

Toxicity of combustion products

Part 2. Guide to the relevance of small-scale tests for measuring the toxicity of combustion products of materials and composites

Toxicité des produits de combustion

Partie 2. Guide sur l'utilité des essais à échelle réduite pour mesurer la toxicité
des produits de combustion des matériaux et composites

Giftigkeit von Verbrennungsprodukten

Teil 2. Leitfaden zur Anwendbarkeit von Prüfungen an Kleinprüfständen zur Bestimmung
der Giftigkeit der Verbrennungsprodukte von Werkstoffen und Werkstoffmischungen

Confirmed
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Foreword

This Part of PD 6503 has been prepared under the direction of the Fire Standards Committee. PD 6503 : Part 1 will replace the existing PD 6503 [1] and will be the UK implementation of the technical report ISO/TR 9122 'Toxicity testing of fire effluents: the state of the art 1987', currently being prepared by ISO/TC 92 of the International Organization for Standardization (ISO).

Small-scale methods of test are now becoming commonplace, particularly overseas, for assessing the toxicity of combustion products of materials and simple composites using biological procedures. These methods are being viewed with considerable reservation in the UK, and consequently no decisions have been made to proceed with national controls. However it is essential that research and development laboratories have access to methods which will continue to ensure that materials and composites can be adequately screened for products of unusually high toxicity. This Part of PD 6503 therefore brings together the 1987 state of the art knowledge of combustion toxicity testing, to give credibility to methods for research and development purposes which meet certain basic criteria. In doing so, it is hoped to encourage researchers to use common approaches, so as to minimize the overall use of biological procedures in the UK and yet maintain the essential work necessary to avoid unacceptable changes in toxicity in the future.

NOTE. The numbers in square brackets used throughout the text of this document relate to the bibliographic references given in appendix A.



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Part 2. Guide to the relevance of small-scale
tests for measuring the toxicity of combustion
products of materials and composites

Correction

AMD 6030 September 1988	Table 5. Fire models In the column headed 'Criteria met', against 'British NES 713**' in the column headed 'Method/model', delete '2,3' and substitute '—'.
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Section one. Background to small-scale tests

0 Introduction

The damaging effects of fire atmospheres in causing the injury and death of persons involved in fires have been recognized for many years. The inhalation of toxic fire gases and smoke is currently the attributed cause of death in over one-half of all fatalities from fires in the UK. Such deaths arise from the acute physiological effects of the chemical constituents of the combustion products. Many other factors are of course important in contributing to injury and death. They include the irritant effects of the atmosphere and factors which increase the exposure period of individuals, such as sublethal physiological effects, psychological behaviour and smoke obscuration.

Over recent years there has been a growing need to understand the potential toxicities of fire atmospheres when materials (including composite items, etc.) are involved in fires. This need is common for the wide spectrum of materials, whether found in the structure, contents and services of buildings and transport, or in consumer products. The impetus for possible action has come from regulatory and control authorities, to ensure that no measures are being overlooked which could improve the safety of life in fires, and from industry, in recognizing its responsibility to supply 'safe' products.

Considerable attention has therefore been directed within research and specialist laboratories towards the possible use of simple methods for assessing the toxicity of combustion products, particularly for the elimination of any materials or material combinations capable of generating products of unusual toxicity during decomposition or combustion.

Fortunately, to date, few examples of material combinations generating high toxicity products can be cited. In the UK, BSI has provided the main technical forum for collecting together viewpoints on the possible advancement of simple test procedures. Experts from the chemical, physical, medical, biological and fire fields, together with representatives from regulatory and control bodies and industry, have been brought together in a single BSI Technical Committee. This Technical Committee also provides the technical support for the UK input to the discussions on test methods in ISO/TC 92, Fire tests on building materials, components and structures and, in particular, Subcommittee 3, Toxic hazards in fire.

In 1982, BSI published PD 6503, intended for wide discussion, expressing current philosophies and outlining the approaches which would be necessary if a future decision was made that simple test methods are an essential feature of a fire safety strategy. In particular, the document expressed grave doubts about the validity of simple approaches, since no proven link has been established between the combustion atmospheres generated from small-scale tests and those of real fires, and asserted that the results of such tests cannot easily be interpreted into practical meaning for reduction of toxic hazards in fires. Additionally, the document stressed both the current limitations of chemical and analytical approaches and that, with existing knowledge, biological procedures are essential for any meaningful assessment of toxicity.

Strong scientific justification has been put forward in the UK to support the above reservations, but international interest in procedures of this kind continues to grow.

No simple approaches are available for addressing the toxic hazards in a meaningful way. An assessment of toxic hazard relies on the integration of information on a wide range of material and composite properties (ignitability, flame spread, rate of heat release, smoke and toxic gas production, etc.) and human conditions (age, etc.). Toxicity is an issue which forms part of the knowledge required of a material or composite property within the complex issue of toxic hazard determination.

Because of the great complexity of addressing and mitigating toxic hazards, two actions have been proposed within BSI.

(a) The development of a code of practice on the assessment of toxic hazards in fires to guide regulatory and control bodies, specifiers, users, etc. in toxic hazard assessment and in implementing the most effective ways of mitigating the hazard. This approach takes into account that, in most circumstances, measures such as the reduction of ignitability and fire growth will be more effective in reducing toxic hazard, rather than attempts to reduce toxicity per se.

(b) The production of a report giving the 1987 state of the art knowledge of how selected small-scale tests for assessing the toxicity of combustion products can be related to real fires, to support essential and ongoing work in the UK research and development fields. This approach recognizes that direct toxicity information can have value as an *input* to toxic hazard assessment and is intended to give some research and development credibility to test methods for which, in the view of BSI, sufficient experience has been gained and published results made available to justify their relevance. It should not be implied that such methods are in any way acceptable for regulatory or control use.

The code of practice is currently under development with the support of a Department of Trade and Industry code drafting consultancy.

This Part of PD 6503 is that defined under clause 0(b). It reviews briefly fire scenarios which are common in respect of the mortality statistics and examines the concept of toxic hazard and hazard assessment.

Section one of this Part of PD 6503 shows how recent research carried out at the UK Fire Research Station, Borehamwood, Herts., has led to a new way of characterizing fire atmospheres by chemical and physical analysis. When this is done, different stages of fire can be readily classified by defined bands of oxygen concentrations, carbon dioxide to carbon monoxide ratios (CO_2/CO ratios), temperatures and/or heat fluxes. By measuring these variables using a given test method, the relevance of the test to the classified fire stages can be determined.

In this way, users in research and development fields can be guided in selecting the most appropriate test or tests from the selected methods given in section two, so as to gain the most useful toxicity data for input into toxic

hazard assessment models. As experience grows it is hoped that the number of test methods given in this Part of PD 6503 will be increased, and it is written in a form to facilitate this. It is also hoped that it will encourage those using other tests, or those developing new tests, to present information relevant to this new classification scheme.

1 Scope

This Part of PD 6503 gives, in section one, the background to small-scale tests for the toxicity of combustion products of materials and composites, and shows how these methods can be related in principle to different fire conditions. Section two gives details of available methods known to comply with certain essential criteria and describes their relevance in relation to defined fire types.

2 Statistical information and fires

2.1 General

Over one-half of all fire fatalities in the UK are now attributed to the combined effects of smoke and toxic gases and there is evidence that this fraction has increased markedly (possibly three-fold) since the early 1970s. A survey of the relevant UK statistics [2] can be very helpful in gaining an overall impression of the probability of events occurring to cause fire, injury and death. Clearly it is beyond the scope of this Part of PD 6503 to deal with this in any detail, but broad trends for different occupancies in occupied buildings over the period 1978 to 1984 are shown in table 1 as annual means. Of the 97 000 fires in occupied buildings, some 56 000 occurred in dwellings. Only about 9 % of all the fires spread beyond the room of origin. Domestic fires are therefore important but large non-domestic fires involving major loss of life (but low in terms of overall statistics) also attract concern in respect of smoke and toxic gases. Domestic fires are discussed in 2.2 and examples of non-domestic fires are given in 2.3 to 2.6.

2.2 Domestic fires

Although a large proportion of fire deaths occur in homes, it is only in recent years that fire-related test methods for the contents of buildings, particularly furniture and furnishings, have been advanced and controls implemented. In this work the experimental studies of furnishings have been supported by investigations of real fires and have shown the importance of the overall composites in determining ignition and fire growth. The work has led to the development of BS 5852 : Parts 1 and 2 and BS 6807 [3] for both domestic and contract applications: these assess the ignitability of composites using smouldering and flaming sources of ignition, and the tests are being advanced within ISO. Methodologies also exist for the measurement of rate of growth of fire but they are in use primarily for research purposes.

In the UK, action was taken in 1980 with the introduction of the Upholstered Furniture (Safety) Regulations [4], which require that upholstery for domestic use carries warning labels if ignition of the upholstery composites could take place with a cigarette or simulated match, as based on a stylized test rig. Mandatory compliance with the cigarette test was enforced at the beginning of 1983*.

2.3 Woolworth store fire, Manchester 1979

The Woolworth store fire of May 1979 has been well-documented and well-reported [5]. It resulted in 10 deaths from a fire developing in a stack of stored furniture within the main furniture display on the second floor of the building. The stack contained soft furnishings (upholstered chairs and settees and mattresses) and panel furniture. The configuration of the stack and loading were not typical of domestic patterns but individual items were of domestic type. The fire was characterized by the rapid release of smoke and toxic gases, as shown by a simulation experiment carried out at the UK Fire Research Station. The simulation with a small fraction of the overall fire load showed a rate of heat output increasing almost linearly at nearly 10 MW/min to a maximum heat output of 23 MW at 2.5 min.

Table 1. Fires in occupied buildings: UK annual means for 1978 to 1984

Type of building	Fires	Non-fatal casualties	Fatal casualties
Dwellings	56801 (58)	6504 (78)	762 (90)
Service and leisure	8990 (9)	582 (7)	37 (4)
Industry and utilities	12145 (12)	561 (7)	18 (2)
Shops and offices	5553 (6)	255 (3)	7 (1)
Schools and hospitals	4598 (5)	177 (2)	11 (1)
Others and unrecorded	9264 (10)	274 (3)	15 (2)
	97351 total	8353 total	850 total

NOTE. Numbers in brackets refer to approximate percentages of total fires.

*Further regulations relating to the flammability of domestic upholstered furniture were being considered as this Published Document approached publication.