

Fire safety engineering in buildings

Part 2. Commentary on the equations given in Part 1

ICS 13.220.20

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Committees responsible for this Draft for Development

The preparation of this Draft for Development was entrusted to Technical Committee FSH/24, Fire safety engineering, upon which the following bodies were represented:

- AEA Technology

Architectural and Specialist Door Manufacturers' Association

Association of British Theatre Technicians

Association of Building Component Manufacturers

Association of Building Engineers

Association of County Councils

Autoclaved Aerated Concrete Products Association

BAA plc

BG plc

British Automatic Sprinkler Association

British Carpet Manufacturers' Association Ltd.

British Electrical Systems Association (BEAMA Ltd.)

British Fire Protection Systems Association

British Iron and Steel Producers' Association

British Plastics Federation

British Railways Board

Building Research Establishment

Car Users Entrapment Extrication Society

Chemical Industries Association

Chief and Assistant Chief Fire Officers' Association

Construction Fixings Association

Consumer Policy Committee of BSI

Convention of Scottish Local Authorities

Department of Health

Department of the Environment (Construction Sponsorship Directorate)

District Surveyors' Association

Door and Shutter Manufacturers' Association

Eurisol — UK Mineral Wool Association

Fibre Cement Manufacturers' Association Ltd.

Fire Brigades' Union

Fire Safety Development Group

Health and Safety Executive

Heating and Ventilating Contractors' Association

Home Office

Home Office (Fire Service College)

Institute of Fire Prevention Officers

Institute of Fire Safety

Institution of Fire Engineers

Intumescent Fire Seals Association

London Fire and Civil Defence Authority

Loss Prevention Council
- Ministry of Defence

National House-building Council

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RAPRA Technology Ltd.

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Scottish Office (Building Directorate)

Scottish Office (Home and Health Department)

Security Systems and Alarms Inspection Board

Smoke Ventilation Association

Society of Chemical Industry

Steel Construction Institute

Timber Research and Development Association

University of Central Lancashire

Warrington Fire Research Centre

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Chartered Institution of Building Services Engineers
- Institute of Building Control
- National Association of Fire Officers

This Draft for Development, having been prepared under the direction of the Health and Environment Sector Board, was published under the authority of the Standards Board and comes into effect on 15 July 1997

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Amendments issued since publication

Amd. No.	Date	Text affected

The following BSI reference relate to the work on this Draft for Development:
Committee reference FSH/24
Draft for comment 94/340340 DC

ISBN 0 580 27920 0

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Foreword

This Part of DD 240 has been prepared by Technical Committee FSH/24. It is being issued in the Draft for Development series of publications and is of a provisional nature. The decision to publish it in this form rather than as a British Standard was taken by the committee responsible, following consideration of public comment on the draft code of practice. It was thought that the current state of knowledge on the use of fire safety engineering made publication as a Draft for Development more appropriate.

A review of this Draft for Development will be carried out not later than two years after its publication. Notification of the start of the review period with a request for the submission of comments from users of this Draft for Development, will be made in an announcement in the appropriate issue of *Update Standards*.

According to the replies received, the responsible BSI committee will judge whether the Draft for Development can be converted into a British Standard or whether other action should be taken.

Observations which it is felt should receive attention before the official call for comments, will be welcome. These should be sent to the Secretary of BSI Technical Committee FSH/24 at British Standards House, 389 Chiswick High Road, London W4 4AL.

This publication is not to be regarded as a British Standard.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 12, an inside back cover and a back cover.

1 Scope

This Part of DD 240 gives guidance on the limits of applicability and confidence limits for the equations given in Part 1. Because fire safety engineering is an evolving discipline, the quality of the models represented by these equations is variable and there are significant limitations in knowledge. While ongoing research will improve the position, design has to proceed using the best available methods, but introducing a margin of safety to take into account the level of confidence which can be placed on any given component of the design process.

To assist in this, and in response to comments following the public enquiry stage of Part 1, a review of the applicability and confidence limits for the equations was carried out by the Department of Fire Safety Engineering, Lund University Institute of Technology. The results of this review will be published in full elsewhere, but are summarized in this Part of DD 240. Clause 3 briefly sets out the factors which contribute to uncertainty in the design process and illustrates these by an example, using a probabilistic design procedure (annex A). Clause 4 outlines the principal approach used by Lund University to identify the limits of applicability and confidence limits for the equations and defines the latter in terms of a 'model uncertainty parameter' β . Clause 5 sets out, for each equation, the results of the review.

As the Lund work was a separate activity from the work of the committee preparing Part 1, it has been published in this separate Part of this Draft for Development. In a limited number of cases, brief additional comments have been added by the relevant BSI committee.

2 Informative references

References are made in this Part of this Draft for Development to a number of other publications that provide information or guidance. Editions of these publications current at the time of issue of this Part of this Draft for Development are listed on the inside back cover.

3 Uncertainty and overall predictive capability

The factors affecting the reliability of predictions have been identified as belonging to five distinct categories:

- a) uncertainty due to improper definition and conceptualization of the assessment problem or scenario;
- b) uncertainty due to improper formulation of the conceptual model;
- c) uncertainty involved in the formulation of the computational model;

- d) uncertainty inherent within the estimation of parameter values; and
- e) calculation and documentation errors in the production of results.

This Part of this Draft for Development concerns itself mainly with factors b) and c). With regard to a), limitations related to any chosen scenario will generally be identified during the Qualitative Design Review. It is also assumed that factor d), input parameter uncertainty, is treated at least implicitly by the assignment of design values to the input parameters. The manner in which these factors, and any underlying assumptions, are taken into account in the design process should be made explicit in the reporting and presentation stage (see DD 240 : Part 1, clause 8).

Confidence in a model is a result of the accumulation of information; it is clear that there is no single measure of model confidence. In undertaking its review, Lund University identified a number of attributes to be investigated further. These attributes included the following:

- 1) completeness and accuracy of underlying data;
- 2) conceptual sufficiency of the model structure;
- 3) appropriateness of embedded, implicit or explicit, approximations;
- 4) model stability and sensitivity;
- 5) model performance compared to known experimental data that was not used in the development of the model.

Consideration of attributes 1 to 4 formed the qualitative component of the model assessment procedure undertaken by Lund University, while attribute 5 constituted the quantitative part of the procedure. For the equations in Part 1, the assessment procedure in its entirety was based on elicitation of expert knowledge, in some cases supported by a statistical verification procedure. The method used is described in clause 4.

An example of the consideration of model uncertainties is given in annex A.

4 Elicitation of expert knowledge

A panel of leading international experts in the area of fire science and fire modelling was assembled and for each equation or mathematical treatment, members of the panel were asked to respond carefully to a questionnaire. The key question relating to quantification of model confidence was formulated as follows:

'Assume that you are able to perform approximately 100 full scale laboratory experiments to verify the equation above. The experiments cover the range of conditions expected in practice (size of room, geometry, fuels, etc.).



Question 1: What are the minimum and maximum credible values a and b of the parameter:

$$\beta = \frac{\text{predicted value}}{\text{measured value}}$$

Question 2: Having established bounds on β , we assume a uniform distribution as the default distribution.

a) Do you consider there is a physical basis for replacing the default distribution with a triangular distribution? If so, where is the mode c (the maximum value) located?

b) In your opinion, are there special reasons for choosing another distribution describing β ? Give your reason and specify the distribution.

Question 3: We will use your estimates to derive 80 and 95 % confidence intervals for β . Can you, as an alternative to item 2, directly specify confidence in this interval?

NOTE. The 80% confidence interval for β is defined as the interval between the 10 % and 90 % fractiles for the derived β -distribution.

The background to questions 1 to 3 was explained as follows:

In question 1 it is assumed that we have a number, let us say n , experimental values x and predicted values y . Each value pair (x_i, y_i) corresponds to a scenario and the n scenarios have equal probability of occurring in practice. We thus have n values of the parameter β with $a = \beta_{\min}$, $b = \beta_{\max}$. Assuming a uniform distribution of β indicates that the n values of β , $\beta_1 \dots \beta_n$, are equally distributed over the range $a \leq \beta \leq b$. Assuming a triangular distribution of β with a mode $c = 1$, means that we think there are more values near $\beta = 1$ than near the outer boundaries a and b . If we have specified the distribution (uniform or triangular) and a and b , we have also specified the 80 % and 95 % confidence interval. In practical terms, specifying a and b in question 1 and the distribution (uniform or triangular) in question 2 makes question 3 redundant. For other circumstances, question 3 is relevant.

Other items in the questionnaire concerned a qualitative assessment of model structure and range of validity. A synthesis of these assessments is reported for each equation under the headings 'limits of applicability' and 'other limitations and considerations'.

For a number of equations and mathematical treatments where the above procedure was not relevant, independent experts were asked to perform a special review (equations 17, and 51 to 57).

The 80 % confidence interval of β is used to indicate the reliability of an equation. Thus much greater confidence may be placed on an equation where this interval is small, e.g. $0.9 < \beta < 1.1$, than in one where the interval is large, e.g. $0.5 < \beta < 2.0$. This does not invalidate the use of those equations in which the interval is large, but indicates to the designer that due allowance should be made, when assessing any safety factor, for the sensitivity of the solution to their use.

Uncertainties associated with the equations only contribute in part to the overall uncertainty associated with any design (see clause 2 and clause 7.5 of DD 240 : Part 1). There are other factors, such as the choice of data, which also contribute. Further, because of the complexity of the fire safety design process, there is as yet no ready method for combining the effects of all the relevant factors to derive the overall level of uncertainty inherent in the design solution, and, hence, a basis for providing a margin of safety. For the present, the information set out in clause 5 should be used to inform the professional judgement of both the designer and those assessing the design, rather than as a basis for the quantitative assessment of overall safety factors.

5 Limits of applicability and confidence limits for the individual equations

5.1 Equation 10: $\theta_c = 6.85 \left(\frac{Q^2}{A_w h_w^{1/2} h_k A_t} \right)^{1/3}$

5.1.1 Limits of applicability

Equation 10 is only valid when a two-directional flow has been established in the vertical ventilation opening(s), i.e. the equation is not applicable to the smoke-filling phase of an enclosure fire process. The model assumes a hot gas layer of uniform temperature. It is not applicable to fire process controlled by ventilation. Special care has to be taken:

- a) when the fire enclosure has more than one opening;
- b) for very well-insulated fire enclosures or in other situations when $h_k \rightarrow 0$;
- c) when fire growth is extraordinarily fast;
- d) for fires in corners or adjacent to a wall;
- e) for complicated fire room geometries.

5.1.2 Confidence limits

The 80 % confidence interval for model uncertainty parameter β is expected to be in the range:

$$0.85 < \beta < 1.25$$