered and local smoke extraction provided and areas of combustible seating are separated by distances large enough to ensure that fire cannot spread from one area to the next. The maximum fire size is limited to one seating area, allowing the smoke ventilation system to function adequately.

When is fire safety engineering used?

There are no rules as to when fire safety engineering can, or should, be used. In the majority of buildings, compliance with the functional requirements will not be contentious and little difficulty will be experienced.

The example given above (Example 1) of the extension of travel distances as a result of an improved alarm system shows a simple justification for a minor variation of the standard guidance. In the case of larger, complex buildings, the proposal may be for a package of interdependent proposals.

Example 3

In a large multi-storey shopping/leisure complex with a mixture of new and existing listed buildings, limited space for natural smoke ventilation can be shown to be adequate using:

- fast response sprinklers to limit maximum fire size;
- control over plume widths for smoke escaping from units in the development.

The expectations of today's society are continually more demanding and the designers and developers of major buildings or development schemes are fully aware of their obligations in this respect. The user will need a return on his/her capital and for this to happen the building user's needs must be met. For instance, in the case of a large shopping mall, the designers must work to create an atmosphere that attracts the public there in the first place. To provide an attractive environment, the architect may often resort to the provision of large, wide-open spaces. This is very attractive to the shopper, but difficult for the regulatory authorities where travel distances to a place of safety may become very long. This particular problem has become so common that standard fire safety engineering solutions have been developed for shopping malls, although these are outside ordinary building regulations guidance and need to be adapted in more complicated buildings that combine retail and leisure functions.

Example 4

CIBSE Guide Technical Memoranda TM19:1995, Relationships for smoke control calculations. Using this document, smoke ventilation requirements for single and two-storey shopping centres can be designed using calculations worked out by hand or simple spreadsheets.

NOTE: BR186, Design principles for smoke ventilation in enclosed shopping centres, may also be suitable depending on the nature of the circumstances under analysis.

The need for an engineered solution will usually emanate from the requirements of an architect or developer. Preliminary considerations will have revealed that the normal

agent flow rate) takes effect, there is considerable feedback required between Sub-system 4 and Sub-system 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 such as the use of inert gas discharge may have to be considered.

Activation times are also determined in Sub-system 4, most often from a wealth of input information available from the 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.

SS5 Fire service intervention

This sub-system provides guidance on the evaluation of the rate of build-up of fire extinguishing resources of the fire service, including the activities on any in-house or private fire brigades and in particular:

- the time interval between the call to the fire service and the arrival of the fire service predetermined attendance;
- the time interval between the arrival of the fire service and the initiation of attack on the fire by the fire service;
- the time intervals related to the build-up of any necessary additional fire service resources;
- the extent of fire fighting resources and extinguishing capability available at various times.

SS6 Life, health and safety of people

The occupants of a building and fire fighters who may have entered that building together with members of the public, and fire fighters who are in the vicinity of the building can, potentially, be put at risk by fire. The main life-safety objectives are therefore to ensure that:

- the occupants are able to remain in place, evacuate to another part of the building or totally evacuate the building without being subject to hazardous (e.g. causing injury or incapacitating) or untenable conditions;
- fire fighters are safely able to:
  – assist evacuation where necessary;
  – effect rescue where necessary;
  – prevent extensive spread of fire;
- collapse of elements of structure does not endanger people (including fire fighters) who are likely to be near the building.

Details of life-safety strategies and evaluation techniques are given in Annex D of ISO/TR 13387-1.

SS3 Structural response and fire spread beyond the enclosure of origin

This sub-system provides guidance on the use of engineering methods for the prediction of fire spread beyond the enclosure (e.g. room or compartment) of fire origin, to adjacent enclosures within the building, other buildings or external items. The exposure of a building to external fires is also addressed by this sub-system.

The sub-system draws on other sub-systems for a prescription or characterization of the fire. Sub-system 1, for example, provides prediction 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 sub-system to predict the likelihood (and time) of fire spread and the likelihood (and time) of structural collapse.

The sub-system provides a framework for critically reviewing the suitability of an engineering method (calculation worked out by hand, computer method or fire test) for assessing the potential for fire spread in a given situation or 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). The availability and reliability of the relevant input data for each unit process is also addressed.

Should fire spread from the room or 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 fire fighters outside the room or compartment of fire origin can be compromised. Hence data generated by Sub-system 3 become input to Sub-system 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.

SS4 Detection, activation and suppression

This sub-system provides guidance on the use of engineering methods for the prediction of the time taken to detect smoke or flames by a wide range of commercial devices. This includes 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 sub-system 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 to estimate the effectiveness of many common fire-suppression and control strategies are also addressed.

Sub-system 4 draws on Sub-systems 1 to 3 for characterizing 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 location from the building design parameters, is employed by Sub-system 4 to predict detection times and the operation of elements, such as those in automatic sprinklers, that allow release of pressurized extinguishing agent (e.g. water or foam) at a nozzle.

The effect of various suppression strategies on the fire-heat release rate is estimated in Sub-system 4. Currently this is carried out by reference to national codes and installation guidelines and the use of engineering judgement in the application of these guidelines to design fire scenarios. Once an assumed suppression strategy (usually in terms of a required

functional requirements are restrictive in a specific case and it will follow that some compromise will be offered. There is little point in presenting the regulator with a *fait accompli* and expecting acceptance. It is very much a joint effort and early discussion should lead to a solution where all the requirements of the regulatory authorities, the developer, the architect, the building user and the public in respect of a safe environment are met.

Who uses fire safety engineering?

Many individuals and organizations will have different interests as well as an involvement in fire safety engineering.

Building Control Authorities and Fire Authorities will have a regulatory interest, with an emphasis on life safety for occupants and fire fighters. They need to be sure that they can approve a fire safety engineered proposal in the knowledge that it provides an equivalent or better level of fire safety in a building or infrastructure project to that provided by a 'standard' code-based solution.

- Insurance companies and building owners and occupiers will be concerned about loss prevention.
- Businesses have a vital interest in business continuity.
- Environmental authorities seek the protection of the environment from air and water pollution from fire incidents.
- Heritage buildings are often priceless and cannot be replaced.
- Developers seek to reduce construction costs and improve functionality and flexibility.
- Designers will seek to provide efficient and innovative buildings with flexible spaces used in new ways.

The principle behind all such uses of fire safety engineering is to tailor the fire safety provision in a building to the actual risk. This is the basis on which the above objectives can be met. One advantage of a fire safety engineered design is that it may offer greater flexibility or significant cost savings as well as being a safer design than a building that meets standard guidance.

In the planning stages, the Building Control Authorities and Fire Authorities are faced with the task of consenting to the necessary building and planning approvals. Once the building is occupied as a place of work, the Fire Authority is charged with the enforcement of the Fire Precautions (Workplace) Regulations 1997 (as amended).

These Regulations are based upon the European Union Framework (89/391/EEC) and Workplace Directives (89/654/EEC), and these European documents ensure that equivalent legislation is in place throughout the European Union. The Regulations place a statutory duty on the employer to carry out an assessment of the risk from fire in his premises. Therefore, employers will be closely involved as the ongoing management of any fire safety engineered solution rests clearly with them.

How is fire safety engineering used?

BS 7974 identifies three main stages in the framework for engineering approach to fire safety.

The Qualitative Design Review defines the scope and objectives of the fire safety design and sets acceptance criteria for any proposed solutions to any fire risk which is to have a fire safety engineered solution.

Quantitative analysis is used to evaluate such items as fire size, quantity and temperature of smoke produced, smoke ventilation, the effect of fire alarm systems, sprinklers, fire service intervention, evacuation times for occupants, etc. Quantitative risk analysis can also be used to establish the risk of particular events occurring which can be compared with the acceptability of those events occurring.

The results of quantitative analysis are used to compare the performance of the design with the acceptance criteria. Where there are a number of possible solutions to be considered, the assessment should allow a comparison of each so that a determination as to the most appropriate can be made.

Code-based approach

The Building Regulations in England and Wales are accompanied by a series of Approved Documents. In the case of fire safety, it is Approved Document B. Approved Document B provides examples as to how the various functional requirements can be accommodated and so achieves an acceptable level of fire safety.

The majority of building control is achieved through the simple means of providing a design that meets all these design criteria. Such a code-based system would not, therefore, require the consideration of an engineered approach.

BS 7974 identifies what might be considered as suitable acceptance criteria. The acceptability or otherwise of the criteria is a matter for the regulatory body concerned or the client's requirements in the case of fire risks outside a regulatory context. Where buildings, railway stations, ships and other structures are concerned, regulatory bodies such as the Building Control Authority, the Fire Authority, the Health and Safety Executive, the International Maritime Organization, etc. must be satisfied.

In presenting the criteria to the Regulatory Authority, the approach by the architect or the developer should be along one of the following lines:

Deterministic approach

This involves showing that the initial assumptions (usually the reasonable worst case) do not produce an outcome that exceeds a set of predetermined conditions. Examples would be calculations of fire size, smoke volume and temperature, toxic potency of the combustion products, evacuation time, structural fire protection, etc. These would be considered in relation to each other to show that any outcomes would meet the design objectives of life safety, property protection, business continuity, etc.

Probabilistic approach

This involves calculating the probability of certain outcomes occurring and showing that these are acceptably low. This could include quantified risk assessments using statistical data to rate the likelihood of particular events taking place and the seriousness of the consequences. Examples of this approach would include comparing an innovative approach against a code-based system as contained in the series of Approved Documents that accompany the Buildings Regulations (see above), or to identify the most important risk factors for business continuity purposes, etc. It can be a powerful tool for comparing two

In the Parts of ISO/TR 13387, the following five important steps in the fire safety design process are identified. They are common to those identified in BS 7974 and the Published Documents that accompany it:

- definition of the safety objectives and scope of the study;
- setting acceptance criteria;
- characterization of the building, occupants and environment;
- undertaking a qualitative design review; and
- conducting quantified analysis.

The evaluation of the fire safety design of a building is broken down, to simplify the process, into eight separate components of the system (sub-systems denoted by the prefixes SS1 to SS8) belonging either to the tools for fire safety engineering evaluation (SS1 to SS5) or the fire safety objectives (SS6 to SS8).

SS1 Initiation and development of fire and fire effluents

This sub-system provides guidance on the use of engineering methods for the prediction of ignition of fire, the generation of fire effluents and the development of fire inside the room of origin.

The sub-system 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 sub-system may also provide the 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 on a building are also addressed.

SS2 Movement of fire effluents

This sub-system provides guidance on the use of engineering methods for the prediction of movement of fire effluents in buildings. The sub-system draws on other sub-systems for the prescription or characterization of the fire. The prediction of the fire development and the production of fire effluents are provided by Sub-system 1, the prediction of the spread of smoke and flames through openings is addressed by Sub-system 2, while the spread of fire through barriers is provided by Sub-system 3.

The sub-system 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 sub-system may also provide the means to assess the effectiveness of fire safety measures meant to reduce the adverse effects of the movement of fire effluents.

Sub-system 7 (in preparation) Risk assessment, uncertainty and safety factors

This sub-system provides guidance on probabilistic risk analysis. It sets out the general principles and techniques of risk analysis that can be used in fire safety engineering. This sub-system also outlines the circumstances where this approach is appropriate and gives examples illustrating the use of risk analysis techniques.

The sub-system also includes data for probabilistic risk assessment and criteria for assessment. The data included is based on fire statistics, building characteristics and reliability of fire protection systems. The criteria included cover life safety and property protection, both in absolute and comparative terms.

This sub-system does not contain guidance on techniques for hazard identification or qualitative risk analysis. Probabilistic risk assessment of fire in buildings (with the exception of nuclear, chemical process, offshore and transport) is not widely used and so a discussion of possible future developments is included.

BS ISO/TR 13387: Parts 1 to 8

When ISO/TR 13387 was being prepared by ISO TC/92/SC4, reference was made to all the documents available at the time. Prominent in this consideration was DD 240, *Fire safety engineering in buildings*. DD 240 was the only document available and the content had a major influence on the drafting of both BS 7974 and ISO/TR 13387. There are a limited number of fire safety experts and they participated in the preparation of both documents. While the British Standard was developed from DD 240 and was subjected to all the national considerations, ISO/TR 13387 was developed in recognition of other, international considerations, particularly from the United States of America and Japan.

While the two documents are different in a number of respects; the basic philosophy remains the same. The differences should not be regarded as corrections or errors in either document; there can be no definitive guidance document at this time. The national and international differences are intended to accommodate the different approaches now being discussed. It is for this reason that the ISO document has been published as a Technical Report. A considerable amount of detailed consideration is needed at the international level before these Technical Reports can be issued as international standards. To provide the outline basis for comparison with BS 7974, a brief synopsis of the ISO Technical Reports follows.

The Parts of ISO/TR 13387 are as follows:

- *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;* and
- *Part 8: Life safety: occupant behaviour, location and condition.*

options that have very different fire safety features and for identifying the most cost-effective improvements to fire safety systems.

Comparative approach

Here it is necessary to show that the proposed design provides a level of safety equivalent to that in a building which conforms to more prescriptive codes. If this approach is used, it is important to understand the intention of each recommendation of the prescriptive code as a particular provision may have more than one objective.

Functional building requirements introduce the concept of ‘equivalency’. The onus is upon the architect or developer to demonstrate that their scheme provides an equivalent level of safety, and if they can do so, then the necessary approvals should be forthcoming from the Approvals Authority.

Who can carry out fire engineering?

The definition of ‘fire safety engineer’ as ‘a person suitably qualified and experienced in fire safety engineering’ flows from the definition of fire safety engineering to be found in BS 7974 (see above). It would normally be expected that a fire engineer would be a member of the appropriate professional body specific to fire such as the Institution of Fire Engineers at either corporate, EngTech, IEng or CEng level, as appropriate, or be a chartered engineer with suitable fire experience.

The level of skills and experience required for fire engineering can vary widely according to the complexity of the project. It may be useful to set out a broad indication of the range of work and the appropriate level of qualification and experience for each type.

Table 1 provides an indication of the potential relationship between the complexity of the tasks and the level of training and experience required to carry out the particular level of task.

Table 6.1 Suggested level of competence to deal with variations

Fire safety solution	Minor variations to standard	Major variations to standard
Qualitative	1	2
Simple calculations	2	2
Complex analysis	3	3

Key to Table 1

The level of experience/qualification recommended for each fire safety solution is given as follows.

1 Competent construction professional with building code experience, e.g. Chartered Surveyor, Building Control Surveyor.
2 As for 1 but with appropriate additional training and experience, e.g. Member of Institution of Fire Engineers or other appropriate professional body.
3 CEng qualification with appropriate Continuing Professional Development.

7

Good questions for those dealing with a fire safety engineering design

Many individuals and organizations may come into contact with a fire engineering design as clients, regulators, users, designers, etc. These will include:

- building owners;
- building occupiers;
- Building Control Bodies;
- Fire Authorities;
- architects;
- non-fire safety engineers;
- surveyors;
- operators of infrastructure businesses, e.g. railways, tunnels, roads;
- owners and operators of ships.

When dealing with a proposal to apply fire engineering to a building, an infrastructure installation or a ship, etc. there are many useful questions that can be asked. The answers to such questions will enable the parties involved to form a view of the validity of the fire safety engineering proposal. It should be noted that the list below is not exhaustive.

Checklist for a fire safety engineering proposal

The fire safety engineer	What qualifications does the engineer have?	CEng, IEng, BEng, MEng, PhD
	What experience does the engineer have?	Previous projects
	Does the engineer's practice use a QA process?	Is BS ISO 9000 registration in place?
Models and methods used in the fire safety engineering process	Are they validated, published, referenced, widely used, from a respected source?	References, journals, peer review
What checks have been carried out?	What are the input data, results, judgements?	
What level of confidence/comfort is there?	What is the scope and type of design? Are conservative features built into the design?	

Sub-system 3 (PD 7974-3:2003) Structural response and fire spread beyond the enclosure of origin

Sub-system 3 provides guidance and information on how to undertake quantitative and detailed analysis of specific aspects of the design. It is a summary of the state of the art guidance and it is intended that it be updated as new theories, calculation methods and/or data become available. It does not preclude the use of appropriate methods and data from other sources.

Sub-system 4 (PD 7974-4:2003) Detection of fire and activation of fire protection systems

Sub-system 4 provides guidance on the development, design and application of fire detection systems and the activation of fire alarm and fire control systems to fulfil a role in the fire safety engineered design for a building. Scientific and engineering principles are used as part of a structured approach. The key elements covered are: detection, activation and control.

In the context of PD 7974-4, fire control includes fire suppression systems, fire barrier systems and smoke/heat control systems.

Sub-system 5 (PD 7974-5:2002) Fire service intervention

Sub-system 5 provides guidance on fire service intervention and evaluates the rate of build-up of fire fighting resources of the fire service. These activities may include in-house or private fire brigades and, in particular, the time interval between the call to the local authority fire service and the arrival of the fire service at its predetermined level of attendance. The time interval between the arrival of the fire service and the start of their attack on the fire relates to the build-up of any additional fire service resources and the extent of fire fighting resources and extinguishing capability available at various times.

This sub-system takes information on building characteristics and the design fire from the Qualitative Design Review (QDR), together with the time of fire service notification from Sub-system 4 and the time of evacuation from Sub-system 6. It provides information on the effect of fire service activities on the growth of the fire, which is used in Sub-system 1.

Sub-system 6 (in preparation) Evacuation

This sub-system will provide guidance on all aspects of evacuation procedures; the text is still in the course of preparation.

A brief extract and description of the scope of each of the sub-systems is given below. These include the scopes of those sections yet to be published. There are slight differences in these individual scopes with those of Parts of BS ISO/TR 13387.

Sub-system 1 (PD 7974-1:2003) Initiation and development of fire within the enclosure of origin

Sub-system 1 provides guidance on evaluating fire growth and/or size within the enclosure of origin, as well as enclosures to which the fire has subsequently spread. Guidance is also provided for 'special cases', which include malicious fires, racked/stacked storage of goods and fires external to the building.

The characteristics of the design fire for any particular scenario are influenced by a number of factors, including building design, environmental influences, potential ignition sources and location, types of combustible materials, distribution and arrangement of combustible materials, ventilation conditions and other events occurring during the fire.

The determination of the characteristics of the design fire from the ignition phase through growth to the decay phase is used by other sub-systems as inputs into calculations of events such as time of fire spread from enclosure (Sub-system 3) and time to activation of fire suppression systems (Sub-system 4).

Sub-system 2 (PD 7974-2:2002) Spread of smoke and toxic gases within and beyond the enclosure of origin

Sub-system 2 provides guidance on the application of fire safety management principles for the treatment of smoke movement, control and management problems. The guidance is intended primarily for professional engineers with a responsibility for the design or assessment of fire safety in buildings.

Sub-system 1 provides information on the rate of production of heat and combustion products from the fire source. The aim of Sub-system 2 is to provide design approaches to estimate the spread of the combustion gases within and beyond the room of origin and to evaluate their properties, i.e. temperature, visibility and concentration of toxic products. This information may be used to calculate the time between the detection of a fire and to conditions developing which are dangerous to building occupants. This will enable the design of fire safety measures to ensure that sufficient time is available for escape. It also provides information that will allow property issues to be assessed.

While PD 7974-2 forms part of the series of Published Documents containing sub-systems 1 to 7, it may, in consultation with the appropriate references, be regarded as 'stand-alone' guidance.

8

Conclusion

Fire safety engineering is a very important and valuable engineering technique. Many building, infrastructure and other types of structure can only be safely designed and constructed using fire safety engineering techniques. In many cases the fire engineering process can deliver major cost savings and higher levels of safety than that provided by standard guidance. The capability of a fire safety engineer should be carefully considered and any design reviewed and approved following the procedures set out in the relevant British Standards and Published Documents.

Appendix A – Terms and definitions

available safe egress time (ASET) calculated time available between ignition of a fire and the time at which tenability criteria are exceeded in a specified space in a building

complex analysis consideration of a design proposal and the application of the statistical data in order to come to an agreed position

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

escape time calculated time from ignition until the time at which all of the occupants of a specified part of the building are able to reach a place of safety

equivalence provision by other means of a level of safety providing the same level of performance as that referred to in guidance relevant to that requirement

evacuation time interval between the time of warning of fire being transmitted to the occupants and the time at which all of the occupants are able to reach a place of safety

fire hazard source of possible injury or damage from fire

fire risk product of probability of occurrence of a fire to be expected in a given technical operation or state in a defined time and the consequence or extent of damage to be expected on the occurrence of a fire

fire safety engineer person suitably qualified and experienced in fire safety engineering

fire safety engineering application of scientific and engineering principles to the protection of people, property and the environment from fire

functional requirement expression of a safety requirement in terms of the required level of performance of the fire safety system referred to

prescriptive requirement expression of a safety requirement by the means of a detailed description of the provisions required which should not be varied

probabilistic risk assessment methodology to determine statistically the probability and outcome of events

qualitative identification of constituents of an evaluation of a proposal

science observation, identification, description, experimental investigation and theoretical explanation of phenomena

simple calculation first or initial consideration of data in order to come to a first impression on the validity of the proposal

trial fire safety design package of fire safety measures, which in the context of the building may meet the specified fire safety objectives

3

Benefits of fire safety engineering

Fire safety engineering can have many benefits; the use of a code of practice such as BS 7974 will facilitate the practice of fire safety engineering and in particular will:

- provide the designer with a disciplined approach to fire safety design;
- allow the safety levels for alternative designs to be compared;
- provide a basis for selection of appropriate fire protection systems;
- provide opportunities for innovative design;
- provide information on the management of fire safety for a building.

The structure of the BS 7974 is given below. This code of practice:

- provides a means of establishing acceptable levels of fire safety economically and without imposing unnecessary constraints on aspects of building design;
- provides guidance on the design and assessment of fire safety measures in buildings;
- gives a structured approach to assessing the effectiveness of the total fire safety system in achieving the design objectives;
- provides a framework for, and describes the philosophy of, fire safety engineering;
- outlines the principles involved in the application of the philosophy to the fire safety engineering of particular buildings;
- can be used to identify and define one or more fire safety design issues to be addressed using fire safety engineering;
- provides some alternative approaches to existing codes and guides for fire safety and also allows the effect of departures from more prescriptive codes to be evaluated;
- recognizes that a range of alternative and complementary fire protection strategies may achieve the design objectives.

In PD 7974: Parts 0 to 7 the following steps in the fire safety design process are identified:

- definition of the safety objectives and the scope of the study;
- setting of the acceptance criteria;
- characterization of the building, occupants and environment;
- undertaking a qualitative design review; and
- conducting quantified analysis.

The evaluation of the fire safety design of a building is broken down, to simplify the process, into the separate components of the overall system (the sub-systems, see below) belonging to either the tools for fire safety engineering evaluation or the fire safety objectives.

BS 7974 defines fire safety engineering as 'the application of scientific and engineering principles to the protection of people, property and the environment from fire'. In practice, fire safety engineering involves the use of scientifically based or statistically based calculations to demonstrate an adequate level of fire safety for a specific building, structure or installation. Often, it will be applied to a specific part of a project while other parts follow standard guidance or codes.

BS 7974 is derived from DD 240 (now withdrawn) prepared by BSI Technical Committee FSH/24. The Draft for Development was prepared with the support of the government departments concerned with fire safety (Department of the Environment and the Home Office – now the Office of the Deputy Prime Minister). BS 7974 therefore provides a framework for an engineering approach to fire safety, which may be applied to both the design of new buildings and the appraisal of existing buildings, and to show that regulatory requirements can be, or are, satisfied. BS 7974 is also intended to provide a framework for a flexible but formalized approach to fire safety design that can also be readily assessed by the approvals bodies.

BS 7974 is supported by a series of Published Documents (PDs) that contain guidance and information on how to undertake detailed analysis of specific aspects of fire safety engineering. This does not, however, preclude the use of appropriate methods and data from other sources.

PD 7974, Application of fire safety engineering principles to the design of buildings, is structured as follows:

- *Part 0: Guide design framework and fire safety engineering procedures;*
- *Part 1: Initiation and development of fire within the enclosure of origin (Sub-system 1);*
- *Part 2: Spread of smoke and toxic gases within and beyond the enclosure of origin (Sub-system 2);*
- *Part 3: Structural response and fire spread beyond the enclosure of origin (Sub-system 3);*
- *Part 4: Detection of fire and activation of fire protection systems (Sub-system 4);*
- *Part 5: Fire service intervention (Sub-system 5);*
- *Part 6: Evacuation (Sub-system 6)* (in preparation);
- *Part 7: Probabilistic fire risk assessment (Sub-system 7)* (in preparation).

BS 7974 can be used to identify and define one or more fire safety designs to be addressed using fire safety engineering. The appropriate part(s) of PD 7974 can then be used to set specific acceptance criteria and undertake detailed analysis.

Within the international and European arena, there has been detailed consideration of the need for guidance and standardization. The International Organization for Standardization (ISO) has produced a comprehensive Technical Report that has now been published by BSI as BS ISO/TR 13387, *Fire safety engineering*. In eight parts, the Technical Reports were prepared by ISO Technical Committee TC/92, Fire safety. This series of ISO documents offers a slightly different approach to that of BS 7974 and the PDs that accompany it. Neither approach can be regarded as the 'definitive' view. As each separate approach offers an alternative and given the consideration now required of both the BS Published Documents and the ISO Technical Reports, it is hard to say which approach will be formally adopted. While it could be one or the other, the more likely outcome would be an amalgamation of both.

Specifically within the European arena, the European Commission has recently funded a feasibility study on the benefits of fire safety engineering within the European Union.

NOTE: Further information is given on both international and European activities in Appendix B.

Appendix B – International and European standardization activities for fire safety engineering

International Standards (ISO)

With no action at the European level, work started at the international level to produce a series of documents covering the subject. BS 7974 was used as the basis of the early work, but was substantially extended. It quickly became clear, that considerable work was needed to make this document useable. The work was undertaken by ISO TC/92, Fire safety and ISO published a multi-sectioned ISO/TR 13387: Parts 1 to 8 and the documents have generated considerable interest.

European Standards (CEN)

Since the publication of the British and international documents, interest has been generated at the European level. While all the early preparation for the subsequent documents was underway, CEN and the European Commission were content to await the outcome.

Given that the Construction Products Directive (89/106/EEC) and the Essential Requirements both make direct reference to fire safety engineering, the Commission Services funded a feasibility study on the application of fire safety engineering principles in all of the Member States.

Also, in preparation for beginning work at the European level, CEN TC/127, Fire safety in buildings, has formed a new Working Group to cover the issue.

The present position is brought into sharper focus as the European Commission have recently funded extensive Research on the Benefits of Fire Safety Engineering in the European Union (BeneFEU). It is clear from the conclusions of this study that a European position will have to be formalized and adopted.

Once the decision has been made by the EU Fire Regulators Group as to what form the European interest will take, CEN will decide who will undertake the work. Given the basic remit of CEN TC/127, it will probably be included in its work programme.

Construction Products Directive (89/106/EEC)

Council Directive 89/106/EEC on the approximation of laws, regulations and administrative procedures of the Member States relating to Construction Products was published in 1989. This Directive contained a number of Essential Requirements; one of which was 'Safety in case of fire'.

Under the Construction Products Directive (89/106/EEC), the Commission Services have established a Standing Committee on Construction. Reporting to this Standing Committee, the Group of EU Fire Regulators has discussed the issue of fire safety engineering several times. Once a full consideration has been given to the BeneFEU Report, the Fire Regulators Group will need to consider their future options.

The Construction Products Directive, through the use of harmonized technical specifications and supporting standards, aims to break down the technical barriers to trade, associated with the movement of construction products between Member States.

At the present time, CEN TC/127 has now published all the necessary technical specifications to enable the Commission Services to publish their formal Commission Decision on the classification of construction products according to their reaction to fire and fire resisting properties. The Technical Committee is still addressing the need for further harmonized technical standards under a direct standardization mandate from the Commission. These technical standards now provide the means of implementing the Essential Requirements of the Directive in respect of reaction to fire and fire resistance testing of construction materials, thereby providing the harmonized European Standards that are needed to make possible the implementation of national laws, regulations and administrative procedures.

Any formal European position would take into consideration all published documents on the subject. These would include ISO/TR 13387, BS 7974 and PD 7974. They would also include consideration of any other documents published by any other Member State. It is probable therefore that once the Fire Regulators Group, with the approval of the Standing Committee, have established a 'European' position, CEN TC/127 may be asked to prepare the European version of ISO/TR 13387 under the existing mandates.

Essential Requirement 'Safety in case of fire'

In a document (Interpretative Document 2) describing the provisions of the Essential Requirement, 'Safety in case of fire' published in 1991, the question of an engineering approach in the field of fire safety was addressed. According to this document, fire safety engineering covered the way in which fire safety in a construction works is evaluated by the means of calculation methods, taking account of the performance and effect of products, i.e. passive and active fire protection measures.

It was also made clear that fire safety engineering included a number of activities of wide scope, which influenced fire safety in use of construction products. This included the use of calculation methods for determining the development and spread of fire and smoke, the time for untenable conditions to be reached and evacuation time.

In a fully integrated approach, fire safety engineering was also judged to include the complex interaction between the performance of passive and active fire protection measures and the construction works. For example, the development of life-threatening atmosphere and human behaviour to achieve safety in the most flexible and cost-effective way must be considered. This engineered approach required that the relevant characteristics of products are provided and calculation and design procedures are validated on an agreed and harmonized basis.

2

What is fire safety engineering?

Fire safety engineering is the provision of adequate fire safety precautions in a complex building or structure that accommodates a departure from the prescribed performances in any specific area by taking other higher or compensatory measures in another area. There could be trade-offs between passive and active fire protection measures that either allow the designer to use materials in a novel application or allow the building user to make optimum use of the space available.

Fire safety engineering can be considered under several headings.

- The *process* of fire safety engineering is about measurements and relationships, backed by scientific study, for engineering application to the required problems, but where experience and judgement can contribute, as in other engineering disciplines.
- The *context* of fire safety engineering is the need to evaluate fire hazard and risk and to offer fire safety strategies and designs based on performance not prescription.
- The *tools* supporting fire safety engineering are the calculation methods (sometimes called models) that describe the measurements, relationships and interactions and any necessary test results.
- The *inputs* are the physical data for the calculation methods, derived from measurement methods (tests, etc.).
- The *framework* of fire safety engineering comprises the essential core, and transfer, of knowledge, which permits an engineering approach, the education and training of users and the professional recognition of the discipline.

As a result of the substantial increase in fire research during the last decades, many components and systems are becoming more amenable to analytical and computer modelling. Consequently, many national building regulators, particularly in the UK, have moved from a prescriptive approach to a performance-based approach.

The fire safety engineering approach may have benefits over the prescriptive approach. It takes into account the entire fire safety package and provides a more fundamental and sometimes 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 systems.

For most buildings the prescriptive recommendations on design in existing codes and guides, as given in BS 5588-0, may be found to be adequate. However, BS 7974 is intended for use to develop and assess fire safety engineering proposals. The use of a fire safety engineering approach enables a more precise design necessary for the assessment of new and complex projects. In addition, although prescriptive regulations have served us well in the past, it is widely recognized that they are inflexible in certain circumstances and therefore unable to evolve quickly enough to meet the modern challenges of new materials and innovative design.

1

What are fire precautions?

The term 'fire precautions' is generally accepted to include matters that are the subject of legal requirements under specific fire precautions legislation. These include The Building Regulations 2000, The Fire Precautions (Workplace) Regulations 1997 (as amended) and The Fire Precautions Act 1971 (as amended). In Northern Ireland the Fire Services (Northern Ireland) Order 1984 (as amended) is in use. More generally, there exists health and safety legislation including the Health and Safety at Work etc. Act 1974 and regulations made under that Act.

Fire precautions legislation deals with general fire precautions. These include:

- means of detection and giving warning in case of fire;
- provision of means of escape;
- means of fighting fire;
- training of staff in fire safety;
- linings that inhibit the spread of fire;
- means to provide structural stability; and
- means to resist the spread of fire within and between buildings.

The Fire Precautions (Workplace) Regulations 1997 also include a requirement for employers to undertake an assessment of the fire risks. The term 'fire risk' is generally accepted to collectively describe both the risk of fire occurring and the risk to people in the event of fire.

The 'risk assessment' is an organized assessment of the work activities and associated hazards in the workplace that could cause harm to people. It is intended to assess whether adequate precautions to avoid or reduce the risk of harm have been taken or whether more action is necessary.

In this context, 'hazard' and 'risk' are defined in ISO/TR 13387-1 as follows.

- A 'hazard' is the potential for loss of life (or injury) and/or damage to property by fire.
- A 'risk' is the potential for realization of an unwanted event, which is a function of the hazard, its probability and its consequences.

The present statutory duty imposed upon employers requires that the employer carry out a fire risk assessment of the workplace. Consideration must be given, amongst other things, to the needs of all employees and all other people who may be affected by a fire in the workplace. Adequate provision must also be made for any people with disabilities or with special needs who may use or be present on the premises.

The Fire Precautions (Workplace) Regulations 1997 require that the assessment is kept under review and is revised as necessary. The Regulations place a statutory duty on the employer, which will be related to the provisions of any fire safety engineered solution provided in his building.

Approved Document B – European Supplement

Approved Document B, Fire safety, 2000 edition, refers to and utilizes within its guidance a large number of British Standards – typically the BS 476 series of documents. In order to facilitate harmonization and the adoption and use of new European technical specifications and supporting standards under the auspices of the Construction Products Directive (see above), it has been necessary to amend the 2000 edition of Approved Document B.

The amendment to Approved Document B ensures that construction products tested by the European harmonized fire test methods can be used in England and Wales as required under the Construction Products Directive. In practical terms this will tend to require increased performance for products tested to BS 476.

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This bibliography is intended to direct readers to the regulatory guidance, standardization and to basic fire safety engineering guidance, handbooks and fire science/engineering textbooks. It is limited to a selection of the guidance most relevant to the UK and is not intended to be comprehensive.

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Part 3: External fire exposure roof test.
Part 4: Non-combustibility test for materials.
Part 6: Method of test for fire propagation for products.
Part 7: Method of test to determine the classification of the surface spread of flame of products.
Part 10: Guide to the principles and application of fire testing.
Part 11: Method for assessing the heat emission from building materials.
Part 12: Method of test for ignitability of products by direct flame impingement.

BS 5588, *Fire precautions in the design, construction and use of buildings.*
Part 0: Guide to fire safety codes of practice for particular premises/applications.
Part 4: Code of practice for smoke control using pressure differentials.
Part 5: Code of practice for firefighting stairs and lifts.
Part 7: Code of practice for the incorporation of atria in buildings.
Part 8: Code of practice for means of escape for disabled people.
Part 9: Code of practice for ventilation and air conditioning ductwork.
Part 10: Code of practice for shopping complexes.

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Part 1: Initiation and development of fire within the enclosure of origin (Sub-system 1).
Part 2: Spread of smoke and toxic gases within and beyond the enclosure of origin (Sub-system 2).
Part 3: Structural response and fire spread beyond the enclosure of origin (Sub-system3).
Part 4: Detection of fire and activation of fire protection systems (Sub-system 4).
Part 5: Fire service intervention (Sub-system 5).
Part 6: Evacuation.[1]
Part 7: Probabilistic fire risk assessment.

DD 240, *Fire safety engineering in buildings.*[2]
Part 1: Guide to the application of fire safety engineering principles.
Part 2: Commentary on the equations given in Part 1.

BS EN 1991-1-2:2002, *Eurocode 1. Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire.*

[1] In preparation.
[2] DD 240 has been superseded by BS 7974 and is withdrawn.

Foreword

This document aims to provide an introduction and initial understanding of the principles of fire safety engineering and its relationship to fire precautions. It also suggests why such engineered solutions might be offered in achieving the objective of satisfactory safety levels in case of fire.

This document does not aim to provide a detailed understanding of fire safety engineering. It is a basic guide for those who are new to the subject and also provides a guide to where further, more detailed information can be found. Such detailed guidance is available from many different sources, some of which are listed in the bibliography.

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Part 1: Application of fire performance concepts to design objectives.
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