

Draft for Development

Guide for the assessment of toxic hazards in fire in buildings and transport

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The preparation of this Draft for Development was entrusted by the Fire Standards Policy Committee (FSM/-) to Technical Committee FSM/16, upon which the following bodies were represented:

- British Cable Makers' Confederation
- British Plastics Federation
- British Railways Board
- British Rigid Urethane Foam Manufacturers' Association
- British Rubber Manufacturers' Association
- Chemical Industries Association
- Chief and Assistant Chief Fire Officers' Association
- Consumer Policy Committee of BSI
- Department of Health and Social Security
- Department of the Environment [Building Research Establishment (Fire Research Station)]
- Department of the Environment (Housing and Construction Industries)
- Department of the Environment (Property Services Agency)
- Department of Trade and Industry (Consumer Safety Unit, CA Division)
- Health and Safety Executive
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- Medical Research Council
- National Council of Building Materials Producers
- RAPRA Technology Ltd.
- Textile Research Council
- Wallcovering Manufacturers Association of Great Britain Ltd.
- Warrington Fire Research Centre
- Yarsley Technical Centre Ltd.

This Draft for Development having been prepared under the direction of the Fire Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 31 December 1989

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Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Definitions	1
3 Use of the guide	2
4 The steps of the guide	2
Appendix A Smouldering	8
Appendix B Ventilation	8
Appendix C Tests for the toxicity of fire effluent	8
Appendix D Toxic hazards in fires: check list	9
Appendix E Assessment of fire hazard: example	11
Appendix F Factors affecting toxic hazard	17
Figure 1 — Cumulative toxic potential dose with time for the warehouse fires	16
Table 1 — General classification of fires	4
Table 2 — Calculation of toxic potential mass	5
Table 3 — Incapacitating and lethal doses and concentrations of the major toxic entities in fire for use in hazard estimation	7
Table 4 — Determination of toxic hazard: unprotected warehouse	13
Table 5 — Determination of toxic hazard: plasterboard lined warehouse	14
Publications referred to	Inside back cover

Foreword

This publication is not to be regarded as a British Standard

It is being issued in the Draft for Development series of publications and is of a provisional nature because test methods to measure toxicity in fires are still in the course of development. It should be applied on this provisional basis so that information and experience of its practical application may be obtained.

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 *BSI News*.

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

Observations which it is felt should receive attention before the official call for comments will be welcomed. These should be sent to the Secretary of BSI Technical Committee FSM/16 at BSI Manchester Office, 3 York Street, Manchester M2 2AT.

This Draft for Development has been prepared under the direction of the Fire Standards Policy Committee.

Though it is only one aspect of a fire, the hazard caused by combustion products, especially in enclosed spaces, has become a subject of increasing concern in recent years. An increased awareness of the toxicological action of these products on persons exposed to fire atmospheres and their role in causing death and injury has led to requests for guidance from many sources.

BSI is currently participating in work on the development of test methods being undertaken in the International Organization for Standardization (ISO). This work supports the view that, based on existing knowledge, the evaluation of the toxicity of combustion products cannot be carried out solely using analytical techniques and that biological methods will be necessary in some situations. Continued support is being given to the development of satisfactory fire models, biological methods and chemical analysis techniques which will provide specific information about toxicity which can then provide results to form part of an overall consideration of hazard and consequently aid the mitigation of that hazard.

This methodology is not yet completely available, but questions of toxic hazard in fires still have to be faced. This Draft for Development provides the best advice currently available for assessing toxic hazard, even though refinements of the methods suggested will inevitably follow in the years ahead. The Draft uses the knowledge gained from research in the last decade that the majority of materials produce fire effluents of similar toxicity and that reducing the ease of ignition and rate of fire spread are the most important factors in minimizing toxic hazard. The Draft is offered as a practical guide to what is achievable now to assess toxic hazard in fires, although there will always be a requirement to balance risk reduction against practicality and it provides a systematic basis for reaching an informed judgement on the balance between the conflicting factors involved.

This Draft for Development has been designed to provide guidelines to be followed when assessing toxic hazard within the context of the overall hazard presented by a defined fire scenario. When using this Draft account should be taken of any statutory or control requirements (e.g. Building Regulations and the Fire Precautions Act), information obtained from fire tests such as those given in BS 476, published literature on non-standard tests and analytical and biological studies of fire atmospheres. Relevant background information on the state of the art of combustion toxicity and the problems of assessing hazard can be found in PD 6503-1 and PD 6503-2 and BS 6336.

The guide given in this Draft for Development enables assessments to be made of the likely hazard to occupants of existing buildings and transport and the effect alterations to these structures may have on possible hazard. It may also aid architects and planners to design and equip new buildings and transport to improve the safety of occupants in the event of fire, and is intended to be complementary to the advice given in the various Parts of BS 5588 and in BS 6853.

It has been assumed in the preparation of this Draft for Development that the execution of its provisions will be entrusted to appropriately experienced or informed people for whose guidance it has been prepared.

The Draft will be updated as knowledge in the area increases.

Appendix E gives an example of how the guidance given could be employed.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Draft for Development provides guidance for fire safety practitioners in their task of reducing the possible risk to life presented by fires in structures (buildings and transport), materials and composites. Measures are detailed as to how to consider the relevant issues to reduce the likelihood of toxic combustion products being formed in significant quantities.

Because of the great complexity of combustion toxicology, the Draft cannot provide a set of rules capable of a single interpretation. Use of the Draft is indicative that the basic *principles* have been considered for assessing toxic hazard. It cannot provide an absolute guarantee of safety.

NOTE The titles of the publications referred to in this Draft for Development are listed on the inside back cover.

2 Definitions

For the purposes of this Draft for Development, the following definitions apply. Where appropriate, the source of the definition is given for information.

2.1

fire hazard

a physical situation with a potential for harm to life or limb, or damage to property, or both, from the effects of fire (see BS 6336)

2.2

toxic hazard

the danger caused to people in fire situations by the formation of toxic products, with respect to their nature, quantity and rate of production and concentration (see PD 6503)

2.3

risk

the probability that a fire hazard will develop as the result of a set of circumstances within a defined fire scenario

NOTE This definition is based on BS 6336 and BS 476-10.

2.4

combustion toxicity

the capacity of a substance within a fire effluent to cause injury to a living organism

NOTE This definition is based on ISO/TAG 5 definition (see ISO/IEC Guide 52, in preparation) and PD 6503.

2.5

irritant

a substance which may cause discomfort, pain or tissue damage to the mucous membranes of the eyes, nose, throat and lungs, which may lead to a degree of incapacitation

2.6

smoke

visible suspension in atmosphere of solid and/or liquid particles in gases resulting from combustion or pyrolysis (see BS 4422-1)

2.7

fire scenario

a generalized description of an actual or hypothetical fire incident

2.8

circumstances

the facts or conditions which affect the hazard created by a defined fire scenario, e.g. the ignition source, the first material ignited, how the fire spread

2.9

fire effluents

the total gaseous, volatile and particulate (liquid or solid) products from combustion or pyrolysis

2.10

asphyxiant

a substance which may cause loss of consciousness or death by depriving the brain of oxygen

2.11

usual toxicity

the toxicity when a given mass of the material consumed produces a similar toxic effect to the same mass of wood consumed under identical test conditions

2.12

mass loss

mass of material consumed by or otherwise lost during burning

2.13

toxic potency factor

a number relating to the toxicity of a material to that of wood, when tested under identical test conditions which are representative of the actual fire conditions

2.14

toxic potential mass

the product of mass loss and toxic potency factor in a fire. An indication of the potential toxic effect of a fire, expressed as the mass of material of normal toxicity consumed in the fire

2.15**toxic potential concentration**

an indication of the toxicity of an exposure environment (expressed as a concentration in g m^{-3}) and derived from the total toxic potential mass divided by the volume into which the effluent is dispersed

2.16**toxic potential dose**

toxic potential concentration multiplied by the time over which it is measured and summed throughout the fire; provides an estimate of the dose available to a potential victim in the fire (in $\text{g m}^{-3} \text{min}^{-1}$)

2.17**LC50 value.** (Lethal concentration — 50 %)

the concentration statistically calculated to cause the deaths of half the animals exposed to a toxicant for a specified time. It may be expressed in parts per million (p.p.m.) (by volume), or milligrams per litre (mg/L)

NOTE In combustion toxicology two values are often used.

a) The LC50 value, expressed as mg/L, which is the starting mass of the material in the study divided by the volume of available air.

b) The LC50 value, expressed as mg/L, which is the mass of material actually consumed (i.e. the difference between the starting mass and the finishing mass) divided by the volume of available air.

Care should be taken to distinguish between the two values. The time of exposure is very important in inhalation toxicity, and the length of exposure should always be quoted for an LC50 value.

3 Use of the guide

The assessment of fire hazard is an extremely complex issue which has been discussed in PD 6503-2, where the main fire processes leading to hazard have been identified. These processes usually involve ignition, growth of fire, developed burning, the release of smoke and toxic gases, oxygen depletion and heat. In defined circumstances these aspects may constitute a hazard. The portion of the hazard associated with toxic gases is usually referred to as the toxic hazard.

It is important to consider the circumstances which will be influenced by such aspects as:

- a) the location of the people (in a building, ship, aircraft, etc.);
- b) their mobility (due to age, disability, illness, alcohol, etc.);
- c) the overall design and use of the building (or transport system) including the provision of means of escape and fire protection measures (automatic detection, sprinklers, etc.).

Each fire process cannot be considered in isolation. For example, the rate at which combustion products are generated is influenced by the rate of burning (or smouldering).

In addition, the environment will also influence the way a fire progresses. For example the layout of local items will dictate the way a fire develops, and the design of a building will control the movement of smoke. The development of a fire scenario is an attempt to link these factors together in order to describe the final outcome.

Assessment of hazard should lead to the estimation of risk (the likelihood that the hazard will occur). It is essential that a judgement is then made as to whether the risk is an acceptable one, and of how the risk is to be handled. The acceptability of risk is difficult to determine, but may be easier where a number of proposed courses of action are considered. An estimation of the risk associated with each course of action can then be balanced against the practical consequences in terms of fitness for purpose of the items or materials involved, cost factors, etc. to arrive at an acceptable solution.

Many different sets of circumstances may lead to a hazard. For example, careless use of smokers' materials may cause a chair to burn or smoulder when someone is sitting in it; alternatively ignition may arise and burning take place in an unoccupied room with people sleeping in nearby rooms. All appropriate scenarios need to be addressed.

The primary aim of the guidance in this Draft for Development is to direct its users towards a consideration of the possible ways that defined fire scenarios can give rise to a threat to life from toxic and/or irritant gases. The approach is to examine each scenario in a series of steps (see clause 4) so that users can select and implement those measures which will be most effective in reducing the overall threat to life.

4 The steps of the guide

NOTE It is important that users of the guide familiarize themselves with all the individual steps before any specific work is undertaken.

The seven steps of the guide are as follows.

- Step 1. Define the particular circumstances
- Step 2. Assess probability of the occurrence of the fire scenario
- Step 3. Describe local growth of fire
- Step 4. Describe developed burning of the fire
- Step 5. Define the toxicity of the relevant fire effluents
- Step 6. Summarize the likely fire and toxicity hazards
- Step 7. Report

The guide requires the reporting of this information, which can then be used in assessing the risks involved. The information can then be used to compare various courses of action which may be used in decision making.

4.1 Step 1. Define the particular circumstances

The aim of this step is to define the particular circumstances to be examined and to provide a basis for the consideration of the hazards and risk associated with various courses of action.

The use of the building or transport system in terms of type and number of occupants, the activities carried out there, and the escape procedures and methods, should be recorded.

Then the contents should be defined. The nature and quantities of the materials involved, their location and relationships to immediate and nearby environments should be recorded.

The fire scenarios to be examined should be selected. These should reflect the different causes of a fire which may occur and the different use patterns, e.g. in a hotel, flaming ignition of bedding in a bedroom at night or an electrical fault in a public area may both be considered. At this stage, it is necessary to determine whether the full consequences of the scenarios need to be considered using step 2.

4.2 Step 2. Assess probability of the occurrence of the fire scenario

The purpose of this step is to assess the likelihood that the particular fire scenario will occur. The probability will be dependent on how likely it is for the designated ignition source to come into contact with the first material ignited. The probability can be estimated by reference to the use pattern, fire statistics and experience in similar situations. It is suggested that the scenarios are classified into one of three categories.

- a) "*Likely to occur*". Events arising from common causes of ignition in the environment under consideration. Examples would be careless use of smoking materials, deliberate ignition of waste paper in school, or a chip pan fire in a domestic kitchen.
- b) "*Unlikely to occur*". Events with a low incidence but nevertheless it may be prudent to investigate their consequences. An example would be a fire in a terraced house resulting from a major gas explosion.
- c) "*Extremely unlikely to occur*". Events which are so unlikely to occur that they need not be considered. An example would be the risk that a burning airliner would crash into a dwelling 100 miles from an air lane.

At this stage it is the likelihood of the scenario taking place which is being estimated, not the consequences.

4.3 Step 3. Describe local growth of fire

Knowledge of ignition and initial growth of fire is essential in understanding the conditions which may prevail to place life in jeopardy. It is under these early conditions that materials and composites undergo smouldering (see Appendix A), oxidative decomposition, pyrolytic decomposition and flaming (see Table 1) with the release of toxic products.

Limited information about the likely behaviour of the defined materials and composites under these fire conditions can be obtained from material tests and reaction to fire tests on specimens and products, but may not be wholly indicative of their performance in fire. Literature studies may be necessary to identify any relevant information emerging from non-standard tests. Wherever possible such tests should also identify information relevant to overall hazard including the rate at which the fire is likely to develop and the amounts and optical densities of smoke.

4.4 Step 4. Describe developed burning of the fire in terms of rate of production of toxic gases, heat and smoke output

A developing fire has enormous potential for the generation and spread of large quantities of heat, smoke and toxic gases.

Developed burning requires a considerable air supply and conditions may prevail of relatively low or high ventilation (see Table 1 and Appendix B).

Some information can be derived from relevant fire tests. Technical literature may provide information from large scale experiments, simulations and non-standard tests (e.g. room burns, corner tests, etc) on the rate and production of toxic products, heat and smoke. Fire growth rates need to be expressed in the form of mass losses. This information is not normally provided by many fire growth tests and data from such tests are not always relevant to actual fire situations.

Knowledge of fully developed fire behaviour, (particularly the time to attain such conditions) and the release of heat and smoke is a prerequisite for the overall description of hazard. Methods of quantifying this information may need to be obtained from suitable sources, such as mathematical models. Knowledge of these conditions is also essential for assessing the likely concentrations and rate of release of irritants and toxic gases.